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The Official Publication of The Pile Driving Contractors Association - Winter 2003, Volume 4, Number 1

In This Issue:

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PILE DRIVING CONTRACTORS ASSOCIATION

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Pile Driving Contractors Association
Winter 2003

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Published for:
PDCA
P. O. Box 19527,
Boulder, CO 80308-2527
Phone: 303-517-0421
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Published by:
Lester Publications, LLC.
2131 NW 40th Terrace, Suite A
Gainesville, FL 32605
Tel: 352-338-2700
Fax: 352-338-2702
www.lesterpublications.com

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Piledrivers.org is published quarterly. Please contact us by mail at P. O. Box 19527, Boulder, CO 80308-2527 Phone: 303-517-0421 | Fax: 303-443-3871 or by E-mail at membership@piledrivers.org.

The subscription rate for members is $18 which is included in the annual dues. The U.S. subscription rate for non-members is $36 for one year and $72 for two years.
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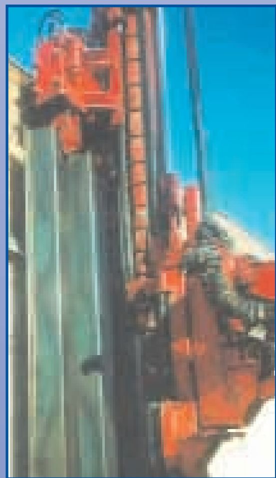

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MOVING FORWARD WITH NEW INNOVATIONS

We're entering a new year and we have made a lot of changes for the incoming year, with the goal to improve our organization and make the PDCA even more successful.

The elections are over and I have been re-elected as President. Randy Dietel was re-elected Vice President and the Executive Committee also remains in place for the upcoming year. Mark Weisz with C.S. Marine Constructors was appointed as the new Education Committee Chairman, replacing Geert Jonker. Secretary of Treasury Wayne Waters remains in place and Steve Witty was voted to continue another three-year term as a board member. We have two new board members, Harry Robins of Palmetto Pile Driving and Anthony Will of Foundation Pile Driving Contractors.

A NEW LOOK

Other changes to the PDCA include an all-new web site. This web site is much more user friendly and helpful for members as well as first-time visitors to the site. Van Hogan has done an outstanding job rewriting and reorganizing the site in order to improve its usability. Now, no registration is necessary to search for pile driving-related services on the web site. Also, past issues of the magazine are available for download from the website so members can review past articles for ideas and information. Please visit our revamped web site at www.piledriving.org.

The PDCA magazine is another important showpiece for the association. Lester Publications has been hired to handle both the sales and editorial responsibilities. Our goal is to make this publication a strong revenue stream for the association, while improving communication to our members.

AND THE WINNER IS…

We began our search for a new Executive Director by asking the membership who would be the best possible candidate for the job - someone with a pile driving background, who also has the necessary marketing and financial skills, a person who can increase membership, who is enthusiastic about the subject of pile driving and our member's needs. We were looking for someone with lots of drive to gain new members, who'd work hard at getting events sponsored, and succeed at fund raising.

As we evaluated candidates, it became clear that Tanya Goble stood out from the others. With her technical and marketing background, engineering degree and MBA in Finance, Tanya had all the qualifications for a PDCA Executive Director. She began her work for the PDCA on January 6th. With Tanya and the new team's contributions, we look forward to a successful and profitable year.

ENDURANCE AND EDUCATION

The pile driving industry continues to be resilient despite the current economic downturn. Business is very good for PDCA members - people are referring business to one another because they simply can't keep up with the work.

In the current market, about half the jobs seem to be private sector and the other half is highway work. The private sector continues to spend money and companies are expanding, building new plants, etc.

The PDCA continues to educate professors, to teach engineering students about pile driving. Many engineers don't have courses in deep foundations and we continue to promote how and when driven pile fits the best. Our Professor's Institute is a summer program that invites 25 professors to learn from guest speakers, who talk to them about the facts and advantages of pile driving.

Lastly, we're working also to promote Codes and Standards for design engineers. We have elected to promote new codes and standards to give driven pile a better advantage than it's had in the past. The PDCA is also involved in re-writing the AASHTO Specs, the government standards for pile driving.

These exciting changes for our association, the continuing success of our membership, the push to further educate professors, engineers and the public, and the new team of leadership including our new Executive Director, makes 2003 the best year yet to be a part of the PDCA.

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"The PDCA is proud to announce that the San Mateo - Hayward Bridge constructed by Balfour-Beatty Construction is the winner of the 2002 Project of the Year Award. The Project of the Year Award is to be presented at the 2003 Winter Roundtable. Details of this project and the runners-up entries will be presented in future issues of Piledrivers.org."

INTRODUCING TANYA GOBLE…

PDCA's New Executive Director

After a lengthy search of well-qualified prospects, Tanya Goble has joined the Pile Driving Contractors Association in early January as the new Executive Director.

Tanya has over seventeen years of experience in a variety of high technology engineering and marketing positions, working for Hewlett Packard and Agilent Technologies. In her most recent job assignment, Tanya was the Product Marketing Manager for a test equipment product line sold into the electronics manufacturing industry.

A graduate of the University of Colorado in Electrical & Computer Engineering, Tanya recently completed her MBA.

The Executive Director's office is based in Boulder, Colorado. She will be helping the association meet its goals of increasing market share for driven piles and serving the membership. Tanya will attend the Winter Roundtable event in February and looks forward to meeting PDCA members there and at future events.

Please do not hesitate to contact Tanya with questions or comments. She would like to hear from PDCA members about their ideas for the Pile Driving Contractors Association.

Tanya can be reached by phone or email:
Phone: 303-517-0421
E mail: ceo@piledrivers.org

Please join us in welcoming Tanya.
- The PDCA Executive Committee

Tanya Goble,
Executive Director, PDCA

PDCA Membership Application

Step 1: Select Membership Type
I wish to apply for the following membership status (check one)

❑ **Contractor** ($650)
A Contractor Member is defined as a specialty subcontractor or general contractor who commonly installs driven piles for foundations and earth retention systems. Includes one primary membership. Secondary memberships are $75 each.

❑ **Associate** ($650)
Associate Members of the Association shall consist firms or corporations engaged in the manufacture and/or supply of equipment, materials, testing, or other services to the pile driving industry. Includes one primary membership. Secondary memberships are $75 each.

❑ **Technical Affiliate** ($95)
Technical Affiliate Members of the Association shall consist of individuals who are involved with the design and installation of driven piles or in teaching the art and science of pile design and installation. They may be employed engineers, architects, government agencies, or universities. Employees of contractors are not eligible to become Technical Affiliate Members.

❑ **Student** ($25)
Student Members of the Association are defined as those who are full-time students studying towards a bachelor, master, or doctorate degree in a regular university program. Student Members are nonvoting members.

I attend the following school as a full time student: ______________________________

Anticipated Graduation Date: ____________

❑ **Retired Industry Member** ($50)
A retired Contractor member shall be defined as any individual who has reached retirement age as defined by U.S. law and who wishes to remain an active member. Retired Contractor members have all the rights of a regular Contractor Member
I am retiring as a: ❑Contractor ❑ Associate ❑Technical Affiliate

Step 2: Demographic Information (*required)

Title: ❑ Mr. ❑ Mrs. ❑ Ms. ❑ Dr. ❑ Prof. ❑ Other

Business Title	____________	*Business Fax	____________
*Name (or Primary Contact)	____________	*Primary Email	____________
*Company Name	____________	Residential Address	____________
*Business Address	____________	City/State/Zip	____________
*City/State/Zip	____________	Residential Phone	____________
*Business Phone	____________	Spouse	____________

* Where would you like to receive PDCA mailings? ❑ Business address ❑ Residence

Step 3. Company Description (complete only the category for which you are applying)
A. Contractor Only Company Description (check all that apply):

❑ Bridge Building
❑ Bulkheads
❑ Deep Dynamic Compaction
❑ Deep Excavation
❑ Docks & Wharves
❑ Earth Retention
❑ General
❑ Highway & Heavy Civil
❑ Marine
❑ Pile Driving
❑ Other ____________
❑ Other ____________

B. Associate Company Only Company Description (check all that apply):
Accessories

❑ Cutter Heads & Drill Bits
❑ Dock & Marine Supplies
❑ Hammer Cushions
❑ Hoses & Fittings
❑ Lubricants & Greases
❑ Pile Cushions
❑ Pile Points & Splicers
❑ Rigging Supplies
❑ Safety Equipment
❑ Other ____________

Applications By Systems

❑ Aluminum Sheet Piles
❑ Coatings & Chemicals
❑ Concrete Piles
❑ Composite Piles
❑ H-Piles
❑ Steel Pipe Piles
❑ Steel Sheet Piles
❑ Structural Steel
❑ Synthetic Material Piles
❑ Timber Piles: Treated Lumber & Timbers
❑ Vinyl Sheet Piles
❑ Other Structural Materials
❑ Other ___________________

Equipment

❑ Air Compressors
❑ Cranes
❑ Drill Equipment
❑ Drive Caps & Inserts
❑ Hammers
❑ Hydraulic Power Packs
❑ Leads & Spotters
❑ Pumps
❑ Specialized Rigs & Equipment
❑ Other ________________

Services

❑ Consulting
❑ Design
❑ Freight Brokerage
❑ Geotechnical
❑ Marine Drayage
❑ Surveying
❑ Testing
❑ Trucking
❑ Vibration Monitoring
❑ Other ______________

General

❑ Rental ❑ Sales ❑ Other _____________ ❑ Other _____________

C. **Technical Affiliate Only** (Check all that apply) Note: Technical Affiliate Membership Category is for individuals only. For a company listing in directory and on web site, you must join as an associate member)

❑ Analysis
❑ Consulting
❑ Civil & Design
❑ Educational/Association
❑ Geotechnical
❑ Materials Testing
❑ Pile Driving Monitoring
❑ Surveying
❑ Vibration Monitoring
❑ Other _______________

Step 4. Geographic Areas Where Contracting, Products and Services Available
(All applicants check all that apply)

❑ All States	❑ CA	❑ IA	❑ MD	❑ ND	❑ OR	❑ VA
❑ Continental	❑ CO	❑ ID	❑ ME	❑ NH	❑ PA	❑ VT
❑ U.S.	❑ CT	❑ IL	❑ MI	❑ NJ	❑ RI	❑ WA
❑ Global	❑ DC	❑ IN	❑ MN	❑ NM	❑ SC	❑ WI
❑ AK	❑ DE	❑ KS	❑ MO	❑ NV	❑ SD	❑ WV
❑ AL	❑ FL	❑ KY	❑ MS	❑ NY	❑ TN	❑ WY
❑ AR	❑ GA	❑ LA	❑ MT	❑ OH	❑ TX	
❑ AZ	❑ HI	❑ MA	❑ NC	❑ OK	❑ UT	

Step 5. Sponsorship: Who told you about PDCA?
Member Name ____

Step 6. Method of Payment
Attached is my payment of $_______for annual dues.

❑ I understand that dues are due annually on December 31, and that if I joined PDCA after March 31 I may be entitled to a prorated dues amount for the subsequent year only.

I am joining PDCA as:

❑ Contractor
❑ Associate
❑ Technical Affiliate
❑ Student
❑ Retired Industry Member

I am making payment in full by

❑ Check # ___________________________
❑ Visa
❑ MasterCard
❑ American Express

Card Number: ___________________________
Expiration Date: _________________

Name as it appears on card: ______________________
Signature: ______________________

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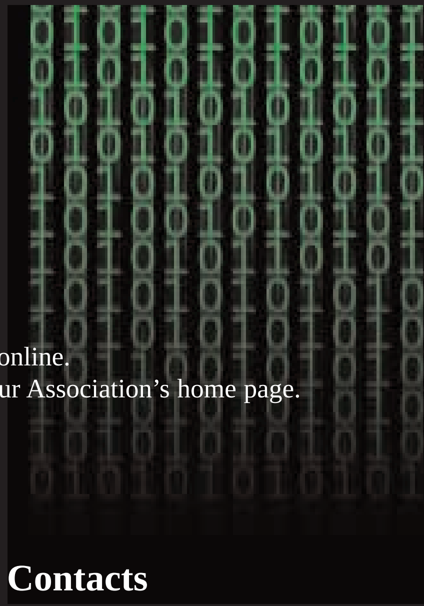

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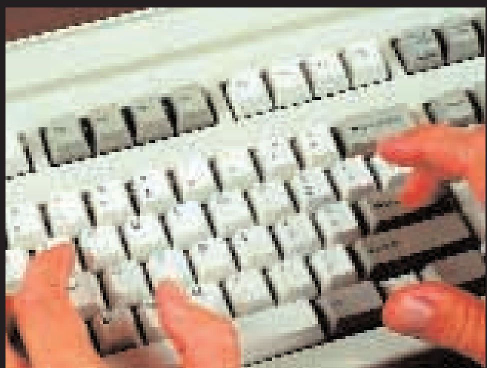

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INCORPORATING SET-UP INTO DRIVEN PILE DESIGN AND INSTALLATION

Van E. Komurka

After installation, pile capacity increases with time. This time-dependent capacity increase is known as set-up, and was first mentioned in the literature in 1900 by Wendel. Set-up has been documented in fine-grained soils in most parts of the world, and has been demonstrated to account for capacity increases of up to 12 times initial. The rate and magnitude of set-up is a function of a number of factors, the interrelationship of which is not well understood.

Set-up is predominately associated with an increase in shaft resistance, and is related primarily to dissipation of excess porewater pressures within, and subsequent remolding and reconsolidation of, soil which is displaced and disturbed as the pile is driven. Independent of changes in porewater pressure (i.e., independent of effective stress), additional set-up occurs due to aging.

Set-up is recognized as occurring in most parts of the world, for virtually all types of driven piles, in organic silt, inorganic saturated clay, and loose to medium dense silt, sandy silt, silty sand, and fine sand. Since set-up is related to dissipation of excess porewater pressures, the more-permeable the soil, the faster set-up develops. Set-up rate decreases as pile size increases.

A number of empirical relationships have been proposed to estimate or predict set-up, and have demonstrated reasonable success (accuracy) in a number of studies. Established relationships are limited in widespread application by having been based on combined (shaft and toe) resistance determinations, inter-dependence of back-calculated or assumed variables, and the complexity of the mechanisms contributing to set-up.

If justified by the scope (size) of a project, a well-designed and executed project-specific test program can yield more-valuable characterization of set-up than empirical relationships. Measurement of set-up requires that a pile's capacity be determined a minimum of 2 times. To maximize measured set-up, the first determination of a pile's capacity should be performed at the end of driving, or as soon after driving as possible, and the second determination should be delayed as long as possible (i.e., as long as the project schedule permits). Capacity determinations should separate shaft and toe resistance, and are most-valuable if the unit shaft resistance distribution (unit shaft resistance as a function of depth) is determined. Such capacity determinations can be achieved with top- or bottom-loaded internally instrumented static load tests, or dynamic testing with subsequent CAPWAP analyses, or preferably both.

Test programs which characterize only set-up magnitude, but not set-up distribution (i.e., where along the shaft set-up is occurring), lack flexibility in developing or modifying production pile installation criteria. Determination of not only set-up magnitude, but also set-up distribution (as a function of depth) provides such flexibility. Determination of set-up distribution also provides other design- and construction-phase flexibilities such as development of installation criteria which incorporate set-up for numerous different required production-pile capacities, and more-

Test Pile No.	Driving Status	Time After Initial Drive, in days	Penetration Depth, in feet	Toe Elevation, in feet	Penetration Resistance, blows/inches	Equivalent Penetration Resistance, blows/foot	Mobilized Capacity, kips			Capacity Fully Mobilized?
							Shaft	Toe	Total	
TP-15	EOID	-----	136.4	-127.6	19 / 1	228	58	380	438	No
	BOR	69	136.4	-127.6	6 / 0.5	144	322	378	700	No
TP-16	EOID	-----	135.1	-126.3	18 / 1	216	57	365	422	No
	BOR	69	135.1	-126.3	8 / 0.5	192	407	355	762	No
TP-17	EOID	-----	130.0	-121.2	7 / 1	84	90	331	421	Yes
	SLT	64	130.0	-121.2	-----	-----	724	220	944	Yes
	BOR	69	130.0	-121.2	9 / 0.5	216	371	455	826	No
TP-18	EOID	-----	131.0	-122.2	80 / 12	80	62	290	352	Yes
	BOR	69	131.0	-122.2	5 / 0.5	120	357	320	677	No
TP-19	EOID	-----	115.3	-106.5	11 / 4	33	130	69	199	Yes
	BOR1	0.7	115.3	-106.5	11 / 1	132	178	290	468	No
	BOR2	70	115.7	-106.9	10 / 0.5	240	463	310	773	No

Table 1. Pile test program data summary.

accurate assignment of reduced capacities to short or damaged piles.

To aid in determining the magnitude and distribution of set-up, static load test piles can be internally instrumented to determine shaft resistance distribution, and test piles can receive restrike testing (i.e., can be restruck). The piles' potentially increased impedance (e.g., from concrete fill) notwithstanding, because of set-up, a larger hammer with greater impact force than used for initial driving may be required to mobilize the piles' capacities (move the piles) during restrike testing.

A pile test program case history is presented herein which demonstrates the characterization of unit set-up distribution (unit set-up as a function of depth), and the development of depth-variable penetration resistance criteria, for high-capacity (190-ton allowable load) pipe piles in Milwaukee, Wisconsin.

PROJECT DESCRIPTION

The Sixth Street Viaduct Replacement Project involved demolition of the existing Sixth Street Viaduct, and construction of its replacement. The 4 major project structures were two bascule bridges, and two cable-stayed bridges. Because of the magnitude of load at each structure, and the number of piles required, a pile test program was performed at each of the 2 bascule bridges, and at each of the 2 cable-stayed pylon structures. The pile test program presented herein was performed at the south pylon structure. The south pylon structure consists of 2 single towers, each 136 feet high. At each tower, design compression load is approximately 7,000 kips, with transverse and longitudinal moments approaching 20,000 foot-kips.

SUBSURFACE CONDITIONS

Subsurface explorations and geotechnical evaluations were performed for the project by others. Boring depths ranged from 121 to 224 feet. Subsurface conditions consisted of fill deposits comprised of silty clay, to fine to coarse sand, extending to a depth of approximately 4 feet, underlain by native loose to medium dense fine-grained granular deposits consisting of clayey silt, to fine sand, which extended as deep as 29 feet. Underlying deposits consisted predominately of very stiff silty clay, with occasional layers of loose to medium dense clayey or sandy silt, to the termination depths of the borings.

PILE TEST PROGRAM

Installation

General

The test piles consisted of steel pipe piles having an outside diameter of 12.75 inches and a wall thickness of 0.375 inch. A total of 5 indicator piles were installed. The test piles were installed closed-end, using a Delmag D30-32 single-acting diesel hammer.

Dynamic Monitoring

Initial driving of the test piles was dynamically monitored using a Pile Driving Analyzer® ("PDA") instrumentation system. Additional analysis of field-measured dynamic monitoring data included performing a CAse Pile Wave Analysis Program® ("CAPWAP") analysis on a representative blow from the end of initial drive ("EOID") of each indicator pile. All EOID CAPWAP analyses were performed using the residual stress analysis ("RSA") option. The PDA data and subsequent CAPWAP analyses were used to determine pile capacities, the division of capacity between toe and shaft resistance, and shaft resistance distribution.

Restrike Testing

General

Determination of unit set-up is typically appropriate for discrete pile sections, such as some fraction of the total pile length for CAPWAP analyses. Unit set-up for a particular pile segment is defined as the shaft resistance increase attributable to set-up for that pile segment, divided by the surface area of that pile segment.

Restrike testing was performed 69 to 70 days after EOID using a Delmag D36-32 single-acting diesel hammer.

Dynamic Monitoring

Restrike testing of the indicator piles was monitored using a PDA. Additional laboratory analysis of

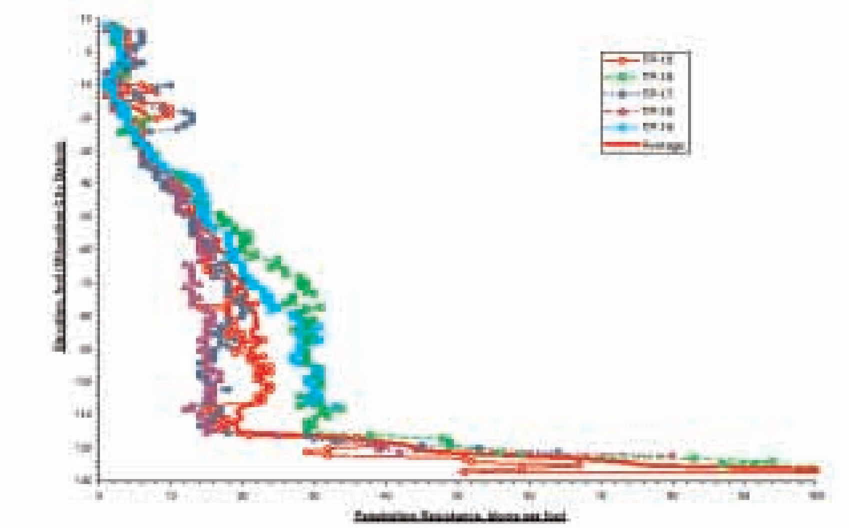

Figure 1. Penetration resistance vs. elevation.

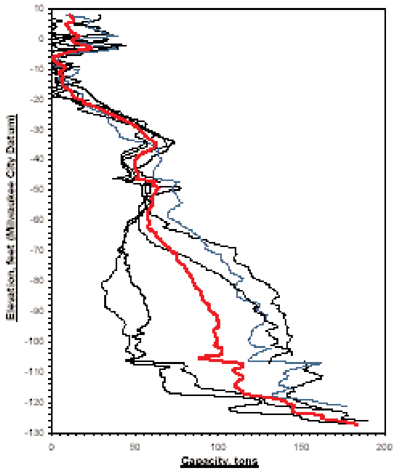

Figure 2. Initial-drive CASE-method capacity vs. elevation

field-measured dynamic monitoring data included performing a CAPWAP analysis on a representative blow from beginning-of-restrike ("BOR") testing for each pile. Similar to EOID CAPWAPs, all BOR CAPWAPs were performed using the residual stress analysis option.

RESULTS AND ANALYSIS

Select pile test program results are summarized in **Table 1**.

Installation

The driving behavior of the test piles is presented as a plot of penetration resistance versus elevation in **Figure 1**. Since the test piles were installed using a variable-stroke hammer, and since the penetration resistances presented in **Figure 1** do not account for variations in stroke, the penetration resistances are not directly comparable to each other. A more-direct comparison of driving behavior can be made using Case-method initial-drive capacities estimated by the PDA based on dynamic monitoring results. These data are presented as a plot of initial-drive Case-method capacities versus elevation in **Figure 2**.

CAPWAP analyses calculated the indicator piles' EOID unit shaft resistance distributions. The CAPWAP-determined EOID unit shaft resistance distributions are presented as plots of unit shaft resistance versus elevation in **Figure 3**.

Restrike Testing

CAPWAP analyses calculated the indicator piles' BOR unit shaft resistance distributions. The CAPWAP-determined BOR unit shaft resistance distributions are presented as plots of unit shaft resistance versus elevation in **Figure 4**.

Set-Up

CAPWAP-determined unit set-up distributions were calculated for each indicator pile by subtracting the EOID CAPWAP-determined unit shaft resistance distribution from the BOR CAPWAP-determined shaft resistance distribution (i.e., by subtracting the values presented in **Figure 3** from those presented in **Figure 4**). The accuracy of the resulting difference (the unit set-up distribution) is sensitive to the accuracy (i.e., the degree to which capacity was mobilized) of both the EOID and BOR unit shaft resistance distribution. An assessment of whether each indicator piles' EOID or BOR capacity was fully mobilized is included in **Table 1**.

If both EOID and BOR capacity are fully mobilized, set-up is determined to a reasonable degree of accuracy. If EOID capacity is fully mobilized but BOR capacity is not fully mobilized, set-up is underestimated. If EOID capacity is not fully mobilized but BOR capacity is fully mobilized, set-up is overestimated. If neither EOID nor BOR capacity is fully mobilized, the effect on the accuracy of set-up determination is uncertain. These scenarios are illustrated in **Table 2**, along with each of the test piles' situation among these scenarios.

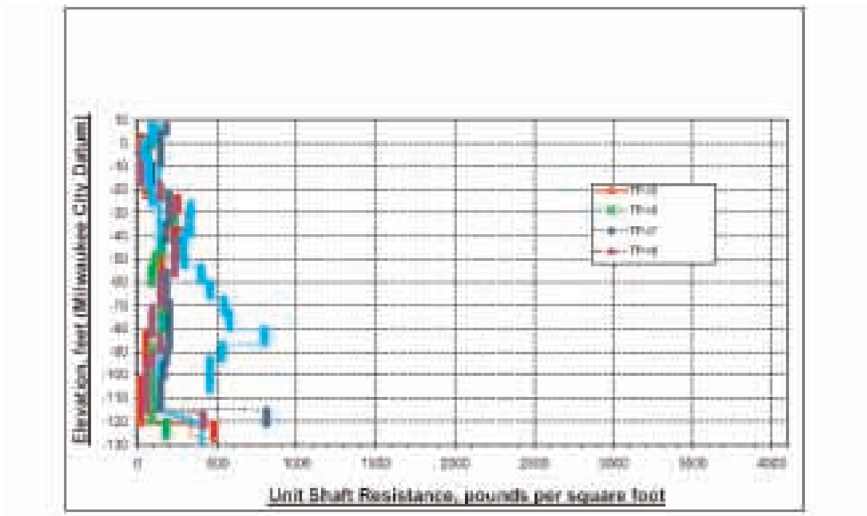

Figure 3. EOID CAPWAP unit shaft resistance vs. elevation.

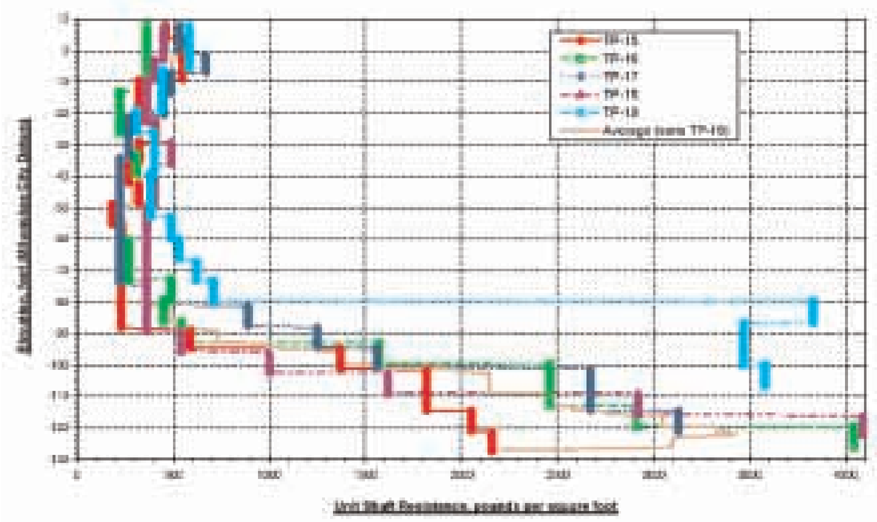

Figure 4. BOR CAPWAP unit shaft resistance vw. elevation.

		BOR Capacity	
		Fully Mobilized	Not Fully Mobilized
EOID Capacity	Fully Mobilized	Set-up Reasonably .ccurate TP-18?	Set-Up Underpredicted TP-17 TP-18? TP-19
	Not Fully Mobilized	Set-up Overpredicted	Set-Up Indeterminate TP-15 TP-16

Table 2. Relationships between EOID and BOR capacity mobilization and determination of set-up.

The CAPWAP-determined unit set-up distributions are presented as plots of unit set-up versus elevation in Figure 5. The test piles' unit set-up distributions being either reasonably accurate, underpredicted, or indeterminate notwithstanding, a review of **Figure 5** indicates that, with the exception of TP19, the CAPWAP-determined unit set-up distributions show relatively good correlation with each other. A review of **Figure 5** indicates that the indeterminate unit set-up distributions (TP15 and TP16) were similar to, or less than, those which were reasonably accurate, and to those which were underpredicted.

Application to Design and Installation

Unit Set-Up Distribution Used for Design

The unit set-up distribution used for design is presented in **Figure 5**. Its application to design is discussed in the following sections.

Allowable Loads Available for Production Piles

For a given toe elevation, the capacity to which piles can be installed is the sum of 2 components: the initial-drive capacity (e.g., as presented in **Figure 2**), plus set-up. It follows that to aid in estimating capacities to which production piles could be installed, the initial-drive capacity and set-up can be added. The result of such an evaluation for piles of the same type as the test piles, and installed using the same hammer as the test piles, is presented in Figure 6. The cumulative set-up curve in Figure 6 was obtained by applying the unit set-up distribution used for design presented in Figure 5 to the surface area of a 12.75-inch-O.D pipe pile. A review of Figure 6 indicates that piles terminating at approximate Elevations 117 and 123 would attain 50 percent of their long-term capacity from set-up.

A review of **Figure 6** indicates that within the depths explored by the test piles, dynamic monitoring results indicated that 12.75-inch-O.D production piles installed using a hammer with a transferred energy similar to that used for the test program (a Delmag D30-32) could achieve capacities of about 345 tons (of which 160 tons, or 46 percent, is set-up), resulting in potential allowable capacities on the order of 172 tons. A review of Table 1 indicates that full capacity was not mobilized for any of the test piles during restrike testing. As presented in **Table 2**, the test piles' unit set-up distributions were either reasonably accurate, underestimated, or indeterminate. A review of **Figure 5** indicates that the indeterminate unit set-up distributions (TP15 and TP16) were similar to, or less than, those which were reasonably accurate, and those which were underpredicted. Accordingly, the values of capacity, set-up magnitude and percentage, and potential allowable load presented in **Figure 6** are likely conservative (lower than actual).

For the south pylon structure, it was desired to install the production piles to as high a capacity as practical. Using GRLWEAP, the drivability of higher-capacity production piles of the same pile section as the test piles, but using the Delmag D36-32 hammer (which was used for restrike testing), was evaluated. It was determined that the larger hammer would provide enough additional capacity at EOID without damage to the piles that, when combined with set-up, a capacity of 380 tons was achievable, resulting in a production-pile allowable load of 190 tons.

Pile: 12.75x0.37 5 Hammer: D36-32 Allowable Load: 190 tons

Pile Toe Depth, feet		Required Penetration Resistance, blows per foot									Pile Toe Elevation	
		Hammer Stroke, feet										
from	to	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	from	to
115	117								—	—	-112	-114
118	120					—	—	—	219	137	-115	-117
121	123			—	—	229	139	102	80	65	-118	-120
124	126	—	—	136	97	76	61	51	44	39	-121	-123
127	129	110	75	58	48	41	36	32	29	26	-124	-126
130	132	49	40	34	30	27	25	22	21	19	-127	-129
133	135	30	26	23	21	19	18	17	16	15	-130	-132
136	138	20	18	17	15	14	14	13	12	12	-133	-135
139	141	15	14	13	12	11	11	10	10	10	-136	-138
142	144	12	11	10	10	9	9	9	8	8	-139	-141
145	147	9	9	9	8	8	8	8	7	7	-142	-144

Table 3. Minimum required production-pile penetration resistance criteria.

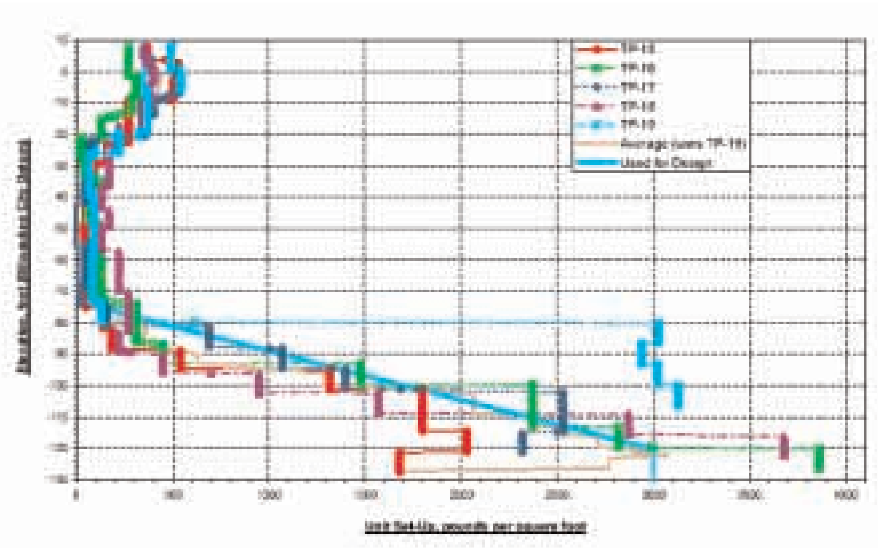

Figure 5. EOID/BOR CAPWAPs unit set-up vw. elevation.

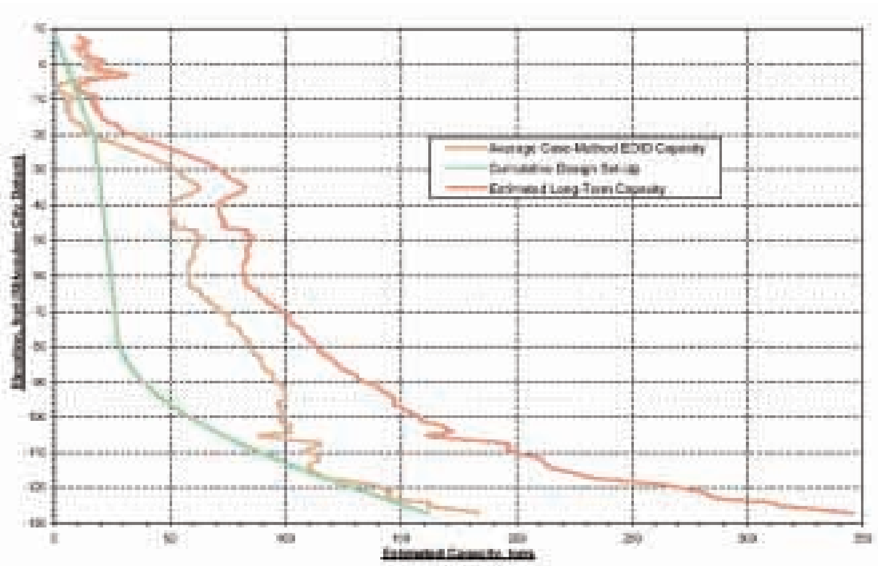

Figure 6. Estimated ultimate capacity vs. elevation - Delmag D30-32 - 12.75-inch pipe pile.

Penetration Resistance Criteria

Subsequent to EOID, a pile's capacity increase attributable to set-up is a function of the embedded side area of the pile, and the unit set-up distribution. The greater a pile's embedment length, the more set-up it develops, and the less EOID capacity is required. In this way, as required EOID capacity decreases with increasing embedment depth, so does required penetration resistance. Therefore, the cumulative set-up distribution for 12.75-inch-O.D. pipe piles presented in **Figure 6** was used to develop depth-variable production-pile penetration resistance criteria which decreased with increasing embedment depth. These criteria are presented in **Table 3**.

Depth-variable penetration resistance criteria account for both the variability of the driving behavior of individual piles (EOID capacity as evidenced by penetration resistance which may vary with depth and location), and the variability of set-up with depth (set-up distribution). This approach allows flexibility in addressing such design- and construction-phase issues as developing depth-variable installation criteria for numerous different required production-pile capacities, and more-accurate assignment of reduced capacities to short or damaged piles.

Production-Pile Installations

The 190-ton (allowable load) production piles driven for the 2 towers at the south pylon structure had an average embedded depth of 123 feet, corresponding to an average toe elevation of 119. Ignoring pile-cap costs, the 190-ton production piles driven for the 2 towers at the south pylon structure had an average support cost of $13.92 per allowable ton supported (support cost is the cost of the installed or constructed foundation element divided by its allowable load). At this location, the relatively deep embedment depths required to reach strata which provided high EOID capacities tended to increase support costs, while the contribution to required capacities from set-up tended to decrease support costs.

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CONCLUSIONS

- Set-up can account for a significant portion of long-term pile capacity. For the case history presented, up to 50 percent of long-term capacity can be attributed to set-up.

- Accounting for set-up in pile design offers a number of benefits, and can result in the use of smaller hammers, smaller pile sections, shorter piles, higher capacities, and more-economical installations (lower support costs) than otherwise possible.

- The characterization not only of set-up magnitude, but also of set-up distribution, offers design- and construction-phase advantages, such as developing depth-variable installation criteria which incorporate set-up for numerous different required production-pile capacities, and more-accurate assignment of reduced capacities to short or damaged piles.

- Dynamic monitoring at both EOID and BOR, in conjunction with subsequent CAPWAP analyses, provides a means to determine both set-up magnitude and distribution.

- Subtraction of the CAPWAP-determined EOID shaft resistance distribution from the CAPWAP-determined BOR shaft resistance distribution provides a means to determine set-up distribution.

- Whether or not full capacity is mobilized during EOID and/or BOR dynamic testing, and the associated effects on calculated set-up distributions, should be recognized and accounted for in selecting a design set-up distribution, and in selecting potential allowable production-pile loads.

- Since set-up is predominately a shaft-resistance phenomenon, and since residual stress and non-residual stress CAPWAP analyses can result in different shaft resistance predictions, the type of analyses (i.e., residual versus non-residual) used to determine set-up distribution should be the same for both EOID and BOR data.

- Piles exhibiting differing driving behavior can exhibit similar set-up distributions.

- Initial-drive dynamic monitoring results, in conjunction with set-up distributions, can be used to predict piles' long-term capacities as a function of depth. This information can prove useful when evaluating potential production-pile sections and allowable capacities.

ACKNOWLEDGEMENTS

The introductory discussion of set-up presented herein is based partly on research funded by the Wisconsin Department of Transportation and the United States Department of Transportation in the interest of information exchange, and is the result of research done under the auspices of the Department and the Wisconsin Highway Research Program.

This article is based on a paper presented at PDCA's September 2002 Symposium. The original paper may be obtained by contacting the author at komurka@wkg2.com.

UNCONVENTIONAL THINKING AND DRIVEN PILE TECHNOLOGY:

Herbert F. Darling, Inc. and The O'Rorke Bridge Project

Built in 1917, the historic Stutson Street Bridge in Rochester, New York allowed people to cross the Genesee River's north end at Lake Ontario without using a ferry. About 80 percent of the original bridge still stands, though it has reached the end of its life. Extensive freighter and dinner cruise traffic required a continued need for a draw bridge, so designers started work on a new bridge with lift capabilities similar to the existing bridge. The O'Rorke bridge project officially began on September 27th, 2000 with a historic groundbreaking ceremony. Construction then began in early October 2000.

The $64 million project is being constructed utilizing federal money, administered by the Monroe County Department of Transportation through a close collaboration with the New York State Department of Transportation. The highway, fixed bridge, movable bridge, landscaping, architectural and marine construction efforts that make up this $64 million project will result in a landmark signature bridge named after Co. Patrick O'Rorke, a local Civil War hero.

The primary component of this project is the replacement of the 83 year old structurally deficient Stutson Street draw bridge over the Genesee with a new landmark caliber, double leaf bascule bridge on a new alignment located south of the existing bridge.

SUCCESSFUL COLLABORATION

Herbert F. Darling, Inc., the engineering contractor in charge of cofferdam design, worked in collaboration with the state and local officials on the structural, geographic, and geological challenges related to the O'Rorke Bridge. Buck Darling explains the logistics involved with the project. This is a multi-span bridge, whose main feature is the draw bridge supported on two river piers. Both river piers are surrounded by permanent sheet pile cofferdams with tremie seals. One pier is supported on driven H-piles, the other supported on 54" drilled shafts, both installed in the wet. All other bridge piers and abutments were supported by driven H-piles.

Buck points out a particular issue faced by their engineers. Because of radically changing geology in the area, there are separate designs for each of the two river piers. Both piers are located inside sheet pile cofferdams. In addition, this project is on a fast track and therefore had to be designed around materials that are on the shelf and immediately available. There was no time to accommodate mill rolling of desired sheeting from Europe. "It was the MacGyver method," Buck laughs. "We put together what was needed for the project from what was available and appropriate."

Adaptation was necessary during the pile driving process. On the east side of the river at pier 2, a typical cofferdam was designed and installed in routine fashion. Bearing piles were then driven in the wet, followed by a conventional tremie placement, which allowed dewatering and further con-

crete placement by the general contractor. The tremie involved the placement of approximately 3000 cubic yards of concrete in a period of twelve hours, representing a record placement for Herbert F. Darling, Inc. and the concrete supplier, Manitou Concrete. Buck was very pleased with the incredible teamwork it took to accomplish this task.

Pier one was unfortunately anything but conventional because of rock found to be sloping at approximately 40 degrees down from the shoreline toward the center of the river. Because of this and the high, steep, riverbank on the shore side of the cell, the cofferdam was not balanced, with the result being the tendency for the coffer to want to slide into the river. To counteract this, circular cells were installed on the landside of the coffer as an anchor, and steel struts were used as tension members to tie the circular cells to the cofferdam. Prior to any of this, a total of 24 drilled shafts of 54 inch diameter with lengths varying from 30 feet on the landside of the cofferdam, to 70 feet on the river side were installed.

Design engineer Dr. Richard Hartman of Hartman Engineering, is well known for his pioneering cofferdam designs, and was crucial in assisting in this endeavor. "He is the first person we think about with this kind of construction." Buck remarks. Dr. Hartman has produced something that is both constructible, and safe.

When the design was completed and plans were reviewed, the complexity of the project became clear. "We were sitting in our office, and I said, 'This is like building a giant Swiss watch.'" Buck elaborates, "Since it is all bolted bracing, some above water, but mostly accomplished by divers underwater, and since it is such a large structure, having everything built in place correctly required a lot of planning and good fabrication." Fabrication of the approximately 248,000 pounds of bracing was performed by Apollo Steel of Niagara Falls, NY, with PDCA member firm Skyline steel supplying all sheet piling, bearing pile materials, and numerous miscellaneous metals for the project.

FLEXIBILITY IS THE KEY

Freighter traffic had to be maintained during construction, thus designers were restricted on what permanent structures could be utilized. There was no way to construct a conventional system utilizing a cellular cofferdam on the West side of the bridge at pier one. Clearance was a vital consideration and rock anchors to tieback the cofferdam to the shore would have been too costly due to imposed design loads, and invasive. The West side of the pier one coffer had narrow access with a working railroad in close proximity, so Dr. Hartman used gravity cells as a mass against which to pull.

Ron Farrell, Project Superintendent, shares how piles were used to ensure safety. There were 24 inch diameter pipe fender piles, and 30 inch dolphin piles ranging in length from 30 to 120 feet in length. These are in case a barge or freighter has difficulty while maneuvering in the river. They can deflect any errant river traffic away from the piers. After the Sunshine skyway bridge issue in Florida, these structures in front of the bridge are put in place for protection.

"This was certainly different than most jobs", Ron explains. During construction, when a ship came into the river from Lake Ontario, and our

barges were in place, we had to move out of the way. Then when the ship needed to come back out of the river, we had to move our barges out of the way again. This was necessary to maintain river traffic, and it was very well coordinated. At the height of the project, there were three barges that had to be move in and out as ships approached the draw bridge. Ron is especially pleased by the interoperation of his team and the bridge employees. "They have to raise the older bridge for some traffic. Our teams and the bridge operator, they all talked to each other and good communications helped to make things smooth. It would have been tough without this communication.

At this time, the cofferdam construction is complete. The team will finish dirt excavation and tremie concrete placement soon. They will then dewater the coffer and turn the project over to the General Contractor, Crane Hogan Structural Systems, Inc., to begin actual pier construction.

Buck Darling is quick to point out who deserves the credit for such a smooth operation under such unusual circumstances. "It depends on good people working together. It is a cooperative effort between engineers, contractors, and owners with everyone and every entity working towards a solution.

PILE DRIVING EQUIPMENT USED FOR THE O'RORKE BRIDGE PROJECT:

American 7260 100 ton crawler crane
Manitowoc 777 series 2 175 ton crawler crane
Link Belt LS-138H II 80 ton crawler crane
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Northwest 9570 60 ton crawler crane
Grove RT-520 20 ton hydraulic crane
Flexifloat Spud Barge Series s-70 80 feet x 60 feet
40 foot x 90 foot spud barge
37 foot Twin Screw 600 hp Tug Boat
IHC s-70 Hydrohammer
ICE 216 Vibratory Hammer
ICE 416 Vibratory Hammer

For further information on the O'Rorke Bridge project, please visit: http://www.ororkebridge.com

Some information in this article is derived from www.ororkebridge.com. The O'Rorke Bridge website was created by the Sear-Brown Group for Monroe County, owner and administrator of the project.

PDCA Member Spotlight:

THE W. M. BRODE COMPANY

CONTRACTORS AND ENGINEERS SINCE 1887

In the late 1800s, Wilson Monroe Brode worked as a master stone-cutter in a large stone quarry. The United States was experiencing a tremendous period of growth and, as a result, the roads were growing quickly and the construction industry couldn't keep up with the demand. Mr. Brode saw this intense demand and, as a result, founded the W.M. Brode Company in 1887. Throughout several generations, the W.M. Brode Company continues to specialize in driving pile.

"We are a General Contractor, but we have always had a directed focus," Bob Brode explains, "What happens in this business, you end up with a starting point which kind of directs your growth for the years to come." Mr. Brode's great grandfather acquired pile driving equipment to move from quarry to pier construction for the railroad system during the expansion of mass transit in the late 19th century. The founding Mr. Brode moved on to work that involved pile driving, creating foundations for government, public structures and private buildings.

The second generation of the Brode family, George B. and Clancy C. Brode continued their focus on pile driving, road construction and bridge construction. During their tenure, World War 2 began. The third generation of Brodes, Gordon G. and Robert M. Brode, returned from the Allied victory. President Eisenhower and the Congress made a conscious decision to connect the country from coast to coast with an interstate highway system. The administration saw just how effective the transportation system was in Germany, particularly with the use of the recently constructed Autobahn national highway. President Eisenhower wanted America to have that same capability. In response to this initiative, the Brode family founded the highway division of the W.M. Brode Company and also began manufacturing their own pile hammers. In recent years, emphasis has been further placed on driven piles and building railroad bridges.

Robert (Bob) W. and George M. Brode and family carry forward the traditions of hard work and initiative. They continue the company's tradition as a multi-disciplined contractor, offering pile foundation design installation, design and installation of cof-

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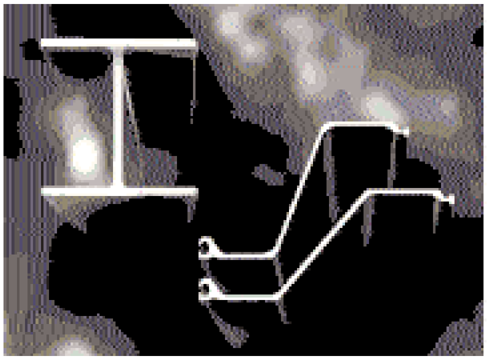

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	in²	cm²	in	mm	in	mm	lb/ft	kg/m	lb/ft²	kg/m²	in⁴	cm⁴	in³	cm³	in³/ft	cm³/m	ft²/ft	m²/m	ft²/ft	m²/m
PZ22	11.86	76.5	22	559	9	229	40.3	60.0	22.0	107.4	154.7	6440	33.1	542	18.1	973	4.94	1.51	4.48	1.37
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ferdams and more. The company's Chief Engineer, Steven W. Brode, is the great, great grandson of founder W.M. Brode. Steven specializes in earth retention structures, sheet piling, shoring and cofferdams.

"Companies have had to grow with needs of our country," Brode observes. "We're seeing now an interesting reconstruction of a lot of the old road structures that were built in pre-1900 days." Bob Brode reiterates the company's historical commitment to pile driving. "We find ourselves submitting proposals to rebuild structures we built the first time around. We like to use our expertise as pile drivers to make us competitive in road and bridge construction."

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"Building Market Share through Professor Education"

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Over the past several years, the driven pile has lost market share to other deep foundation types, primarily because of the excellent job that has been done in selling cast-in-place systems. Outstanding educational programs promoting these systems have been an important factor in increasing the use of drilled shaft deep foundation solutions.

2003 is the second year for the Professors' Piling Institute, which provides an organized educational program for 25 college professors each year. Over the course of an intense, five-day program, professors will be presented with extensive educational material covering all aspects of driven pile design and installation. Attendees will have the opportunity to establish long lasting contacts with PDCA members and other attendees.

Additionally, a pile will be driven as a demonstration during the Institute. It will be statically load tested and dynamic measurements made. The course attendees will have the opportunity to: (1) predict the pile capacity based on the subsurface information; (2) predict the drivability of the pile; (3) predict the pile capacity using dynamic measurements made during driving, together with an analysis using the CAPWAP program; and (4) compare all of these results with the field observations.

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PDCA IS Working For You To Improve Market Share

Over the past 30 years there have been tremendous changes in piles, installation equipment, quality control and the way driven pile design is performed. These changes are not covered in current foundation design textbooks. Instructors for the course have been selected from among the leading driven pile specialists in the United States. They will cover all aspects of driven pile design, installation and quality control.

Extensive technical material, notes, course outlines and teaching material will be provided to the attendees.

We Need Your Help

The Piling Institute is a cost- and labor-intensive project. Your Association is funding virtually all expenses for invited professors, including housing, meals, instructor expenses and travel. That's why we need your help. Please consider sponsoring a professor at this prestigious event. Contributions in any amount will be accepted. All sponsors will be acknowledged on the PDCA website and in an upcoming issue of Piledrivers.org. With your help, we can increase your market share and build a solid foundation of enlightened engineers for the future.

"I truly enjoyed the First Annual Professors' Piling Institute course. It was great interacting with colleagues from all over the United States and now I can relate their faces to their names. The materials we received as attendees were very well organized and enabled me to formulate a new graduate course."
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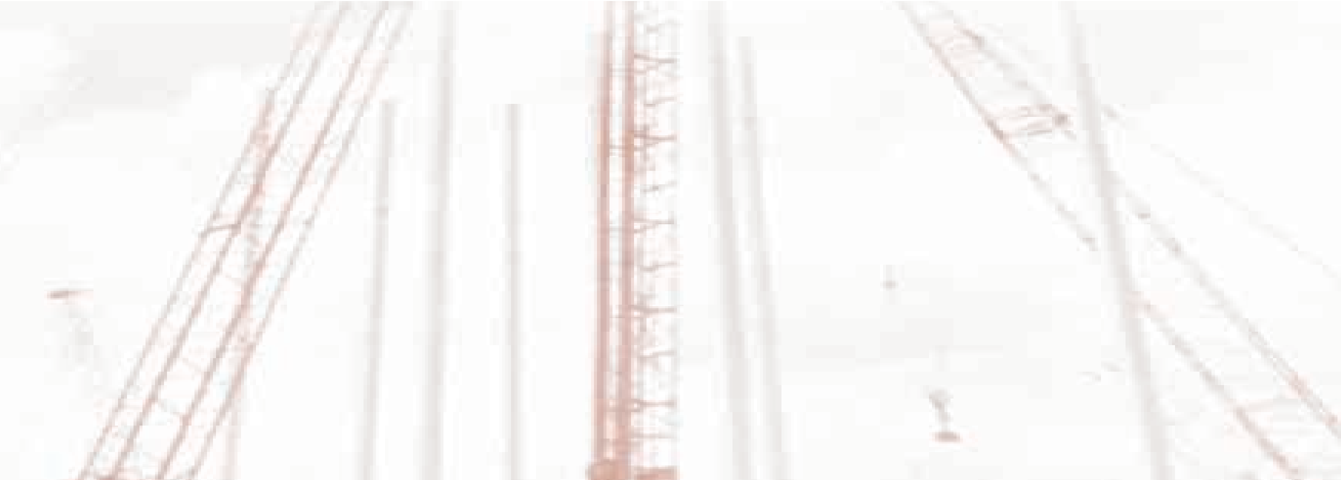

The Woodrow Wilson Bridge:
OVERCOMING CHALLENGES ON LARGE PILE DRIVING PROJECTS

Completed in 1961, the Woodrow Wilson Bridge, which spans 1.2 miles, now carries nearly three times its original intended traffic volume. As a result, improvements to the bridge have been under consideration for several years. Currently, the eight-lane Capital Beltway converges into the six-lane Woodrow Wilson Bridge resulting in one of the worst bottlenecks in the country. Once finished, the new bridge currently under construction will dramatically relieve this enormous congestion.

The driven pile-related work was one of the first contracts in this mega project. In March 2001, TKC, a joint venture of Tidewater Skanska, Kiewit Construction and Clark Construction, placed their bid on the first part of the Woodrow Wilson Bridge foundations. This bid included the construction on the foundations for the entire outer loop of the I-495 beltway and the majority of the inner loop of the beltway.

The aggressive schedule established by the contract documents was managed by separating the project into three distinct areas with each area supervised by a TKC Area Superintendent. The land portion crossing Jones Point Park in Alexandria, VA, consisted of 14 foundations, 10 of which were supported on a total of 408 each 24" pre-stressed concrete piles supplied by Bayshore Concrete Products. Most foundations, however, are over water. The bascule piers, supporting the draw span of the bridge, contain the largest piles and footings on the project. Each one of the hour 6,000 cy concrete footings are supported by 35 to 39 each 72" diameter steel piles ranging in length from 190 to 210 feet long. The balance of the project consists of 9 piers, names "M2" through "M10", each consisting of 4 individual footings. These piers are on the Maryland side of the river. Piers M2 - M10 have 12 steel piles under each foundation. In total, there are 420 steel piles from M2 - M10, ranging in length and diameter from 169 ft. and 48" to 190 ft. and 66" inches.

The deepest driven pile on the project was driven down to a tip elevation of 225 feet below water level. On land, pier V2 was adjacent to the shoreline, and consisted of four footings containing 15 steel piles per footing, 54" in diameter and 200 ft long. According to TKC's Project Manager James "Brook" Brookshire, III, these piles "were the most technically challenging piles to drive on the project."

Brook explains the challenges faced

by the team, "Because it was on land, there was significantly more soils through which the piles were to be driven. Soil borings in the area indicated that driving resistances would be much higher than the river piling. We had to erect a Manitowoc 4600 Ringer with 300 feet of boom in order to have sufficient crane capacity and head room to unload the piles from the barge, upright them, and drive them on land."

The process of driving all 628 large steel piles took 11 months. Most steel piles were manufactured in Houston, TX, by Kellogg, Brown and Root, Inc. "They fabricated all of the 54", 66" and 72" piles." Brook remarks, "We were very impressed with their quality control and ability to meet our schedule." The 48" steel piles were supplied by Skyline Steel, who provided equal attention to schedule and quality.

The actual construction process mobilized on June 4th, 2001, and TKC started driving steel piles in September 2001. Although still in phase one of the project, there are three more phases to building the entire superstructure to be advertised and awarded. As of January, phase one of the project is 90% complete with the pile driving portion finishing in July 2003. The bridge is projected for completion in 2007.

Overall, the tremendous size of the piles was the biggest challenge to the team. "It's unusual for this area. You normally don't see such large piles but the size of this bridge required the designers to use the larger piles in order to support the structure," Brook notes. The span between the footings is over 300 feet, which places an enormous load on each footing. Large pile hammers were needed and two hammers were used. The main hammer used was an IHC S500 with 368,000 foot pounds of energy. The backup hammer, also used to drive the V2 piles on land, was a Menck MHU 500T with 405,600 foot pounds of energy.

Construction was under a very tight and rigorous timetable. "In order to achieve the schedule, we had two superintendents assigned to drive the piles, using the same crane on split shifts." Brook is proud of their efforts to fulfill the timetable, "We could only work in daylight hours, from dawn to dusk. Each team worked four days on and four days off, seven days a week, daylight to dusk, to get these piles done."

When asked about the lessons taken from such an enormous project, James Brookshire is quick to share the credit. "You learn something from every project. We did a lot of planning and it was a lot of teamwork and hard hours," he says. "Our planning and teamwork paid off and we ended up completing the piles right on schedule."

Note: The 2002 DICEP conference (PDCA), held in New Orleans, spoke on this project. To obtain a copy of the proceedings from PDCA headquarters, please call (888) 440-7453

Aren't Specs Terms Supposed to be Plain? MOVING TOWARD A MORE UNIFORM TERMINOLOGY

By: Bengt H. Fellenius and Mohamad H. Hussein

Technical Contract Specifications are supposed to reflect good and proper design and many do. Far too many, however, are bewildering due to the use of ambiguous terminology. Piling lingo, in general, contains an astonishing array of confusing vocabulary and nomenclature. The carefree vernacular of the job site includes slang, jargon and colorful phraseology. For example, a disinterested person may be amused by hearing the upper end of the pile referred to as the "butt". However, not so disinterested persons, such as design engineers, contractors, and inspectors, are adversely affected by ambiguous terms and absurd definitions that abound in project specifications, contract documents and job reports. Lack of precise language and uniform terminology causes confusion, creates problems, and is often the root of disputes and costly claims.

The February 2002 International Deep Foundations Congress organized by the Geo-Institute of the American Society of Civil Engineers (ASCE), Orlando, Florida, gathered more than 500 piling practitioners from across the United States and around the world. More than 100 papers were presented on the current state of the art and practice in deep foundations. A review of the 1,566 page, two volume conference proceedings reveals that the terms used to communicate, qualify, or quantify the related but not identical concepts of pile "capacity" and "resistance", resulted in more than twenty different definitions, descriptions, expressions, and terms. Sometimes the terms were used interchangeably. The terms ranged from precise, vague, and ambiguous, to outright careless. Some of the more nebulous expressions to quote from the papers are: "foundation ground resistance", "safe working load capacity", "total allowable resistance", "effective total pile resistance", "useful capacity", "dynamic capacity", "pile resistance", and "design safe working load".

Actually, the parade of confused and confusing phrases is no wonder considering that specialized engineering textbooks employ a similarly lax, if not directly erroneous and misleading vernacular.

The following example taken from actual contract specifications demonstrates the desirability of devoting more thought toward terms and expressions used in the specs: A design engineer, in an area where the piles would normally be installed to a 200-ton capacity, was faced with the problem of the piles potentially reaching into a boulder layer existing at depth at a site. To avoid potential pile damage, the engineer reduced capacity per pile to only 100 tons, so that the piles would be correspondingly shorter and not reach into the boulder zone. However, someone-it was never determined who-thought that plain 'capacity' sounded too casual and added the adjective "load" to the term "100-ton pile capacity" used in the designer's draft specs so it now read "100 ton pile load capacity". At the outset of pile driving, the contractor asked what loads he was to drive to

and was told that the specs indicated that the pile loads were 100 tons. So, naturally, he drove to a capacity of twice the 100 ton load, which meant that the piles had to be longer and, as the designer had feared and wanted to avoid, the piles were driven into the boulder layers. The results were much breakage, problems, delays and cost overruns. The contractor's claim for extra length of piles and prolonged driving was $300,000.00, or $75,000.00 per letter of the misleading adjective.

Incidentally, of all terms, "capacity" is most often misused. A recent DOT specs text required the Contractor to achieve an "intimate capacity", probably a misspelling of "ultimate capacity". "Capacity" simply means "ultimate resistance" and adding the adjective "ultimate" is redundant, because the term does not require an adjective (other than "axial" as opposed to "lateral", for example).

Similar to "capacity", "load" is often combined with adjectives that can result in confusion. Combinations such as "allowable load", "factored load, "dead load", "live load", "permanent load", "transient load", etc. are well defined and therefore unmistakable. However, some people find different meaning in "design load", and "working load" and some believe the two to be synonymous. If both are used in the same specifications, a judge, at least, will take them to have different meaning-if not so, then only one should have been used in the specs-but, same or different, what do the terms mean? The term "design load" is usually taken to mean the maximum load acting on the foundation (the pile) from the structure. It could be equal to the "allowable load", but it cannot be larger. The term "working load" does not work very well and is best not used. Adding the word "safe" to either term, or to any term, increases the potential for confusion.

On the topic of using jargon: the word "set" is not a synonym for "blowcount" (the blows counted for a certain penetration distance). "Set" is the net penetration for one blow or possibly for a series of blows. Its origin is an abbreviation of "settlement", meaning the net penetration, usually for one blow. The following is an example of what the use of "set" can cause: Specifications for a project stated that piles were to be driven to depths indicated by the plans and drawings and added "the piles will be driven to a very small set and the Contractor is cautioned not to overdrive the piles". Of course, the Contractor took care not to damage the piles by driving them too hard, which is what "overdriving" means,

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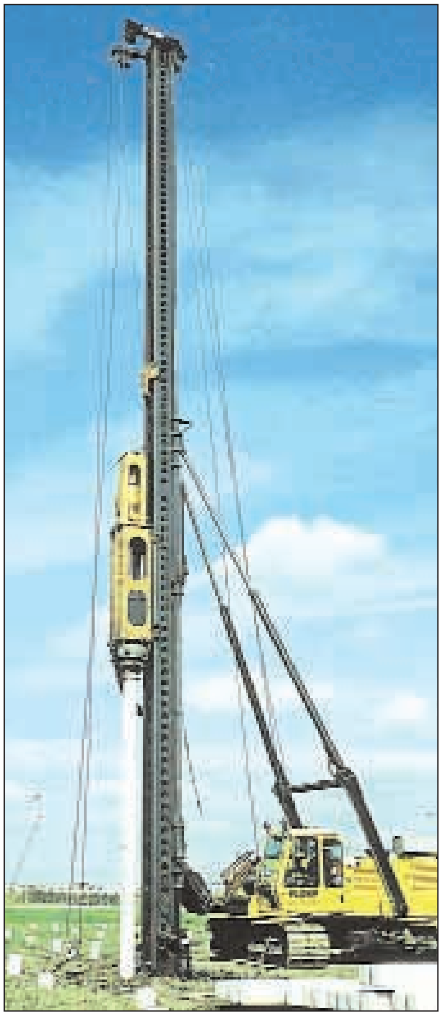

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and which can occur when the penetration per blow is very small. However, the driving turned out to be very easy, and, in the Contractor's search for the "very-small-set" termination criterion, he drove the piles much deeper than the plans and drawings indicated. Unfortunately, in writing the quoted sentence, the spec-writer meant to warn the Contractor that the penetration per blow was expected to be very large and that the piles, therefore, could easily drive deeper than desired. Talk about diametrically opposed interpretations! And predictable surprises. In this case, the Engineers insisted that their intended interpretation was the right one and a costly claim and litigation ensued. Because the industry has a vague understanding of the proper meaning of the term "set", avoid using it in any context. Use "penetration resistance".

The word "set" is also frequently misconstrued to be a synonym for "termination criterion", which, incidentally, is not the same as "refusal", and the jargon confusion does not get any better by shifting from "set" to "refusal". Although most people have a qualitative understanding of what is addressed, one person's refusal is another person's promise. "Refusal" is an absolute term. It implies that one just cannot drive the piles deeper after having exhausted all means to do so. Then, specifications suggesting "a refusal of 6 blows/foot" sounds not only silly, but implies a spec writer with a poor command of language. Instead, "Termination criterion" should be used. It is a neutral term that states exactly what is meant.

What about "battered"? It is a term that really separates the men from the boys, or people experienced in-or at least exposed to-piling from people who are not. The latter group includes lawyers, judges, and jury members. A case in point is the true story, experienced by the first author, of a contractor appearing in court to argue a claim and did he ever have an uphill battle once the judge realized that he had battered his piles. The judge had experience of battered spouses and children, but he had no knowledge and little appreciation of that the term would have a discrete meaning for piling people. When the matter was made clear to him, he was quite annoyed by that a group of professionals would use a jargon term that had a perfectly suitable every-day English term available, i.e., "inclined". Please, stop using "batter". Alas, a cry in the wilderness; it is getting worse rather than better; recently a paper used the "batter" term to characterize a leaning structure!

There is more to the matter than a poor choice of terms and definitions. You may enjoy the following direct quotes from real life contract specifications:

1. Piles shall be driven to reach the design bearing pressures.
2. The minimum allowable pile penetration under any circumstance shall be 17 feet.
3. The Contracting Officer will determine what procedure should be followed if driving refusal occurs.
4. The hammer shall have a capacity equal to the weight of the pile and the character of the subsurface material to be encountered.
5. The hammer energy in foot-pounds shall be three times the weight of the pile in pounds.
6. Inefficient diesel, air, or steam hammers shall not be used.
7. Each pile shall be driven until the bearing power is equal to the design piles pressure.
8. All piles incorrectly driven as to be unsuitable as determined by the Contracting Officer shall be pulled and no payment will be made for furnishing, driving, or pulling such piles.
9. All piles determined to be unsuitable by the Contracting Officer shall be replaced by and at the expense of the Contractor.
10. The driving shall continue, using hammer falls of 150 mm to 200 mm in a series of 20 blows until penetration of the pile has stopped. The height of the fall shall then be doubled and the pile again driven to refusal. This procedure shall be continued until the design load of the pile has been achieved.
11. The pile design load is defined as 1.5 times the working load. The design load will be deemed to have been achieved when the pile exhibits zero residual (= net?) set under 10 successive blows of the

hammer, where each blow has a sufficient energy to cause elastic deformation of the pile at the ground level equal to the static shortening of the pile at design load, as calculated by Hooke's Law.

12. Inclined head to be used for batter piles.
13. Cut off portions of pile, which are battered, split, warped, buckled, damaged, or imperfect.
14. Where unwatering is required, the Contractor shall effect a dewatering scheme.
15. When the hammer performance is requested to be verified, all costs associated with this work will be included in the contract price when the energy delivered is less than 90 % of the stated potential energy specified in the submission. When the energy is greater than 90 % of the potential energy stated in the required submission, the costs will be paid as extra work.
16. Pile shall be accepted if ... the pile reaches refusal at a load, which would give a working load equal to or greater than the design capacity.

17. The piles will be driven to a factored design load of 630 kN (71 tons) which is about 3 times the estimated required bearing capacity.

As a Contractor, would you want to have these requirements imposed on you? As an Inspector, would you want to be the one enforcing these specs? And, as an Engineer, how do you feel about your professional association with such nonsense!

Surprises occur frequently during construction projects. The surprises take many forms, but one aspect is shared amongst them: they invariably result in difficulties at the site and, more often than not, in disputes between the parties involved. When the unexpected occurs at a site and costs escalate and delays develop, the Contractor feels justified to submit a claim that the Owner may see little reason to accept. Well-written specifications can resolve disputes and avoid claims. However, when the parties turn to the technical specifications for the rules of the contract, these often fuel the dispute instead of mitigating it, because the specifications are vague, unclear, unbalanced, and containing ambiguous language and weasel clauses that help nobody in resolving the conflict.

The piling practice differs with geologic conditions and geographic location. It would be difficult to come up with a set of master specifications that would fit all projects. However, we should be able to agree on a common usage of the terms and definitions involved in our industry. Maybe a list of well-defined terms could be a task for the PDCA, in order to move toward a more uniform terminology.

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