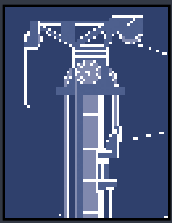

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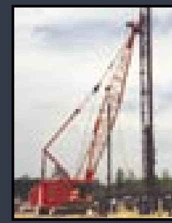

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PILEDRIVER

The Official Publication of The Pile Driving Contractors Association | Winter 04/05 vol. 2, no. 1

PROJECT SPOTLIGHT:

PND Completes Alaskan Tourship Task in Stride

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COVER:
Jacobsen Dock, Juneau, Alaska. Photo courtesy of PND Incorporated Consulting Engineers.

Welcoming the Challenge

PDCA is not only a national organization providing leadership and educational programs for its members, it is also developing a network of local chapters across the country where there is a need to handle local concerns and issues.

By Randy Dietel, PDCA President

It is indeed an honor to be at the helm of this dynamic and active organization for the year 2005. Having served on the board for the past five years, I have seen many changes, which have moved PDCA through its infancy and early growing pains, to an organization with many ongoing activities, as well as some significant projects just starting and others already proposed. PDCA is not only a national organization providing leadership and educational programs for its members, it is also developing a network of local chapters across the country where there is a need to handle local concerns and issues.

But, first I would like to share a little about who I am, because I think it is important for you to know that I am probably a lot like many of our members. I run a small family-owned business, specializing in pile driving. We have both land and marine operations. The company was founded in 1931 in Texas City, Texas, and caters primarily to the petrochemical business along the Gulf Coast. I am a third-generation owner along with my wife Peggy.

I would be remiss in this first message if I did not give a very big thank you to our past president Wayne Waters and Tanya Goble, our executive director. These two, along with the board of directors, have led PDCA to a much stronger position and have put into motion actions that will be of significant benefit to the organization for many years to come.

PDCA, with its diverse membership of contractors, engineers, suppliers, manufactures and technical affiliates, has a wealth of knowledge and resources. Many of these individual members are putting their skills to work for the good of our organization.

I hope you will read through this publication and take advantage of the educational articles included. I also hope you will be attending our Winter Roundtable in Charleston, South Carolina from February 17-19, 2005. I encourage you to make your reservations today.

If you are not already a member, you need to join today. We don't just want your money, we want your input. We want to know what PDCA can do for you and what issues in your business are in need of some outside help from our national organization. We have the ears of more and more agencies, organizations, and businesses. And, remember, driven piles are tested piles! ▼

Dr. George Goble was honored at the GeoInstitute's July 2004 GeoTrans conference with a new book published in honor of his pioneering contributions to the advancements of the state of the art of deep foundations. The book, *"Current Practices and Future Trends in Deep Foundations"* was edited by Mohamad Hussein, GRL Engineers and Jerry A. DiMaggio, FHWA and presents 26 papers on developments in deep-foundation design, construction, testing and inspection which can save time, reduce cost, improve quality and enhance performance. The book can be purchased for $69 from the ASCE Web site at www.asce.org/bookstore/book.cfm?book=4503. Pictured from left to right are Mohamad Hussein, GRL Engineers; PDCA President Randy Dietel; Wayne Waters, PDCA past president; and Dr. George Goble.

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FOUNDATION SOLUTIONS

PDCA Takes on **Pile-driving Noise and Vibrations**

By Tanya Goble

In 2004, PDCA decided to establish a new environmental committee, with PDCA board member John Linscott of H.B. Fleming as chairman. The committee is busy working on solutions to a variety of environmental issues facing our industry, with an initial focus on pile-driving vibrations and noise.

Vibrations and noise generated during pile installation are a concern for many driven-pile projects, particularly those located in urban environments. These concerns can be a factor in selection of other deep-foundation alternatives over driven piles. For some projects, noise and vibrations concerns can be overstated and take away from the other advantages of a driven pile solution. Although experience has shown that noise and vibrations concerns can be managed, the currently available information makes it difficult to illustrate.

Over the years, many driven-pile projects have had a combination of noise and/or vibration monitoring conducted. However, there is currently no way for people in the industry to access and examine the resulting data and case histories. By collecting this data into a single database, research can be conducted to examine the generation of noise and vibration from pile-driving operations, develop accurate noise and vibration attenuation (dissipation with distance) relationships and establish realistic criteria for driven-pile projects.

Now, a research effort is underway at The Citadel to develop a national noise and vibration database. This research effort is sponsored by the PDCA and conducted in conjunction with Wright Padgett Christopher Inc., an engineering firm located in Charleston, South Carolina.

Noise and vibration concerns can be overstated and take away from the other advantages of a driven-pile solution.

PDCA needs our members, including contractors, suppliers and engineers to contribute noise and vibration data. You may have this data from past or current projects. Requested data includes but is not limited to the following:

- Vibration measurement data (e.g. peak particle velocity, vibration frequency, distance of vibration measurement to driven pile).
- Noise measurement data (e.g. linear or A-weighted noise in decibels, distance from driven pile to noise measurement).
- Pile information (e.g. type, size, and length).
- Hammer information (e.g. type, rated energy, cushion materials).
- Soil information (e.g. soil profile, boring logs with SPT N values, insitu testing data), pre- and post-condition survey data.
- Other relevant information (e.g. complaints from neighbors).

Data can be supplied in any format — the research team at the Citadel will sort through it and place it into the database. Any contribution of data would be of tremendous help to the development of a robust noise and vibrations database.

Please send your noise and vibration data to:

PDCA
Attn: PDCA Vibration/
Noise Database
P.O. Box 19527
Boulder, CO 80308

Upon completion of the project, the new database will be accessible from the PDCA Web site at www.piledrivers.org. It will be presented to the engineering and contractor communities via articles published in relevant industry publications, in *Piledriver* magazine and at PDCA events as well as through cooperative arrangements with other industry groups. Extensive education material and compilation of existing papers on the subject will also be made available on the PDCA Web site.

PDCA wishes to thank Ed Hajduk of WPC, Inc. and Dr. Kevin Bower and Dr. Timothy Mays of The Citadel for their efforts in getting this important project off the ground. ▼

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PND Completes Alaskan Tourship Task in Stride

By Dennis Nottingham, P.E., President and Todd Nottingham, P.E., Vice President, PND Incorporated Consulting Engineers

Constructing a floating dock to moor cruise ships, up to 1,100 feet in length in water depths reaching 100 feet, with tide ranges of 30 feet, was the task recently assigned to PND Inc. Consulting Engineers for new cruise ship facilities at Whittier and Juneau, Alaska.

Floating docks are popular in the cruise ship industry, particularly where significant tides prevail, because of ease and speed of embarkation and disembarkation of passengers without using costly adjustable ramps. Ship servicing is also made easier.

However, floating docks can be very expensive. To counter this expense, PND chose to use refurbished barges held in place by their research and development product termed “spin-fin” piles and connected to shore by ramps which account for tide changes. Pipe-pile dolphins extend off each end of the floating component to provide adequate mooring length. Shore terminal facilities are located on armored fills with paved access for pedestrians, buses, vehicles or to trains at Whittier.

Floating docks provide the best access for pedestrians and service vehicles. Ramp in background adjusts for tides.

The Solution

Both port sites featured granular soils, Juneau being less dense silts and sands than Whittier's medium dense sands and gravels. Depth of water and soils conditions dictated use of driven piles for dolphins and to anchor floating docks. In each case, maximum pile lengths would have to be in the 200- to 300-foot length range.

The type of vertical and batter-pile systems envisioned are relatively light and require piles to develop both high compression and tension loads.

As background, PND began researching a new driven pipe pile type termed the "spin fin" around 1983 and first used them for retaining wall tiebacks for the Seward Coal Port.

The Alaska Department of Transportation and Public Facilities and Federal Highway Administration became interested and helped support research and testing. Subsequently, a piece was published in the AASHTO Quarterly promoting the concept. Performance observations, including one large cruise ship collision (on video), also helped to verify "spin-fin" pile performance. To date, more than 3,000 of these piles have been driven and are functioning well.

Pipe piles selected for Whittier and Juneau ranged from 24- to 42-inches in diameter and were fitted with slanted steel-tip plates and shoes "spin-fin tip." These tips have been found to act like enlarged anchors and not only greatly add to tension resistance, but also compression resistance. An uncommon benefit from these piles is reliability and energy absorption, which is of major importance for ship impact, surge and seismic events.

"Spin-fin" piles can be driven using vibratory hammers or impact hammers as appropriate. Driving resistances are typically 20 percent to 30 percent higher than non-finned piles. However, after installation, these piles exhibit capacities typically twice that of non-finned piles. Driving "spin fins" with a vibratory hammer also seems to increase surrounding soil density, which is consistent with other PND research involving deep soil densification. Misplaced vibratory hammer-driven piles have been extremely difficult if not impossible to pull.

Construction Methods and Field Conditions

Both sites provided the marine contractors with unique construction challenges. However, both were constructed in winter conditions and in areas with high-tide ranges. Also, both projects required the handling of relatively heavy long piles with the majority driven at a batter (rake) of 6:12.

The 6:12 batter on the piles was a challenge met by the contractors through effective rigging and templating

Spin fin piles used at Juneau.

Spin fin pile ready for stabbing.

methods. For most dolphin structures, a fixed template was constructed of temporary piles to handle the significant lateral loads imparted during driving of the batter piles. In addition the templates provided a work platform for final positioning and welding of the piles.

In Whittier, water depths ranged from EL -100 MLLW to EL -35 MLLW with tides to EL +17 MLLW. The longest pile driven was about 200 feet in leads with 50 feet of penetration. The entire project was able to be driven with a vibratory hammer, an HPS Model 500. Pile capacity was based upon obtaining a minimum required embedment. For this project, with shallow bedrock beneath medium dense gravel, spin fin piles provided the necessary tension capacity without using expansive rock anchors. The HPS hammer was able to drive the 42-inch diameter spin fin piles with open tip over 50 feet into relatively dense sandy gravel. Pile capacity in compression and tension was based upon historic testing in similar soils, since tension capacity of spin fin piles cannot be determined by PDA or similar methods. Twenty-four piles were driven and connected over a period of two months to support the floating dock and dolphins for a total pile length of about 3,900 linear feet.

Whittier Dock

In Juneau, water depths ranged from EL-70 MLLW to EL -35 MLLW with tides ranging from a high of EL +23 MLLW to a low of EL –5 MLLW. The longest pile driven was about 300 feet with approximately 200 feet of penetration. Combinations of hammers were used to drive the dolphin piles. Initially, piles were started with an APE 200 Vibratory which in general was able to advance the initial pile length of 160-feet in the relatively softer soils to the template level. Pile splices of 40 to 80-feet mostly on a batter were completed using AWS field butt welds with backing rings and then the pile was driven further with either an ICE 120 or I-80 impact hammer. Final pile embedment varied from 100 to nearly 200 feet depending upon load and the variability of soil conditions across the site. Some piles were retapped after setup with increases in bearing capacity of between 150 percent and 300 percent in less than three days. Pile capacities in tension and compression were based upon driving resistances and historic testing in similar soils. Ultimate pile capacities of over 800 kips in tension and compression were obtained. A total of 69 piles for breasting and mooring dolphins, floating dock mooring and fenders were driven over a two month period. ▼

The Participants

Whittier Cruise Ship Facility
Owner – Whittier Dock Enterprises
Developer – Passage Canal Development
Marine Contractor – West Construction Company

Juneau Jacobsen Dock
Owner and Developer – Cruiseline Agencies of Alaska
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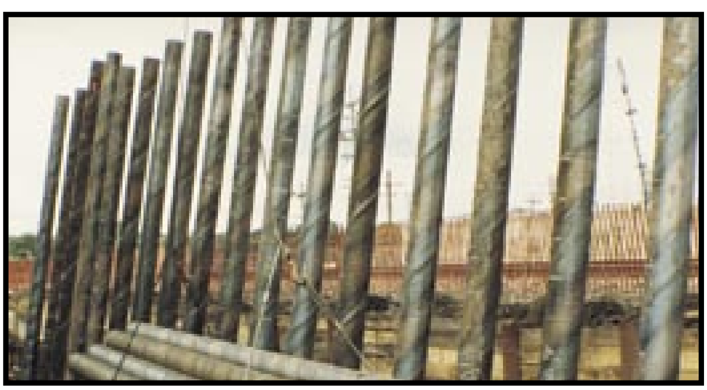

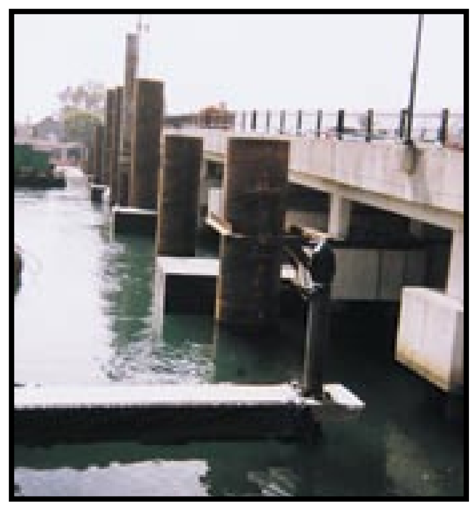

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Pile Cushions:

A Make or Break Proposition

By Steve Whitty, Specialty Piling Systems, Inc.

Pile cushions are one of those details often overlooked or misunderstood in the execution of a piling project. Pile cushions are a type of pile-driving cushion and differ from hammer cushions. However, like hammer cushions, they represent a small item in the overall scheme of things. They are consumables, just like fuel, oil and other items necessary to the execution of the work but not incorporated in the finished project. They have an anomalous function in that they are provided to "cushion" a blow and protect parts of the system, but are required to "transmit" as much of the driving energy as possible to the pile. Pile cushions are not necessary to almost every project as are hammer cushions, but they are essential when driving concrete piles and, although they are a minor cost item when compared to the cost of the pile, the total cushion expense on many projects can be substantial.

The question is, "What are pile cushions and why are they important or required"? As the name implies, pile cushions are provided and necessary to protect the pile during driving; plain and simple, or so it would seem. The fact is that pile cushions perform a rather more complex task than they appear from first glance.

When concrete was first used as a pile material, the piles were conventionally reinforced and cast. The length of the individual pile sections was limited by the reinforcing steel content to short lengths that could be supported in the horizontal as a beam (such as when the pile was lifted from the form, transported to the job site or picked from the ground and tilted to the vertical in preparation for driving). In these early days of conventional reinforcing, the piles were rather simple in design and usually driven with simple equipment such as drop hammers. It was obvious that a drive cap would be required to avoid striking the pile top directly by the cast iron or steel hammer and that some sort of material was required to avoid damage to the pile top from spalling. This was accomplished by the use of pieces of wood planks on top of the pile, inserted into the drive cap. Often times, other materials such as a tight coil of rope would be used. With the increased use of mechanically operated hammers imparting greater energy to the pile top, this issue became more critical and the usual remedy to problems was to increase the thickness of the cushion material or to use hardwood blocks.

As the name implies, pile cushions are provided and necessary to protect the pile during driving; plain and simple, or so it would seem.

When pre-stressing was introduced for the manufacture of piles, pile lengths were able to be extended considerably. During manufacture, transport and handling, "residual compressive forces" due to pre-stressing of the strand, provides rigidity which allows for lengths longer than for conventionally reinforced piles. Over time, additional advancements were introduced. Stronger cement mixes, larger and stronger stressing strand, and differing aggregates all contributed to the strength, increased length, and cross section of the piles. It was not long after that these longer and larger piles were being driven with bigger hammers and differences in the characteristics of the piles became apparent. Certainly, the longer lengths required additional attention during handling and this was readily apparent because it was observable while the pile was above ground. However, with more piles of longer lengths being driven, it was noted that increasing numbers of piles were cracking or breaking during driving and not just at the tops.

Without going into a lot of history, it is sufficient to say the problems were studied and a better understanding of how the pre-stressed, pre-cast concrete piles reacted during driving was provided. Instruments employed to monitor piles during driving confirmed much about how piles behaved in differing scenarios, i.e. differing soil types and differing hammer types and energies. As a result, it was discovered that the piles are not as rigid as once thought and, in fact, are rather elastic. The effect of the pre-stressing causes the pile to be compressed throughout its length. During driving, especially when piles drive through a rather stiff soil layer and into a soft to very soft strata, the piles have a tendency to "drive the tip portion away from the body of the pile" in a similar fashion as a croquet ball is driven away from its touching neighbor when the neighboring ball is struck by the mallet. The problems occur when there is relatively little resistance at the tip, causing the tensile forces to exceed the residual compressive forces due to pre-stressing. The residual compressive forces in the pile are acted against by the energy of the hammer blow being transmitted through the pile toward the tip, and reflected back toward the top as tensile forces. This is where the pile cushion is called upon to do its job. It acts to dampen the intensity of the forces generated by the hammer blow while allowing the transfer of as much energy as possible to drive the pile, pushing it into the ground, rather than having the tip tend to pull away from the rest of the pile.

Identifying the problems that can occur in driving pre-stressed concrete piles has resulted in different materials being tried as pile cushions. Different combinations of wood and wood products have been the most popular materials tried with some manufactured products showing some promise. Presently, the pile-driving industry predominantly uses plywood materials although some contractors use manufactured products with success. Regardless of the material employed, there are certain characteristics during use common to all cushions. Considering the job that the cushion performs, it is essential to understand that a fresh cushion is better able to do its job than one that has been used for a while. After being pounded by the hammer for some time, the cushion tends to become compacted and its ability to cushion the blows is diminished. In the case of the wood and plywood cushions, this can be carried to the extreme and they start to retain heat energy, not only robbing the systems of driving energy but also producing heat in sufficient amounts to cause the cushion to char or burn. At this point, the cushion is not able to cushion the blow, and continued use can expose the pile to damage. For this reason, a fresh cushion should be used for each pile at the start of driving. Also, when a pile is stopped during driving (to change cushions or other reasons) it is subjected to "freeze" or "set up" in the soil, frequently making it difficult to start the pile moving again when driving resumes. In addition, this mandates that the driving rig be checked closely for alignment with the partially driven pile before driving resumes to avoid bending and possible breaking of the pile.

In addition to thickness, another consideration when selecting pile cushions is that the cushions are properly fitted to the pile and drive cap. A misaligned cushion can cause the hammer blow to be transmitted unevenly to the end-face of the pile, possibly causing harmful high stresses to one side of the pile and, consequently, spalling of the end. Just as it is a requirement that the pile ends be provided smooth and square to the axis of the pile, it is necessary to have the cushion sit tightly and in intimate contact with the end of the pile, allowing for the uniform transmission of the energy to the pile.

When selecting cushions, consideration must be given to the pile length and the soils anticipated to be encountered. A preferred way to select the proper cushion is to get this information when running a wave equation analysis of the pile, hammer and soil system. Modern practice dictates that a consistent, predictable cushion be provided. Plywood cushions are frequently specified with multiple layers of plywood of alternating grain orientation generally having consistent properties. Cylinder piles can be driven using cushions made with layers of segmented arcs of plywood with the arc sections overlapping in each successive layer. Specially constructed cushions can be provided for pile ends with exposed reinforcing or for improved performance in hard or unusual driving situations.

Presoaking cushions in water before use, as some have tried, does not make them perform better. Cushions are porous and absorb water which cannot be compressed by the hammer blow. Rather, the soaked cushions tend to come apart or delaminate, disintegrate quicker and are more susceptible to the ravages of heat.

Regardless of the material used, the things to consider about cushions for a successful concrete pile installation are to have a proper fitting cushion; use a cushion of the appropriate thickness; start each pile with a fresh cushion; change cushions when they no longer are able to provide adequate cushioning. Most importantly, remember that the cushion is much cheaper than a pile, even a broken pile! Pile cushions really can literally make or break a concrete pile job.

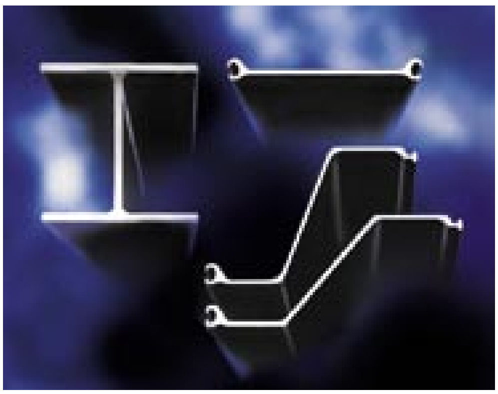
Several PDCA supplier members provide pile cushions and can be a good source of information about pile cushions and their applications. For additional information, visit the PDCA Web site at www.piledrivers.org and search for suppliers of pile cushions in the "Member Search" section. ▼

Steve Whitty is a PDCA board member and can be reached at (985) 643-0690 or swhittysps@earthlink.net.

Apology

Piledriver magazine wishes to apologize to Steve Whitty and Herb Engler for neglecting to include their bylines on their article entitled, "Does Size Really Matter? In Hammer Cushions, Little Things Count!" in the summer 2004 issue. We sincerely hope this has not caused an inconvenience.

Nucor-Yamato Steel's HP8, HP10, HP12 & HP14, PS and PZ Sheet Piling



PILING PRODUCT FEATURES

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NATIONWIDE PILING DEALER NETWORK

SHEET PILES HAVE PREFERRED BALL & SOCKET INTERLOCK

H-PILING AVAILABLE IN ASTM A572 GRADES 50 & 60 AND ASTM 690

SHEET-PILING AVAILABLE IN ASTM A328, ASTM A572 GRADES 50 & 60, AND ASTM 690

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SHEET PILING TECHNICAL DATA

Section Designation	AREA		WIDTH		HEIGHT		WEIGHT (MASS) PER SINGLE		WEIGHT (MASS) PER WALL		MOMENT OF INERTIA		SECTION MODULUS Per Single		SECTION MODULUS Per Wall		SURFACE AREA Total Area		SURFACE AREA Nominal Area*	
	in^2	cm^2	in	mm	in	mm	lb/ft	kg/m^2	lb/ft^2	kg/m^2	in^4	cm^4	in^3	cm^3	in^3/ft	cm^3/m	ft^2/ft	m^2/m	ft^2/n	m^2/m
PZ22	11.9	76.6	22.0	559	9.0	228.6	40.3	60.1	22.0	107	151	6301	32.5	532	17.7	952	4.92	1.50	4.48	1.37
PZ27	12.1	78.2	18.0	457	12.0	304.8	40.5	61.3	27.5	134	282	11734	45.3	742	30.2	1622	4.93	1.50	4.48	1.37
PS27.5	13.4	86.6	19.7	500	—	—	45.1	67.9	27.8	136	5.02	209	3.19	52.2	1.94	104	4.58	1.40	3.88	1.18
PS31	15.2	98.2	19.7	500	—	—	50.9	77.0	31.5	154	5.51	229	3.35	55.0	2.04	110	4.58	1.40	3.87	1.18

*Note: Nominal coating area excludes socket interior and ball of interlock.

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APRIL 2004

THE VIBRATORY PILE INSTALLATION TECHNIQUE

Viking K., Fugro-McClelland Marine Geosciences, Inc., 6100 Hillcroft, Houston, TX 77081, viking@fugro.com

PART I

INTRODUCTION

As a response to the article 'Vibratory Driver/ Extractor Overview' published in PILEDRIVER Spring 2004, the present article intends to describe the cutting edge of the application of vibratory drivers/extractors to drive piles, as well as the latest developed equipment, applied techniques and research.

History and background

The use of the vibratory driving technique dates back to the early 30's and appears to have been commercially used at the same time in both former USSR and Germany, [1] and [2]. Major vibratory manufacturers are now located in Germany, France, the Netherlands and USA. Even though there has been an extensive development of the machines, it's still the engineering limitations that are the main impediment for the vibratory technique to enjoy its full potential.

There is still today a great hesitancy amongst the engineering community to permit foundation piles to be installed by vibratory drivers. The hesitancy is based on a combination of reason, with lack of knowledge and experience as the main. Today's lack of knowledge boils down to the inability to describe the sub soil strata's transformation, from its initial state to its post-disturbed state that affects the outcome of obtained capacity. The lack of well-documented cases of vibro-installed foundation piles is another limiting factor, especially for those engineers and contractors that could consider pursuing an extensive field-test program using vibratory drivers, however, even if such a program were undertaken and could clearly show that the use of the vibratory driving technique could be a good alternative, the vast majority of the engineering community would still not accept the installation of the pile without verification of pile capacity through demonstrated blow count resistance. Today's rigid enforcement of specifications for pile capacity in the foundation industry is another big limitation, especially when mirrored with today's rapid development of new technologies. It's therefore equally important to rapidly update and develop the necessary verification criteria for pile acceptance of vibratory installed piles.

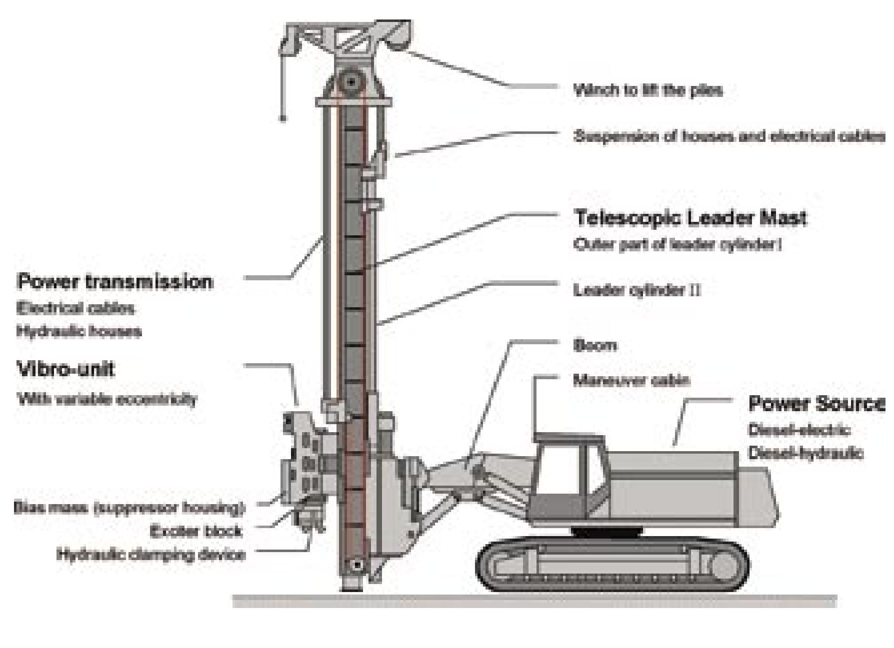

Figure 1. A modern leader mounted vibratory driving equipment, and it's main parts, [16].

Engineering issues

The engineering issues related to using vibratory drivers/extractors covers the following three main engineering issues.

Vibro-drivability: which vibratory equipment will be able to drive a given pile geometry to a pre-defined design depth in a certain sub soil strata, and what penetration speed will be achieved.

Environmental impact: how much of the generated pile-vibrations will be transmitted to the surrounding soil, what is the magnitude of the potentially induced settlements and what's the risk of damaging neighboring structures.

Bearing capacity: what is the expected long term bearing capacity of the vibro-installed pile geometry, since the installation process might influence the long-term strength soil parameters.

The correct optimization of above mentioned engineering issues boils down to the knowledge of the engineers regarding how the key parameters of the vibro, pile, and soil interact with respect to the three above mentioned engineering issues, which is further addressed in section 'Choice of vibratory driver related parameters'.

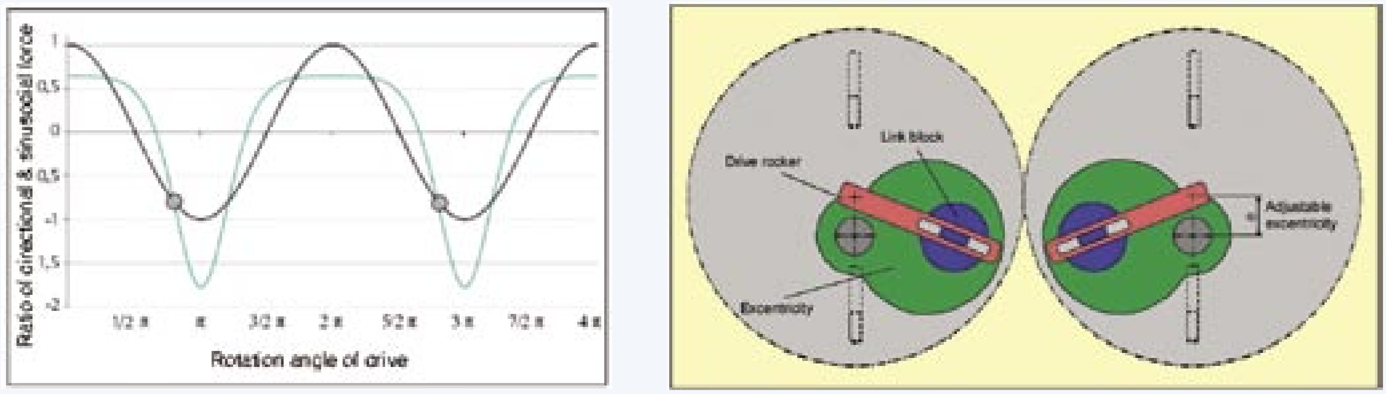

Figure 2. Directional vibrator: a.) ratio of new directional- and sinusoidal force, b.) principle of new vibrator, [17].

MODERN VIBRATORY DRIVING EQUIPMENT

There are two types of modern vibratory equipment commercially available, and these are 'free hanging' and 'leader mounted' systems. Hydraulic vibratory driving equipment predominates the market because they are both lighter in weight compared to electrical, and hydraulic allows both frequency as well as eccentricity adjustments. Advantages with free-hanging systems include lower costs and greater reach. In addition, they can also be more beneficial when bearing capacity of the underlying soil is low. Built-in limitations are lack of both controlling and guiding the pile to desired position, as well as changing the static surcharge force during the installation. The built-in advantages of the leader-mounted system enables the system to operate with greater precision with respect to positioning, displacement amplitude, as well as driving and extracting forces. Drawbacks are usually costs together with weight, which can cause stability problems at the construction site. However, the main parts of leader-mounted equipments are essentially the same as free hanging systems, and consist of the following parts (see Fig. 1).

Power source: normally a basic hydraulic power pack containing necessary components to both power and control the equipment.

Power transmission: high-pressure hydraulic hoses and electrical cables for signal and sensor control.

The vibro-unit: is the part of the equipment that generates the sinusoidal motion of the pile profile.

The pile profile: intended to be installed.

Both 'free hanging' and 'leader-mounted' systems can be equipped with different types of vibro-units. However, vibro-units used as 'free hanging' are normally constructed with rotating eccentric weights laid horizontally, and 'leader mounted' normally have their rotating eccentric weights stacked vertically to make them less bulky and to be able to raise the unit along the leader without stability problems.

Mechanical action of vibratory drivers/extractors

The mechanical action of vibratory drivers is governed by the generated driving force, F_d, which in turn consists of two parts: a stationary part, F_o, and a dynamic part, F_v, schematically illustrated by Fig. 3. The stationary part, F_o, (further explained below), and the dynamic part, F_v, governed by the counter-rotating eccentric masses within the exciter block of the vibro-unit, imparts the generated driving force, $F_d = F_o + F_v$, to the pile head. The driving force, F_d, is governed by the following 'vibro-related parameters'.

Surcharge force: F_o, in the case of a 'free-hanging' vibro, is represented by the sum of the dead weight of the bias mass W, minus the suspension force T of the carrier (crane), according to F_o=W-T (see Fig. 5). The surcharge force of a 'leader mounted' vibro consists of the dead weight of the bias mass W, plus/minus the hydraulically applied pre-stress/tension force $P=P_oA_{cyl}$, which is controlled by the hydraulic pressure, P_o, generated on the area A_{cyl} of leader cylinder II, (see Fig. 1), according to $F_o=W\pm P$.

Eccentric moment: M_e is given in pound-inch [lb-in.] and computed by the product of the eccentric weight W_e [lb] and the radius of gyration r_e [in.] (i.e. distance between center of the motor shafts and the gravity center of the rotating eccentric weight).

Driving frequency: f_d is specified by the revolution per second of the eccentric weights [Hz], sometimes also specified as revolution per minute, n [rpm]. Another common expression is revolution in radians per second w [rad/s]. The three different ways can be combined as follows: w =2pf_d=2pn/60.

System efficiency: ξ which is applied to the dynamic part, (centrifugal force F_v), in the theoretical expression of the driving force F_d (see equation) because the actual force delivered to the pile head will always be less than the theoretically rated.

The theoretical peak amplitude of the driving force F_d in [tons] can be assessed by the following expression.

$$F_d = F_o + \xi F_v = F_o + \xi M_e \omega^2 =$$
$$\xi\,[-]\, M_e\,[\text{lb-in.}]\,(2pn)^2\,[\text{rpm}]^2$$
$$= F_o\,[\text{ton}] +$$

$$32.2\,[\text{ft/s}^2]\ 12\,[\text{in./ft}]\ 2{,}000\,[\text{lb/ton}]\ 60^2\,[\text{s/min}]^2$$

Parts and types of vibro-units

The main parts of modern vibro-units consist of the following parts.

Bias mass: a part of the vibrator that's also called 'suppressor housing', which is the non-vibrating part of the unit. It connects to the exciter block via elastomer pads that isolate the dynamic motion of the exciter block from being transmitted to either crane line, electrical cables, hydraulic hoses or leader mast, which all connects to the bias mass.

Elastomer pads (or springs): connects and at the same time isolates the non-vibrating part from the vibrating part of the vibro-unit.

Exciter block: contains the rotating eccentric weights, gearbox and hydraulic motor, which combined generate the sinusoidal motion and centrifugal force of the vibrator.

Clamp; at the bottom of the vibro-unit, which forms the rigid connection between pile and vibro-unit; used to transfer the generated force and motion, (preferably 'axially'), to the pile profile. The clamp must be adapted to the size of the vibro as well as to the shape of the pile.

Five different types of vibratory drivers (free or leader-mounted) can be distinguished, based on applied driving frequency (f_d [Hz]) and eccentric moment (M_e [lb-in.]), see Table 1.

Table 1.Type of modern vibratory drivers/extractors.

Type	Frequency range [rpm]	Eccentric moment M_e [lb-in.]	Max F_v force [tons]	Displacement amplitude S_p [in.]
1 Standard frequency	< 1,800	20,835	517	1.26
2 High frequency	> 1,800	520 – 3,980	45 - 303	0.51 – 0.87
3 Variable eccentricity	1,800 - 2,400	866 – 4,670	67 - 371	0.55 – 0.67
4 Excavator mounted	1,800 - 3,000	90 – 1,125	8 - 56	0.24 – 0.79
5 Directional force*	1,800 - 2,400	*	*	*

* Still not commercially available, but considered as the next generation of vibratory drivers.

Standard frequency: are still the vast majority of vibro-units in use today since they combine a frequency range that interacts properly with most soils, and generates sufficient displacement amplitude to penetrate denser sub-surface stratas. These units are primarily used for heavy piles and large toe resistance such as concrete and large steel pipe piles. They are at the same time the simplest, but also the most powerful, since they are able to generate both the highest driving force and displacement amplitude due to being equipped with the largest eccentric weights.

High frequency: these units are the second generation of vibrators. They were primarily developed to meet the higher demands of reduced transmission of harmful ground vibrations to neighboring structures, which can cause undesirable settlements. This was accomplished by using higher driving frequencies (>30 Hz). However, these units are not as powerful as standard units, they are also less successful in overcoming large toe resistance compared to standard units since they do not generate as high displacement amplitudes.

Variable eccentricity: also known as resonant-free vibrators, is the third generation, and they distinguish themselves through their ability to start up and stop without resonant vibrations. This is accomplished by adjusting the eccentric moment on the fly, (read adjusting the displacement amplitude on the fly). These units are considered as the "state of the art equipment" in the application of the vibratory installation technique to drive piles. Their applications are advantageous in densely populated areas or city centers and for the use on vibration-sensitive jobs, i.e., near old buildings and/or hospitals with sensitive equipment (computers), etc.

Excavator-mounted: refers to vibro-units that are typically quick and easy to connect to the excavator-boom of a backhoe with a swivel connection after

Continued on page 35

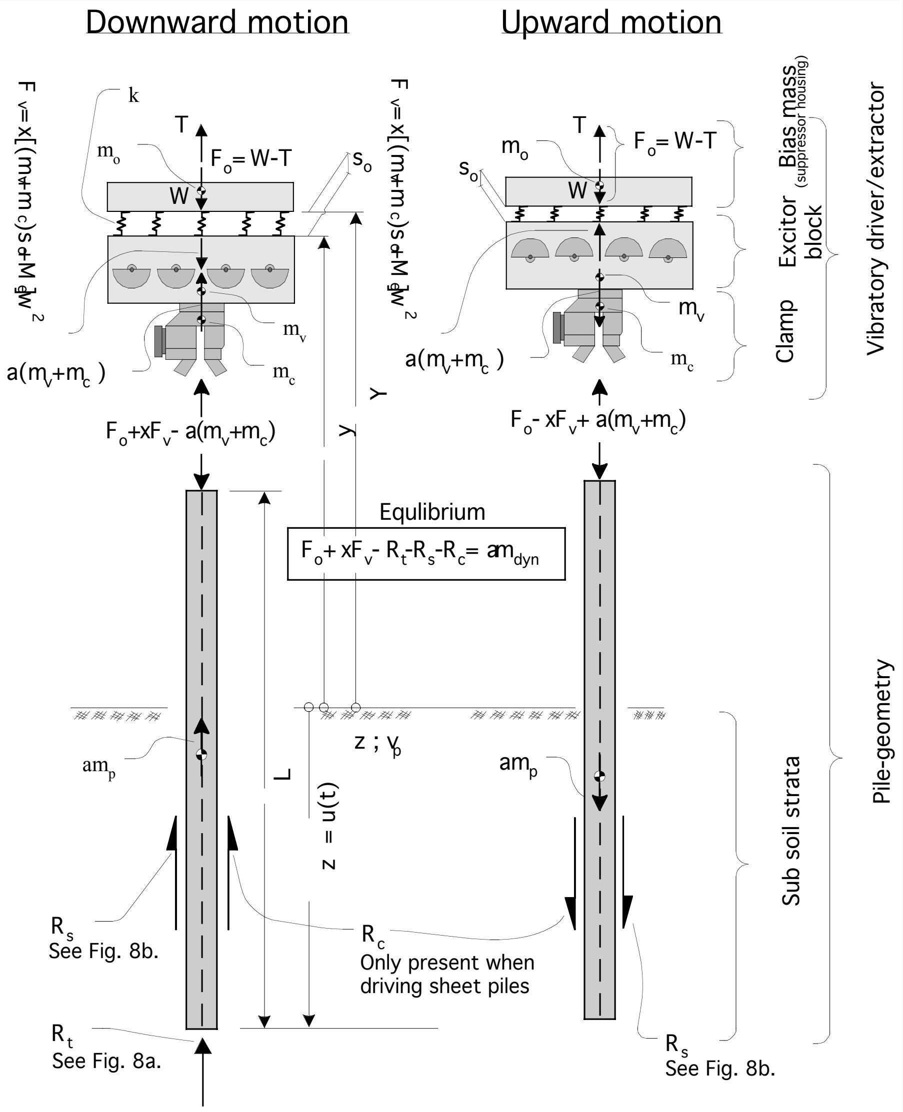

Fig. 5. Forces at play when driving piles (free-hanging vibro equipment), after [16].

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PDCA Member

Buck Darling Delves into his Dual Roles Daily

By Lisa Kopochinski, Piledriver Editor

When speaking with PDCA member Buck Darling, president, safety director and half-owner of Williamsville, NY-based pile driving/shoring company Herbert F. Darling, Inc., the first thing one notices is his wit and self-deprecating sense of humor.

"What I really enjoy about pile driving is that it is something seemingly so repetitious, that I have been doing for so long, and yet very little is ever the same about it from job to job," he says. "That makes it continually interesting, very refreshing and sometimes even surprising!"

While Darling, 47, has been exposed to the pile-driving industry all his life (his grandfather Herbert F. Darling, Sr. founded the company 65 years ago) it wasn't until he graduated from college that he really became active in the industry.

"I was on the "five-year plan [at Clarkson College, now Clarkson University] and wasn't the best, brightest student who ever graduated from the place," he laughingly recalls. "I worked for Dad (Herbert F. Darling, Jr.) during vacations and summers, throughout my college days, as a timekeeper, gopher, laborer and surveyor assistant. I graduated in 1980 with a Bachelor of Professional Studies (BPS science) degree which allowed me to take courses both from the engineering school and the management school. I started with Dad as an assistant superintendent in early 1981 and worked my way up from superintendent, project manager, chief estimator, vice-president and finally to president. If one believes in the Peter Principle, I am probably done for. Time will tell."

Herbert F. Darling, Inc. specializes in driven deep foundations of all types in New York, Pennsylvania, and northeast Ohio (H-piles, pipe piles, timber piles) along with braced-shoring systems and cofferdams primarily consisting of sheet piling or soldiers and lagging. In conjunction with braced-shoring systems, the company performs minor rock and soil anchor work.

The company does work in three states (New York, Pennsylvania and Ohio) "with totally diverse geology, totally different people in them, who have different ways of doing the same thing, and yet it all gets done in the end," Darling says. "I very much enjoy and appreciate the daily education I receive. Not only in the ways of our pile-driving industry, but all industry and its people. Our work takes us into interesting fields of technology through the buildings and infrastructure that are built for them. Among my favorites are learning about industry and technology through work at various plants. At every one of these facilities, you meet incredible people doing incredible things. Through them, we can all add to our body of understanding of not only how things work, but about the people behind the processes."

"What I really enjoy about pile driving is that it is something seemingly so repetitious, that I have been doing for so long, and yet very little is ever the same about it from job to job. That makes it continually interesting, very refreshing and sometimes even surprising!"

The company has also been heavily involved in the environmental remediation of hazardous waste sites, mostly in New York state, through the installation of sheet pile barrier walls, earth-filled circular cofferdams, bearing piles for treatment buildings, or utility trench shoring for leachate collection systems.

Darling is also quick to point out what a pleasure it is to work with his dedicated co-workers.

"They are the ones that truly make this company what it is. Without the field and shop personnel, we wouldn't be able to build anything. Without the engineering and estimating staff, we wouldn't have anything to build. Without the office staff, the endless payroll, payables and equipment paperwork required of the day would not get done. It is the coordinated and dedicated efforts of all these people that allow us to continue a fine family tradition of nearly 65 years of working safely in the construction industry."

Proud PDCA members

Herbert F. Darling, Inc. first became members of PDCA in 2000 because "the only other deep foundations association we belonged to was too broad based in terms of both geographical area (it was world-wide) and the foundation systems they dealt with (everything from piles to caissons, auger-cast, secant walls, slurry walls, tiebacks, you name it). The annual meetings were far away and therefore too expensive to go to and membership costs were too high for what we got out of it," he says.

He adds that the PDCA represented an opportunity to have a voice in his own specific part of the construction world. He is also grateful to have a venue for getting assistance in troublesome matters and for having meaningful conversation with non-local contractors regarding problems that face all those in the industry. "It represents an opportunity to give back to the industry at least in some small way, part of what it has given me and my co-workers."

He adds that PDCA has done a tremendous job of educating engineers and owners to the benefits of the driven pile and that these benefits need to be further reinforced in light of the steel crisis. "It will only be the intangible benefits unfortunately that will lead an engineer to specify the driven pile if cost and delivery (schedule concerns) problems continue to prevail. Can we overcome the cost disadvantage that is currently imposed on pile driving? Is steel in the pile-driving industry a microcosm of a bigger industry (structural steel, rebar, bridge beams, etc.) that by its nature will insulate us from further problems? Are we making too much of this? Precast concrete buildings and bridge beams are more prevalent now. Caissons, auger-cast and geo-piers are always nipping at our heels. Perhaps the present problem is only temporary and the pricing will go down, but what if it doesn't? At the very least, we all need to pay attention and do our part to help our association, and thereby ourselves."

For its part, Darling says his company will continue to take out plans on caisson jobs and attempt to redesign them to the driven pile. This works well in the private sector, he explains, but only marginally well in the public sector given value engineering provisions. "Sometimes, it works and sometimes it does not. It takes a commitment of time and personnel to accomplish this. We have found that one successful sales and redesign effort on a

Darling says that PDCA has done a tremendous job of educating engineers and owners to the benefits of the driven pile and that these benefits need to be further reinforced in light of the steel crisis.

moderate size job helps cover the added costs of a number of failed attempts."

Facing obstacles

While he's been exposed to pile driving all of his life and has been actively involved in it for 24 years, Darling says the largest obstacle the industry faces is the threat of engineers and owners designing steel out of the deep foundation part of a project due to recent problems associated with steel pricing and availability. "We spent the first few months of that crisis trying to figure out how to get and pay for the necessary steel for our projects without going broke or breaking the schedules of our general contractors due to rolling and delivery concerns. Given more time to think after the initial shock and hurdles were overcome, the next thought was that with these problems, more designers would shift over to caissons, geopiers, soil mixing and auger-cast piles to minimize steel impacts and keep costs down in our ever cost conscious industry. This would be a death knell to not only our family business, but perhaps to an entire industry of mostly closely held companies."

Letting loose

In his limited spare time, Darling enjoys spending it with his wife Inger and his two daughters and son.

"My wife and I were married in 1988, the victims of the dreaded set-up, though our parents will not admit it," he laughs.

"When I take the time for hobbies," he continues, "I like to play golf. I get to do this about twice a summer now, having spent a great part of my youth doing so. I also play tennis once a week in a group with my dad. I wish I could keep up with him. My biggest activity now is skiing in the winter. Now that the whole family is up on skis, we go every week at least once, weather permitting. Weather permitting in Buffalo, NY you say? It's not as bad as the media would have you believe and very often is not what you would like for skiing."

Darling also loves being a leader for his eight-year-old son's cub-scout troop. "I'm a Pack 248 wolf den leader to six cub scouts, having survived the first harrowing year as a rookie Tiger Cub den leader," he smiles. "What better investment can we make than in our youth?" ▼

Benefits of Driven Piles

A driven pile is a relatively long and slender column, provided to offer support or resist forces, made of pre-formed material having a predetermined shape and size that can be physically inspected prior to and during installation. It can installed by impact hammering, vibrating or pushing into the earth.

Quality

Driven piles are a total engineering solution. The design, installation and quality assurance, that are a part of each driven pile, combine to eliminate guesswork and produce a known, reliable and cost-effective product that can accommodate a wide variety of subsurface conditions.

Driven piles consist of natural materials or pre-manufactured structural shapes built to precise tolerances utilizing high strength materials and reliable quality control. All driven piles conform to ASTM standards. Their quality is consistent from the first pile to the last and can be seen and verified prior to installation.

Driven piles maintain their shape during installation. They do not bulge in soft-soil conditions and are typically not susceptible to damage from the installation of subsequent piles. Many hollow-section piles can be visually inspected after installation to assure integrity. Most solid-section piles are uniform in section and can be dynamically inspected to verify integrity.

The pile-driving process can be easily modeled prior to installation to determine adequate and economic equipment selection. Static or dynamic testing can confirm load-carrying capacities of installed piles. Dynamic testing can easily confirm proper hammer performance and its effect on the pile. Many modern hammers have impact velocity measurement devices permanently installed, providing a very high level of quality control.

Cost Effective

Driven piles are usually the most cost-effective deep-foundation solution. You pay for only what you need. There are no hidden extra costs or added expenses for site clean-up. The wide variety of materials and shapes available for driven piles can be easily fabricated or specified for high structural strength, allowing them to be driven by modern hammers to increased working loads, thus requiring fewer piles per project, resulting in substantial savings in foundation costs.

Pile capacity is easily verified by either static or dynamic pile testing. Capacity per pile or pile length can be easily optimized to provide exactly the required capacity (including safety factors) to minimize foundation costs. Testing also eliminates the uncertainty of bearing capacity estimates based on static analysis. There is no need to be overly conservative and thus wasteful to protect against failure.

As an additional benefit, driven piles often gain capacity after installation. Shaft soil strength usually increases with time after pile installation is complete to provide additional load capacity. This phenomenon, called "setup", can result in substantial foundation cost savings when considered in the design and confirmed by testing. The incorporation of setup into the foundation design results

Driven piles can be:

- Steel
- H-Pile
- Pipe (open-end or closed-end)
- Tapered
- Shell (mandrel driven)
- Sheet Pile
- Concrete
- Square
- Octagonal
- Cylinder
- Sheet Pile
- Timber
- Composite piles that combine pile types (i.e., a concrete pile with a steel tip extension).

in fewer piles and/or shorter piles driven with lighter equipment. The reduction in time, labor and materials provide substantial cost savings to the owner.

Adaptability

Driven piles are installed to accommodate compression, tension or lateral loads. Piles can be selected to meet the specific needs of the structure, site conditions and budget. You can select from a variety of materials and shapes that best meet your needs.

Driven piles easily adapt to variable site conditions to achieve uniform minimum capacity with high reliability, thus eliminating uncertainty due to site variability. Driven piles are usually installed to established criteria (i.e. minimum blow count per unit penetration, sometimes with a minimum penetration). Because they are normally driven to a blow count to assure the desired minimum capacity, pile lengths may vary when subsurface conditions are not uniform. Driven piles may either be cut-off to shorten their length or spliced to extend their length. Splice designs usually meet or exceed the strength of the pile itself. Pile shoes or "points" can be added to assist penetration requirements and provide very reliable contact with rock. The optimum length is used for each pile which accommodates all site conditions.

Driven piles adapt well to unique site conditions and restrictions. They are ideally suited for marine and other near-shore applications. There are no special casings required and there are no delays related to the curing of concrete. Piles driven through water can be used immediately, allowing construction to proceed in a timely manner. For bridges or piers, driven piles can be quickly incorporated into a bent structure allowing the bridge or pier itself to be used as the work platform for succeeding piles in top-down construction.

To minimize disturbance in wetlands or allow work over water, driven piles can be used to construct temporary trestles. Piles installed to meet any temporary construction need can be extracted when the need is ended.

In earthquake prone regions, large diameter driven piles are well suited to resist seismic forces. Non-displacement pile sections (i.e. H piles) can be utilized to minimize vibration effects on nearby existing structures. In corrosive environments, coatings and/or additives can be used to mitigate the effects of corrosion thereby lengthening the service life of a structure. Coatings can also be used to mitigate the effects of negative skin friction.

Reliable and Available

Pile-driving contractors can be found all over the country. The equipment and installation methods are time-tested and well proven. Advances in materials, equipment, methods, and testing continually combine to improve the efficiency of driven piles.

Recording the blow count versus depth during pile driving easily documents successful pile installation. You know what you have at the completion of driving. Because driven piles are usually driven to a blow count criterion, they will have a measurable capacity providing assurance that they meet the project requirements. Piles can be easily driven through upper soft soil layers regardless of the soil type and groundwater conditions.

Driven piles have vastly superior structural strength. Driven piles almost never fail structurally during static testing or static loading. They have high lateral and bending resistance for their entire length making them ideal to resist wind, berthing and seismic loading conditions. Driven piles can tolerate moderate eccentricity in the application of superstructure loads due to their full-length strength. Piles can be driven either vertically or at various angles of inclination to increase support for lateral loads. In special cases, piles can even be driven horizontally.

Residual Benefits

Pile driving is relatively easy in many soils. Since the soil at the toe is in a compacted condition for displacement piles, end bearing can often carry a substantial load. There are no “soft bottom” soil conditions, so large settlements for end bearing piles are eliminated.

Driven piles displace and compact the soil. Other deep-foundation options can require the removal of soil and considerable subsidence, which can undermine the support of adjacent structures and cause excessive deformations, both of which can result in structural problems. Drilling for cast-in-place piles relieves soil pressures and reduces unit shaft resistances. In groups of drilled piles, the removal of soil generally loosens and weakens the soil structure, reducing the capacity of previously installed piles. Groups of driven production piles densify the soil, improving the capacity of previously driven piles. In groups, driven-production piles usually have a higher capacity than the test pile, while drilled production piles often have a lower capacity than the test pile. Thus, driven piles generally have higher capacities than other pile types of the same diameter and length.

Driven piles require no curing time and can be driven in natural sequence rather than skipping alternate piles, thus minimizing the moving of the equipment and speeding installation.

Environmentally Friendly

Driven-pile installations usually produce no spoils for removal and therefore no exposure to, or costly disposal of, potentially hazardous or contaminated materials. The site is left clean and ready for the next construction activity.

Alternate Uses

The most common use of the driven pile is in deep foundations. Driven piles can also be utilized in other applications such as pile-supported embankments, sound wall barriers, retaining walls, bulkheads, mooring structures, anchorage structures and cofferdams. ▼

PDCA New Member List

We would like to welcome the following companies as new members. Please visit the PDCA Web site at www.piledrivers.org and click on Member Search for complete contact information on all PDCA members.

NEW CONTRACTOR MEMBERS

Cianbro
Pittsfield, Maine
Contact: Tom Ruksznis
Services provided: bridge building, bulkheads, docks and wharves, earth retention, general contracting, marine, pile driving.

Hal Jones Contractor, Inc.
Jacksonville, Florida
Contact: Paul C. Kirkland
Services provided: bridge building, bulkheads, docks and wharves, pile driving, marine.

Hasse Contracting
Albuquerque, New Mexico.
Contact: William Hasse
Services provided: pile-driving contractor.

R.L Morrison and Sons
McClellanville, South Carolina
Contact: Michael Morrison
Services provided: pile-driving contractor.

Signor Enterprises
Austin, Texas
Contact: Rusty Signor
Services provided: pile-driving contractor.

NEW ASSOCIATE MEMBERS

AB Chance / Hubbell Power Systems
Centralia, Missouri
Contact: Rich Zinser
Services provided: composite piles, helical steel piers, steel pipe piles, drill equipment, drive caps and inserts, leads and spotters, marine equipment.

CDS Manufacturing
Quincy, Florida
Contact: Clayton Sembler
Services provided: concrete piles, trucking services.

TA Services, Inc.
Mansfield, Texas
Contact: Lilli Schaefer
Services provided: trucking.

T+R Pipeline Services
Houston, Texas
Contact: Warren Cross
Services provided: steel pipe piles, steel sheet piles, pipe.

United Wood Treating Co.
Whitmire, South Carolina
Contact: Wayne R. Comtois
Services provided: timber piles, treated lumber and timbers.

NEW TECHNICAL MEMBERS

Shawn "Tiny" J. Etier
Charleston, South Carolina
Services Provided: geotechnical engineering, pile-driving monitoring, vibration monitoring.

Allan Yourman
Santa Ana, California
Services provided: geotechnical engineering.

PDCA

MEMBERSHIP APPLICATION

Step 1: Select Membership Type

I wish to apply for the following membership status (check one):

❑ **Contractor** ❑ **(Annual Gross Sales >$1 Mil./year: $700/year).**
❑ **(Annual Gross Sales <$1 Mil./year: $350/year)**

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 ($700/year)**

Associate Members of the Association shall consist of firms or corporations engaged in the manufacture and/or supply of equipment, materials, testing or other services to the pile driving industry. Secondary memberships are $75 each.

❑ **Technical Affiliate ($95/year)**

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. Note: Technical Affiliate Membership category is for individuals only. For a company listing in the directory and on the Web site, you must join as an Associate Member.

❑ **Retired Industry Member ($50/year)**

A Retired Member shall be defined as any individual who has reached retirement age as defined by U.S. law, who has left active employment and who wishes to remain a member.

I am retiring as a: ❑ Contractor ❑ Associate ❑ Technical Affiliate

Step 2: Demographic Information

Company Name ______________________ Phone ______________________

Your Name ______________________ Fax ______________________

Address ______________________ Email ______________________

City/State/Zip ______________________ Home Page ______________________

Step 3. 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 making payment in full by

❑ Check # ______________________________

❑ Credit Card: ❑ MasterCard ❑ Visa ❑ American Express

Card Number: ______________________________ Expiration Date: ______________________

Name as it appears on card: ______________________ Signature: ______________________

Please send this completed application to: PDCA

P.O. Box 19527, Boulder, CO 80308-2527 | Phone: 303-517-0421 | Fax: 303-443-3871 | www.piledrivers.org

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that the bucket is removed. The small excavator-mounted vibro-units normally use both the existing electric circuit and hydraulic system of the backhoe. The excavator-mounted unit is used for small or remote jobs where a cost effective method is needed to vibrate a few piles. They are also ideal for low height applications and where a long reach is required to vibrate sheets, beams or casings.

Directional force: noteworthy amongst the recent developments is the so-called "directional vibrator". Fig. 2a shows the principal difference between a standard unit and the new directional vibrator. The usual sine wave is modified in order to generate more centrifugal force F_v in the driving direction and less in the other, which is accomplished by new eccentric weights within the gearbox (see Fig 2b). The soil surrounding the pile cannot follow the larger acceleration in the driving direction; the pile therefore rips away from the surrounding soil, illustrated by a circle in Fig. 2a. Due to the decoupling of soil and pile during parts of each driving cycle, less energy is transferred into the ground and therefore reduces the amount of transmitted ground vibrations to the surrounding environment. The directional vibrator is also less noisy (due to new bearings); it can sustain harder driving and is more efficient (needs ~30% less energy). However, the new directional force vibrator is at present not in production; however two prototypes have successfully under gone both laboratory as well as full-scale field tests. ▼

Even though there has been an extensive development of the machines, it's still the engineering limitations that are the main impediment for the vibratory technique to enjoy its full potential.

REFERENCES

[1] *Barkan, D.D., (1962), "Dynamics of Bases and Foundations" (translated from Russian by L. Drashevska and translation edited by G.P. Tschebotarioff, original title in Russian "Dynamicka Osnovanity I Fundamentov", (1948), Moscow) McGraw-Hill book company Inc., N.Y., 434 pp.*

[2] *Rodger, A.A., (1976), "Experimental and theoretical investigation of the parameters influencing the vibratory penetration of dry cohesionless soils", PhD Thesis, Aberdeen Univ., Aberdeen, Vol. 1, Chapters 1-15, pp. 338.*

NEXT ISSUE: PART II

Calendar of Events

February 17-19, 2005

9th Annual PDCA Winter Roundtable Conference
Francis Marion Hotel
Charleston, South Carolina

June 19-24, 2005

PDCA Professors Piling Institute
Utah State University
Logan, Utah

September 15-16, 2005

PDCA Design & Installation of Driven Piles Seminar
Sheraton Framingham Hotel
Boston, Massachussets

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