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The Official Publication Of The Pile Driving Contractors Association - Spring 2002 - Volume 3, Number 2

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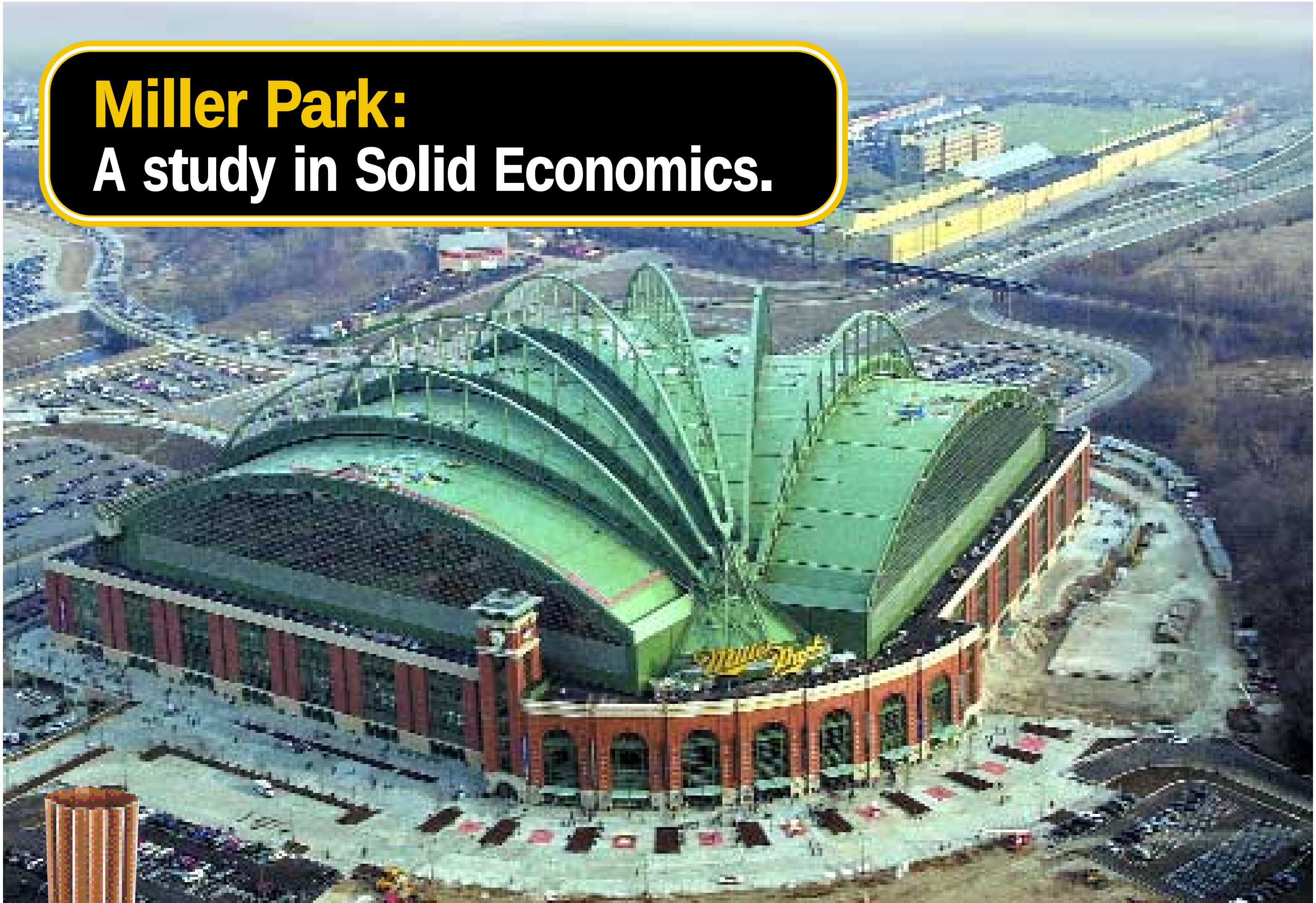

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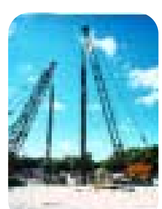

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Be Proactive To Gain Market Share

From The President
By Jim Frazier

On the heels of our Winter Roundtable in San Francisco, where much of the conversation focused on the promotion of the driven pile, I would like to comment on how we proactively attack the deep foundation competition in our region on a daily basis.

When a new pile driving job comes across my desk, the first thing we do is review the overall job, paying special attention to pile capacity. To stay competitive, we must reduce the owner's cost on the project. One way to do that is to determine if the designer has specified the most economical size and number of piles. In our area, deep foundation projects are consistently "under designed." Many times it is feasible and cost-effective to suggest either an increased pile capacity or reduction in pile size, both of which reduce the cost of materials to the owner. Materials savings can total between 20 percent and 40 percent. And we all know that materials, especially when the job involves steel, is typically the largest part of the job's cost.

We have forged relationships with various geotechnical and structural engineers who we offer as consultants to help a structural engineer complete the design or redesign of a project. In our experience, many of the structural engineers specifying deep foundation projects in this area do not have much experience – or even much information – on driven piles. This makes it difficult for the driven pile to get a fair shake in the marketplace.

The ideal situation is to be involved in the project's design from the beginning. Almost every day I get phone calls from design engineers with questions on driven piles. For example, a large engineering firm in Denver contacted us for help with the foundation design for a power plant. We have a very good relationship with this firm, and its engineers now contact us frequently for advice. A well-designed driven pile foundation is often very competitive with other deep foundation alternatives.

So what can you do in your area to stay competitive and increase market share? Get proactive. Gather some driven pile resources and information about your company and mail it to the local structural engineering firms. Follow up on the mailing with a phone call to introduce yourself and offer your company as a resource for information. Be prepared to cite the amount of experience and success your company has had in driven pile foundations. Not all engineers will be receptive, but the ones who are will become valuable partners in our quest for increased awareness of driven pile solutions.

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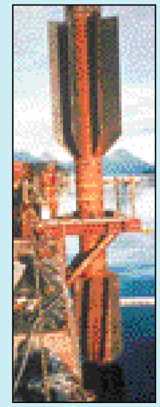

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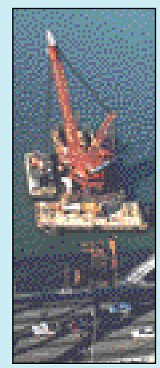

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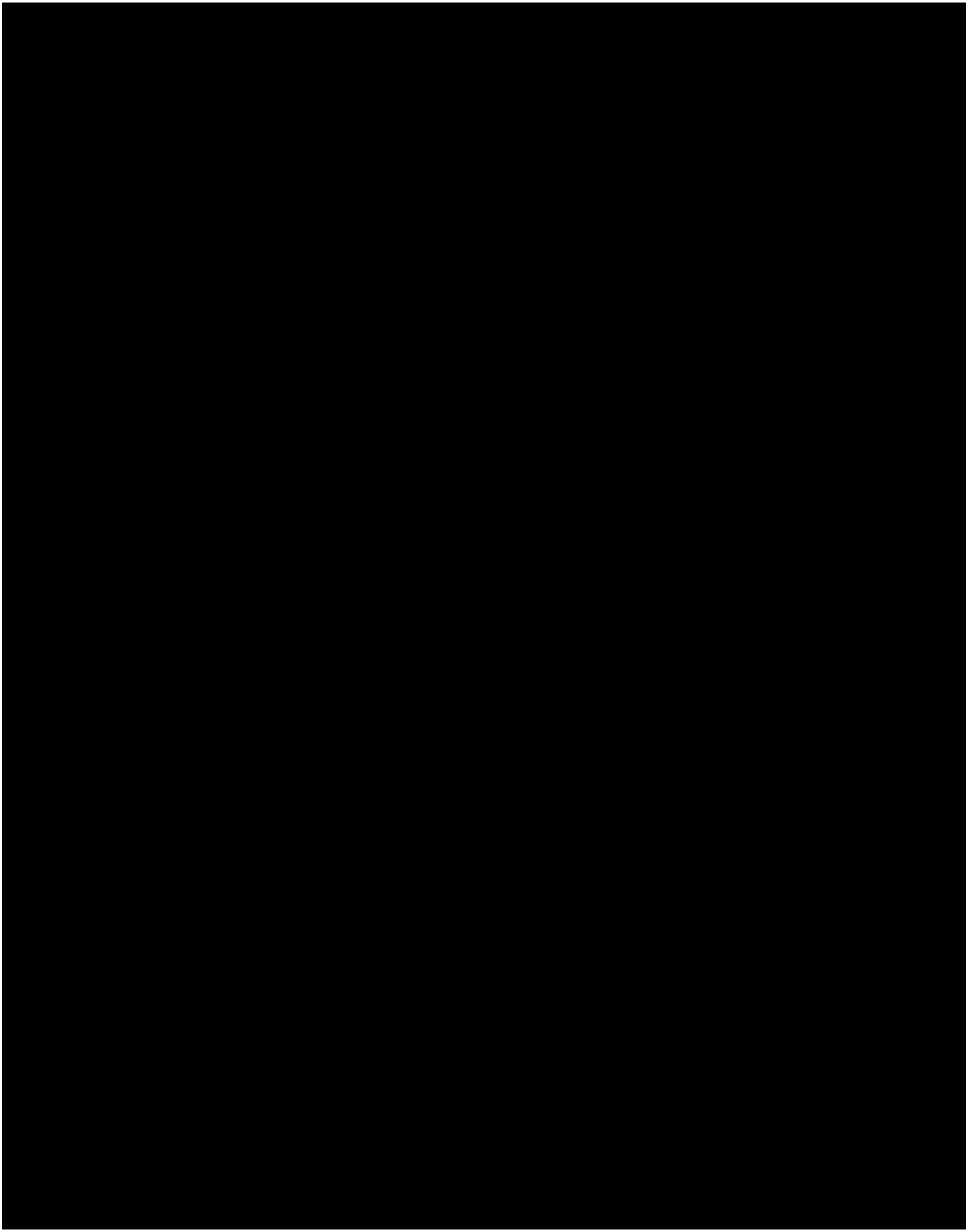

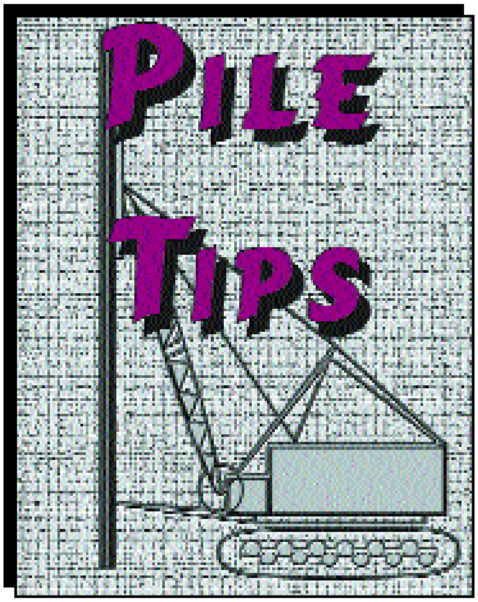

Link-Belt's Newest Addition

Link-Belt and Tadano, Ltd. have signed an agreement that enables Link-Belt to sell an entire line of all-terrain cranes under the Link-Belt name. The ATC-3130, a 130-ton all terrain crane introduced at the CONEXPO-CON/-AGG show in Las Vegas, is produced by Faun GmbH of Laul, Germany, and has undergone rigorous Link-Belt testing. After passing all SAE standards, it was set to ship in May. The introduction of the ATC-3130 into the North American market is a significant first step to expand sales of mobile cranes worldwide.

- Lifting and Transportation, April 2002

Conference Set On Deep Foundations

The Deep Foundations Institute, in association with the European Federation of Foundation Contractors, will hold its Ninth International Conference on Piling and Deep Foundations in Nice, on the French Riviera, in June 2002.

The Conference will be held in the Acropolis Convention Center. Its purpose is to provide a wide forum to delegates from all disciplines in the field of deep foundation engineering and to address the most advanced technologies and the most recent developments in design methods throughout the world. A session will be dedicated to the ongoing development of the European codes for foundation engineering and foundation engineering in seismic areas. Special attention will be given to floor discussions so that participants can share their views on technical items.

- www.dfi.org

DOT Vows To Maintain GPS System

Responding to a report released last year that revealed the various forms of interference through which the nation's global positioning system (GPS) technology is vulnerable, the U.S. Department of Transportation has announced a plan to maintain the system's adequacy.

The study (see the October 2001 issue of *CE News*, Page 14), noted that GPS is susceptible to unintentional disruption from atmospheric effects and communications equipment, as well as to deliberate disruption.

"Following the report's release, I directed DOT's operating administrations to assess the adequacy of backup systems for each area of operations in which GPS is being used for vital transportation functions," said U.S. Transportation Secretary Norman Y. Mineta.

The DOT's solution for building redundancy into critical transportation systems includes:

✓ Ensuring that sufficient backup systems are maintained;

✓ Sustaining its partnership with the Department of Defense to continue modernizing GPS with the implementation of new civil signals;

✓ Easing the transfer of anti-jam technology from the military for civil use;

✓ Soliciting GPS industry input for receiver performance standards;

✓ Educating state and local departments of transportation about GPS vulnerabilities;

✓ Completing an assessment of radio navigation capabilities across all the modes of transportation to identify the most appropriate mix of signal systems. This will include finalizing an evaluation of the long-term need for continuing Loran-C, a ground-based, long-range, 100 kHz radio-navigation system.

To read the full report, "Vulnerability Assessment of the Transportation Infrastructure Relying on the Global Positioning System," visit the Coast Guard's Navigation Center Web site at www.navcen.uscg.gov.

- CE News, April 2002

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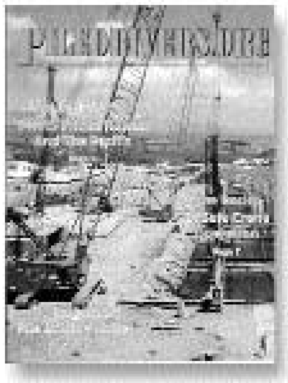

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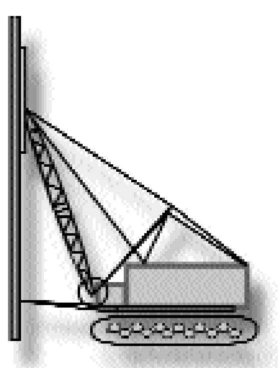

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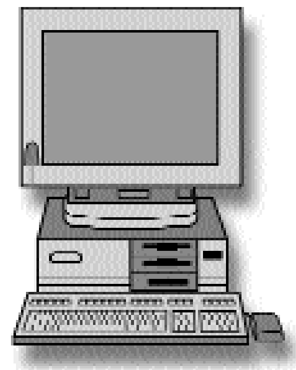

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Design and Construction of Driven Foundations Manual

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PDCA 2002 Winter Roundtable Proves Educational And Entertaining

San Francisco was the ideal setting for a meeting of the minds at the Pile Driving Contractors Association's 6th Annual Winter Roundtable, held Feb. 21 through Feb. 23. Amidst the charm of engineering marvels such as the Golden Gate Bridge and San Francisco/Oakland Bay Bridge, conference attendees participated in seminars, panel discussions and debates.

Alan Christopherson accepts the Driven Pile Project of the Year Award for Peratrovich, Nottingham and Drage, Inc.

"We had a stellar lineup of presenters who were available to answer questions during and after their presentations," said PDCA Executive Director Stan Orr, CAE. "The panel discussions were especially interesting and raised many industry issues that we as an organization can focus on and address. I look forward to working with members on these types of projects in the future."

PDCA members, exhibitors and other attendees enjoy the educational opportunities offered by the PDCA Winter Roundtable.

The roundtable discussion on issues facing the contractor/supplier/engineer relationship proved particularly interesting. Contractors from across the country voiced their concerns about some of the drilled-in shafts or auger cast piling that is being used in their home state. It seems in many instances that driven piles and auger cast piles are being compared solely on price and the amount of noise and vibration generated. The standards for judging these two foundation alternatives is not equal yet is being presented equally. An educational campaign for owners, engineers and the public is necessary to level the playing field. PDCA is currently sponsoring a professors' course to address these and other driven pile issues.

PDCA's first Driven Pile Project of the Year Award recipient was recognized during a luncheon at the conference. The engineering firm Peratrovich, Nottingham & Drage, Inc. (PN&D) of Anchorage, Alaska, was named as the winner for its work on BP Exploration (Alaska) Inc.'s Northstar Island project. The project involved dock construction for an oil drilling production facility located more than six miles off Alaska's North Slope. Frigid temperatures, 24-hour darkness and polar bears were just a few of the challenges PN&D faced.

PN&D Senior Vice President Alan Christopherson, PE, gave attendees a firsthand look at some of the unique aspects and driven pile techniques of this project, which is featured in this issue of *piledrivers.org*.

For more highlights of the PDCA Winter Roundtable, visit the Association's Web site at www.piledrivers.org.

Probably the most memorable part of the conference was the Great Hammer Debate, Part II. Patrick Bermingham of Berminghammer Foundation Equipment; Geert Jonker of IHC Foundation Equipment BV; and John White of American Piledriving Equipment acted as moderators for the session. The hammer manufacturers constructed a quiz that was distributed before the session and the correct – and incorrect answers – were discussed during the debate. A prize was awarded to the attendee who answered the most quiz questions correctly.

A lively debate on hammer specifics ensued, with varying opinions coming from suppliers, contractors and engineers. Some myths were expelled, some facts were disputed and, overall, each group learned a little more about what hammers mean to different people associated with the pile driving industry.

"I would definitely count this year's conference as a success," Orr commented. "The exposition provided a great opportunity for networking, and many attendees sought out presenters or exhibitors to have their questions answered. It is always great to see the sharing of information that takes place at these events."

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A Discussion Of Marine Cofferdams

4-Bay Cofferdam - Setting return sheet piles, McAlpine Lock & Dam, 2001, Ohio River at Louisville, Ky.

By Harold V. Anderson

Marine cofferdams are temporary structures erected to allow certain underwater work to be performed in the dry.

Rock-filled cofferdams have been used to dewater large areas such as dam foundations, but, because of environmental regulations, this type of structure is seldom, if ever, used any more.

Gravel and sand-filled cellular cofferdams used for dewatering large areas such as dam and lock construction in large rivers are used often. These unique structures are a subject too large and complex to be covered in this article.

Rock-filled wood and timber cribs are considered passè. These structures were commonly used as cofferdams when they cost less and intensive labor was not a factor.

Steel sheet-piling is a common 21st century component of marine cofferdams, particularly bridge foundations. Variations on the use of sheet piles include caisson followers, precast concrete cofferdam followers and double-walled ocean cofferdams.

Cofferdam structures that cling to the sides of steel vessels, concrete structures and concrete lined canals are seeing more and more usage. They are referred to as "limpets" in the United Kingdom, a term usually applied to marine crustaceans such as abalones.

Where none of the above apply, patented fabric cofferdams such as "portadams" and "aqua-barriers" may be appropriate. Some are simply rubberized fabric dams, while others may be inflated, water-filled or sand-filled bags. They are not described any further in this article since they apply mainly to shallow water installations.

You may find the following bibliography helpful if you are confronted with the design of cofferdams in deep water where sheet piles are used to isolate areas for underwater construction: "Steel Sheet Piling Design Manual" (Pile Buck); "Handbook of Heavy Construction" (Havers & Stubbs); "Handbook of Temporary Structures in Construction" (Ratay); "Cofferdams" (White and Prentis); and "Underwater Construction Using Cofferdams" (H.V. Anderson).

For those interested in using the metric system, you may find publications in the United Kingdom helpful, including: "The Design and Construction of Sheet-piled Cofferdams" (Williams & Waite); "Foundation Design and Construction" (Tomlinson); "Sheet Piling, Cofferdams and Caissons" (Donovan H. Lee); and "Corus Piling Handbook 2001" (www.geocentrix.co.uk).

If you are faced with having to design cellular cofferdams to dewater large areas, go to: "Design of Sheet Pile Cellular Structures" (CofE EM 1110); "Steel Sheet Piling Cellular Cofferdams on Rock" (CofE Nomograph No. 75); or "Cellular Cofferdams" (Pile Buck).

This is a short reference file but one that covers the subject well.

Some of these books were published 50 years ago, such as Prentis' "Cofferdams," and therefore are somewhat outdated.

Common Problems

Environmental regulations may restrict methods of pre-excavation and disposal of bottom materials, and there may be "windows" established for all marine work in authorized permits. Excavation inside sheet-piled cofferdams is difficult, costly and risky. Marine cofferdams may fail suddenly if clam buckets damage cross-members, struts or wales, causing them to buckle under external loading conditions.

Pile driving is more often than not a part of a bridge pier foundation. Piles may be driven before or after the cofferdam is in place. Special attention must be given to the size, shape and location of struts to avoid conflict with pile driving, including the hammer, its leads and the piles, particularly batter piles.

Concrete seals are often an integral part of sheet-piled marine cofferdams, particularly where bottom materials are comprised of soils that may cause seepage to occur from under sheet pile tips, gradually increasing in volume over time, often causing boils to become rat-holes and eventually full-blown gushers. Where soils are soft clays, such as San Francisco Bay's "bay mud," cofferdams with no concrete seal may squeeze and deform, making construction difficult or impossible. Concrete seals,

(Continued On Page 13)

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Marine Cofferdams

Continued From Page 11

of course, are simply bottoms of a big tub and are also designed to prevent upheaval due to buoyancy, the force caused by displacement of the cofferdam in seawater, muddy seawater, liquid mud or even fluidized sand. The seal's design involves weight: the greater the seal's thickness, the deeper the tub and its buoyancy. It's like chasing one's tail.

Construction of the bridge pier footing in the dry is made possible by the cofferdam if it is watertight or nearly so. Recent developments of water-swelling liquids and compounds have made water-tightness of sheet pile interlocks possible. Adeka's A50, poured into interlocks prior to upending and installing sheets, has significantly reduced the time required to dewater marine cofferdams. Without sealants such as this, dewatering often required multiple pumps working for days. What might have been three or four six-inch (1,500 gpm) centrifugals and a couple of three-inch submersibles fighting six days to get a differential head and eventual dewatering has been reduced to one 6-inch (1,200 gpm) submersible working eight hours. This presumes that soils have been adequately removed between concrete seal and sheet piles so that no water enters from below.

Marine cofferdams, unlike their shoreside counterparts, must be designed to survive storms, wind-driven waves, tidal currents, ship impact, debris pile-up and a multitude of unknown combinations of forces, vibrations, overtopping and lateral loads caused by mooring lines, not only during dewatered conditions but also during installation and removal of the cofferdam.

The sequence for removal of cofferdams is not exactly the reverse of the installation procedure. It may be practical to remove the wales and struts prior to pulling sheet piles, but only if sea conditions permit. Wales and struts may consist of a prefabricated frame, originally held up by spuds or pile supports. These no longer exist when the footing and pier column are constructed but are hung off of sheet piles. If lifted free, sheets are susceptible to sea conditions.

Types Of Marine Cofferdams

Sheet-piled cofferdams may be founded on rock, sand, gravels, mud and any possible combination. Borings are necessary, particularly to establish sheet pile lengths around the perimeter of the cofferdam. Sheet pile penetration must be adequate to resist not only hydrostatic pressure but pressure from any exterior soils; thus soil sampling is a basic requirement. Sheet piles may also have to resist interior pressures that develop prior to dewatering from placement of the tremie concrete seal. Cofferdams may take the shape of the structure to be built, square or rectangular, but may also be circular, hexagonal or octagonal.

Sheet-piled cofferdams may have to be used to partially or fully surround an existing concrete structure or footing to allow modification work such as seismic retrofit, pile repairs or replacement or concrete additions. In some instances sheet piles have to be (Continued On Page 14)

From The Civil Engineer's Pocket Book (1906)

About 100 years ago, Trautwine published some observations for sinking timber crib cofferdams. He also had something to say about pile driving:

1. Piling driven close together to prevent leakage are called "sheet piles." Generally they are thinner than they are wide; frequently they are square.

2. When driving underwater timber piles by exploding small charges of dynamite, first place an iron plate on top of the pile. The amount of dynamite is not specified.

3. When using gun powder, place in a suitable receptacle on top of the pile and explode by dropping the hammer on it. About 1/3 lb. of gunpowder is necessary to drive a timber pile 20 feet into mud. Use about 1 1/3 lb. to drive pile into gravel.

4. The Major Sanders Rule for determining the safe load of driven piles is to divide the height of fall of hammer in inches by sinking distance per blow of the pile. Multiply this by the weight of the hammer and divide by 8.

5. The author offers a better formula: Multiply the cube root of the fall in feet by the weight of the hammer in pounds and by .023. Divide this by 1 plus the sinking in inches. The result is in tons. Divide this by whatever safety factor is desired for the safe load.

Trautwine's description of "The Hydrostatic Paradox" is still true today and should be recognized in cofferdam design:

"One pound of water can exert a pressure of up to 2,250 lbs./sq. ft., even if it is nothing more than a thin film on the side of a wall 36 feet high. It does not matter if the wall is sloping or curved. It is the same pressure exerted on a 36-foot high dam because the amount of water behind the dam is not relevant. (This often occurs between sand backfill and sheet piles.)"

Marine Cofferdams

Continued From Page 13

butted up against concrete surfaces. In this case, a seal of some kind is necessary to make the interface watertight. Wood, rubber, tarps or belting has been used with various degrees of success.

Prefabricated steel cofferdams (limpets) may be designed to isolate relatively small areas of concrete (or steel, as in the case of a ship's hull). The design of these structures is ideally half-round but may be rectangular. Half-round limpets are easily made watertight by virtue of the hydrostatic pressure pushing against the cofferdam, flattening the seal against the surface of the structure. This seal must also resist uplift pressure because the entire cofferdam wants to float up. Frictional resistance is the answer and the means to provide stability in all directions. This means that the smaller the cofferdam, the less buoyant force to be resisted.

Prefabricated steel cofferdams may be used to cling to the sides of drydocks at sills for concrete repairs, on the sides of concrete-lined canals for construction of outlets, on the sides of dams for modifications and on the bottoms of spillways for repairs. Circular cofferdams have been used for access to tops of underwater piles and made watertight by inflating a doughnut-shaped seal.

Prefabricated concrete cofferdams that float are often used as forms for underwater footings. By floating in and submerging over previously driven piles, these structures can be dewatered similarly by seals surrounding project pile heads. Followers may be necessary to extend the concrete portion above water for access. Either sheet piles or prefabricated steel boxes may be used to attach to or set down on the concrete structure before submerging. Often guide and support piles are necessary to hold these structures in proper position before submerging.

Underwater cofferdams with access shafts have been used to provide access for workmen to perform repairs on certain concrete areas underwater. The perimeter of the cofferdam is "sucked down" to the concrete surface prior to dewatering by displacing water between a double row of rubber seals.

Harold V. Anderson, now retired, began consulting for west coast contractors in 1971 as H.V. Anderson, Engineers. He was awarded the Golden Beaver for outstanding achievements in engineering for heavy construction in 1999 and is the author of "Underwater Construction Using Cofferdams," which was published in 2001.

PN&D Thrives Among Polar Bears Frigid Temperatures And Harsh Alaska Conditions

PDCA 2001 Driven Pile Project Of The Year Award Winner

By Jennifer Hart, Editor

Peratrovich, Nottingham & Drage, Inc. (PN&D) of Anchorage, Alaska, has left its hallmark on engineering projects all over the 49th state. Most recently the company served as the structural and geotechnical engineer for BP Exploration

(Alaska), Inc.'s Northstar Island, an oil drilling and production facility six miles offshore in the Beaufort Sea on Alaska's North Slope. The man-made 4.5-acre gravel island is the first offshore arctic oil production island in the United States.

According to Alan Christopherson, PE, PN&D's senior vice president, the North Slope is known for its severe weather conditions, long winters and short summers. Working in this remote region presented a number of unique challenges for PN&D. First and foremost was the region's typical environment.

"Temperatures on the slope in the winter are typically minus 50 degrees Fahrenheit, and there is 24-hour darkness," Christopherson explained. "We also had to overcome frequent high winds, snow and frozen soils."

Combine the weather with a remote location, seasonal thaw and settlement, unusually large load requirements and up to 6 feet of first-year sea ice and massive multi-year ice runs and this project becomes a serious challenge, even for the likes of PN&D. And of course, there are those pesky polar bears.

"Alaska's polar bear population can be a real problem while working on a project, particularly on the arctic coastline," said Christopherson. "The bears have no fear, are very sneaky and can come up to 30 miles inland. Most buildings in the area are equipped with a cage around the perimeter to protect against attacks."

The island was formed by mounding gravel 55 feet onto the sea floor through slots cut into the winter ice, then allowing the gravel to seasonally thaw and set-


Photo By Judy Patrick

tle. PN&D's open cell technology was used on the south end of the island; the remaining three sides of the island were contained using cantilever sheet pile.

Open cell technology was incorporated to build a 315- by 140-foot dock at the island's south end. The dock had to be designed to withstand the transport of modules weighing up to 5,000 tons. It was built in halves – an unprecedented approach – to allow the installation of a pipeline onto the island, and it was later closed by a sheet pile element.

The dock not only had to withstand the weight of offloaded modules but also the severe environmental conditions. High waves and wave scour, ice, weak sub-bottom soils and difficult construction conditions were factored into PN&D's dock design.

PN&D recommended its open cell technology after other consultants were unable to offer a suitable solution.

"While tied-back or cantilever sheet pile walls often require deep toe embedment for lateral strength, open cells do not require deep embedment for stability," said Christopherson. "The open cell utilizes unconnected sheet pile tail walls that act as soil/friction anchors for curved sheet pile cell faces. By not connecting tail walls at the landward side, cost savings are realized, including less sheet pile area, greater construction tolerance and adjustment capability, minimal pile penetration and easier backfilling. Viewed from above, the structure becomes a series of U-shaped horizontal membrane structures that need no toe embedment for stability."

As with many projects in Alaska, logistics presented its own challenges for PN&D. Sheet piles were transported by rail from Texas across the United States, then barged to Alaska. From there, the piles were moved by rail north of Fairbanks and finally delivered in trucks to the North Slope.

"In some parts of Alaska, there is only a small window of time when materials can be moved by barge because of ice," Christopherson explained. "There have been times when no barges have moved at all because the ice did not thaw or move out of shipping lanes."

Piles were driven with APE 200 vibratory and Delmag 62 impact hammers supplied by PDCA members American Piledriving Equipment and Pileco. Predrilling of small- or large-diameter holes the full length of the pile and steam and hot water were used where PN&D encountered difficult frozen soil conditions. This thermally modified pilot hole procedure was developed by PN&D research and development. The combined lengths of open cell sheet pile wall totaled approximately 800 feet, and the project utilized 1,049 sheets up to 60 feet long. Piles were supplied by PDCA member L.B. Foster Company of Hayward, Calif., and manufactured by Chaparral Steel of Midlothian, Texas. Christopherson commented on L. B. Foster's ability to meet the project's strict deadlines.

"L. B. Foster was very helpful and a great supplier

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Project Spotlight

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to work with," said Christopherson.

When obstacles were encountered along the cell face that would interfere with sheet driving, the debris was excavated and removed and the subsequent void refilled. Ice was removed by drilling and steaming. If obstacles or ice were encountered along the tail wall, the debris or ice was removed or the wall alignment was directed away from the obstacle in a smooth curve.

Driven flat sheet piles (PS31) were used on a unique, 8-foot-diameter seawater intake system. This system mated to the sheet pile and served as a template, with piping housed within a frame shaped to coincide with the curve of the face wall. Once positioned, a section of wall was cut away to accommodate the flow of seawater into the interior of the island through pipes into a rectangular sheet pile cell approximately 25 feet deep.

PN&D worked on other aspects of this project, including heliport design; foundation design for the very heavy processor, compressor and fuel tank buildings; budgetary, administrative and project management; alliance support; and design for temporary island access during the first year of a two-year construction program.

PN&D completed work on Northstar Island in fall 2001. The new oil production facility enables environmentally safe offshore oil production. Oil in place is estimated at 247 million barrels, with a 7 billion cubic foot inferred gas cap and 480 billion cubic feet of total gas. BP Exploration expects to recover some 176 million barrels of oil and natural gas liquids with enhanced oil recovery - miscible gas injection from five gas injection wells in the central portion of the field and 21 producing wells.

Shortly after successfully completing this project, PN&D received PDCA's request for entries in the 2001 Driven Pile Project of the Year Award. The firm submitted a detailed entry, complete with pictures, a map of the region and project information on Northstar Island. According to Steve Whitty, PDCA Public Relations chairperson and head of the Award Committee, PN&D demonstrated the most unique application of driven piles.

"PN&D used breakthrough technology and innovative ideas to complete a project that other engineers may have shied away from," said Whitty. "From an engineering and pile driving perspective, our committee found the project – and PN&D's techniques – fascinating."

Christopherson presented his winning project at PDCA's annual Winter Roundtable in San Francisco in February.

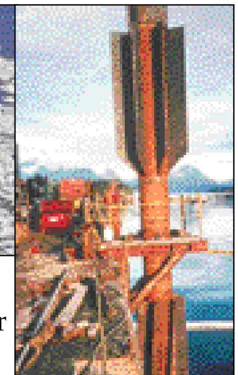
PN&D was founded in 1979 by Roy Peratrovich and Dennis Nottingham. The firm currently employs 80 people and has undertaken a wide variety of engineering projects, most of them in Alaska. PN&D has participated in several projects in the lower 48 states, Hawaii and Russia. The company is also exporting its expertise oversees to area's such as Japan.

"The work in Alaska is never cookbook," said Christopherson. "We are always testing technology and our engineering capabilities to make projects happen. On more than one occasion, we have invented new techniques to handle unique engineering and construction challenges."

One of PN&D's inventions is the open cell bulkhead, used on the Northstar Island project but originally developed in 1980 for the purpose of meeting the demand for an economical, easily constructed strong retaining wall. In seismic or weak soil regions, the tail anchor walls of the open cell can be extended as required to guarantee fill mass stability. To date, more than 100 open cell structures have been used in docks, bridge abutments and erosion control structures. The open cell bulkhead has won a number of awards, including the 1998 Construction Innovation Forum's annual NOVA award, often referred to as the Nobel Prize for construction.

Another PN&D innovation is spin fin piles, steel pipe piles with heavy steel plate fins welded at an angle near the tip. As spin fin piles are driven into the ground, they literally screw themselves into the soil. Once connected to a structure and prevented from unscrewing, they are much stronger than conventional pilings. Developed in the 1980s, more than 3,000 spin fins have been used successfully on projects around the world.

The permeable wave barrier is PN&D's solution to improving harbor sanitation and minimizing costs associated with traditional rock breakwaters. It is constructed with steel or pre-stressed concrete piles and faced with treated timber or concrete panels. The barrier provides wave protection for a harbor while minimizing wall pressure and allowing for improved harbor flushing. Because of the methods and materials used for construction of the permeable wave barrier, it can be attached to an existing dock, used as a foundation for a future dock or easily removed to allow for dock expansions.



A spin fin pile.

The permeable wave barrier is less expensive to build and easier to install than traditional rock breakwaters. It is better for the environment and allows natural basin flushing. One was installed in Garibaldi, Ore., in 1980 and withstood a major storm five years later.

Christopherson likes to think of PN&D as a different kind of engineering firm.

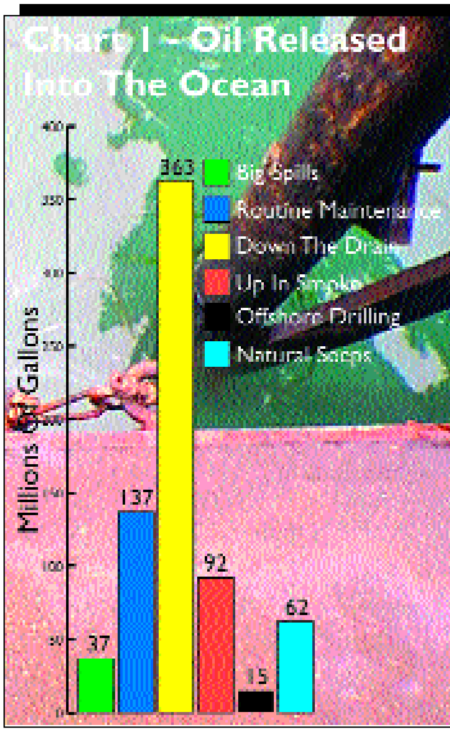
"We are not afraid to get our hands dirty and get heavily involved with contractors working on our projects. We are a results-oriented firm," he said. "We also like working with contractors and try to see things from their perspective whenever possible. We were extremely honored to be presented with the Driven Pile Project of the Year Award from a contractors' group such as PDCA. And I think it is really great to be the first recipient of this award, for a project that had so many firsts itself."

Thank you to BP Exploration (Alaska), Inc. for undertaking the project involving PN&D. Construction was made possible through the tremendous efforts of the Alaska Interstate Construction, LLC, and its capable contractors.

Marine Oil Spill Regulations: Myth Or Reality?

By Shari Miller
Curt Scharf
Mark Miller
Terresolve Technologies, Ltd.

There is growing concern regarding the environmental impact and associated costs of lost petroleum-based fluids. The National Oceanic and Atmospheric Administration (NOAA) estimates that more than 700 million gallons of petroleum enter the environment each year, over half of which is through irresponsible and illegal disposal. Industry experts estimate that 70 percent to 80 percent of hydraulic fluids leave systems through leaks, spills, line breakage and fitting failure.



Petroleum is persistent and toxic. It damages living organisms, including plants, animals and marine life, for many years. In addition, the Coast Guard, Environmental Protection Agency and local governments are increasing the range of responsibility of lubricant releases, including significant fines and cleanup costs.

Conscientious pile driving contractors and equipment manufacturers are using "environmentally friendly" or "green" lubricants that should protect them against oil spill damages and costs. There seems to be some confusion on this subject in the marketplace. This article should help to separate fact from fiction.

Release To The Environment

According to NOAA, 706 million gallons of petroleum are released into the ocean each year. More than half of that, 363 million gallons, are a result of irresponsible maintenance practices and routine leaks and spills. Chart 1 shows the various contributors to oil released into the ocean.

As demands on lubricant systems increase, the likelihood of accidental release of fluids rises. Increased operating temperatures, pressures and working cycles shorten the life of circuit components. The single best approach to protecting the environment, the equipment and the operation is to prevent leaks and spills through good routine maintenance. A good preventive maintenance program will:

- Increase productivity since equipment is utilized more;
- Better utilize in-shop maintenance since there is less emergency work;
- Improve control of spare parts inventory and reduce parts usage;
- Reduce equipment down time;
- Reduce safety hazards;
- Increase equipment life;
- Reduce fines and cleanup costs due to environmental release;
- Reduce down time related to environmental release.

Myth 1
The Coast Guard Approves "Non-Sheening Oils"

Regulatory pressure is increasing from the EPA, Coast Guard and other environmental organizations. While small releases will not result in a Resource Conservation and Recovery Act (RCRA) cleanup, large spills will. All petroleum hydraulic fluid spills are "reportable events." These events involve high cleanup costs, administrative procedures and punitive fines that can range from tens of thousands to hundred of thousands of dollars.

While spilling large quantities of biodegradable hydraulic fluid is still considered under RCRA to be a reportable event, agencies are required to evaluate "bio-based oils" differently than petroleum-based oils. As awareness of biodegradable fluid increases, state and federal agencies become more lenient regarding fines and cleanup costs. In fact there are several case studies of equipment releasing several hundred gallons of vegetable-based hydraulic fluid into environmentally sensitive areas with no fines and minimal cleanup expenses. In most instances, the operator was able to continue working while cleanup efforts were underway. Since the fluids were biodegradable and non-toxic, there was no long-term negative effect to the ecosystem.

There is a common misperception that the Coast Guard approves oils based on the oil not leaving a sheen. This is not true. The Coast Guard does not approve, recommend or endorse any fluids. Furthermore, the Coast Guard does not approve or recommend any test procedures but follows U.S. laws. The oil sheen that is frequently referenced is inferred from the Clean Water Act as defining "any substance that leaves a sheen, emulsification or discoloration as a pollutant and be subject to appropriate fines and regulations governing pollutants." The Coast Guard also relies on the guidelines as outlined by equipment manufacturers and highly favors the use of bio-based and biodegradable fluids.

Myth 2
"Inherently Biodegradable" Products Are Environmentally Safe

There is no single definition of biodegradability. Throughout the United States and internationally there is a wide range of environmentally preferable definitions. The American Society for Testing and Materials has defined biodegradable as a function of degree of degradation, time and test methodology.

Despite these definitions, there are two widely used designations for biodegradability:

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Myth Or Reality?

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readily and inherently. Readily biodegradable is defined as degrading 80 percent within 21 days as measured by the decrease of a test sample. This type of degradation is preferable because in most cases, the fluid will degrade long before environmental damage has occurred. Because of this, these fluids require little in terms of long-term bio-remediation. Vegetable-based lubricants and some synthetic ester-based products exhibit ready biodegradation.

Several petroleum-based lubricants claim "inherent biodegradability," defined as having the propensity to biodegrade, with no indication of timing or degree. These types of products can persist in the environment for years, continuing to cause substantial damage, and they require long-term remediation. Typically, these products are petroleum-based, such as conventional lubricants. Chart 2 illustrates the difference in degradation timing of a readily biodegradable product compared to an inherently biodegradable product.

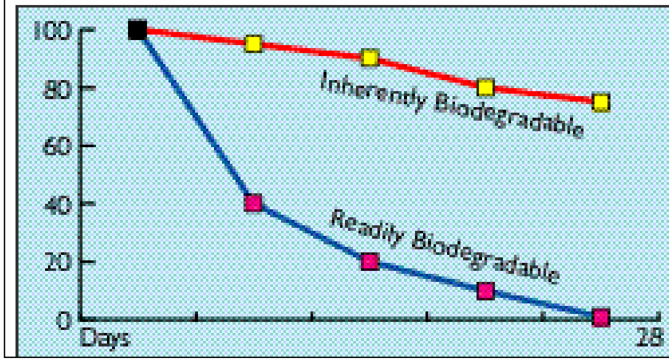
Looking at Chart 2, it is easy to see the difference between a readily biodegradable product and an inherently biodegradable one. The EPA and Coast Guard utilize this differentiation when evaluating an oil release.

Myth 3
Food Grade Products Are Environmentally Safe

Another measurement to determine the environmental effect of a lubricant is "eco-toxicity." Historically, tests for eco-toxicity have concentrated on the aquatic environment with a number of standard test procedures. Most typically, the tests are for "acute toxicity." This is a measurement of the concentration required to kill various organisms over a short period of time ranging from 24 to 96 hours. Depending on the test and its end points, the toxicity of a fluid is described by a loading rate that has a 50 percent effect (EL50) or causes 50 percent mortality (LL50) after the stated time. That is, at the concentration of fluid one half of the sample organisms die.

Attempts have been made to use "food grade" lubricants to protect the environment. While food grade oils seem like a good idea, they are highly impractical for underwater applications. First, food grade products are designed for equipment in food processing plants. They are toxic. In fact an entire batch of food must be discarded if there is contact with the lubricant. Second, they are environmentally persistent (non-biodegradable), which means they are toxic to marine life for long periods of time. Finally, they are designed for very light duty usage and break down quickly under typical pile driving temperatures and pressures.

Chart 2 - The Degradation Timing Of A Readily Biodegradable Product Compared To An Inherently Biodegradable Product



Myth 4
All Biodegradable Products Work The Same

There are a wide variety of performance levels among biodegradable products. Traditionally, a lubricant is compounded from base oil and a variety of performance chemistries. Early pioneers in the vegetable-based lubricant market used the same chemistry that was used for petroleum lubricants. It was a great idea, but it didn't work. The characteristics of vegetable oils are vastly different than those of petroleum oils. Vegetable oils had to be formulated for their individual strengths and limitations. Today there are several vegetable-based products on the market. They offer good performance and a fair price. While all vegetable-based lubricants have temperature limitations, some are better than others. One should check with his or her lubricant supplier to determine a lubricant's maximum and minimum operating temperatures. While most vegetable-based lubricants have a maximum operating temperature of 140 degrees Fahrenheit, some offer protection as high a 220 degrees Fahrenheit. Similarly, most vegetable-based lubricants offer good performance to 30 degrees Fahrenheit yet some flow below -30 degrees Fahrenheit.

When an environmentally preferable product is required outside the common temperature ranges, a biodegradable synthetic is usually necessary. While offering biodegradation, these products can operate in temperatures in excess of 400 degrees Fahrenheit and still offer long fluid life. As would be expected, these products are significantly more expensive.

Care must be taken in choosing the appropriate product for the specific application. Responsible environmentally preferable product (EPP) suppliers can clearly indicate their definition of environmentally preferable. The Federal Trade Commission has been specific in its requirements for environmental claims and states: "Look for claims that give some substance to the claim, the additional information that explains why the product is environmentally friendly." Many would be EPP suppliers use misleading environmental claims such as "inherently biodegradable" or "food grade." Suppliers should be able to support performance claims with testing data. Data can include standard industry tests (ASTM), field-testing and equipment manufacturer tests. Unless an EPP supplier specializes in environmentally preferable products, it is probably not an expert in the field.

Myth 5
Using A Biodegradable Product Will Void Your Warranty

While biodegradable products are relatively new to the

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Myth Or Reality?

Continued From Page 20

pile driving industry, they have a long history of successful performance. Due to the obvious benefits in the marine construction area, most pile driving equipment manufacturers have evaluated and approved a biodegradable hydraulic fluid for use in their equipment. While only one manufacturer exclusively utilizes biodegradable oils for initial and service fill, most manufacturers offer them as an option. In the rare case where the manufacturer has not approved a truly biodegradable product alternative, a reputable EPP supplier will guarantee its fluid.

Biodegradable fluids have been used in various other industries for many years. As such, even if an equipment manufacturer has not given its approval for biodegradable fluids, a high quality fluid probably will be approved by several manufacturers. It is always a good idea to check with the lubricant supplier to find out which manufacturers have approved its fluids.

Growing concern over the cost and environmental impact of lubricant spills in the pile driving industry has led to increased interest in environmentally safer fluids. These fluids can be biodegradable and non-toxic so that they will have no long-term negative impact in the environment if there is an accidental discharge.

While pile driving contractors are trying their best to adhere to the regulations, there is still much confusion regarding biodegradable oils and the regulations pertaining to them. In an attempt to clarify some of this confusion:

1. The Coast Guard does not approve any oils.
2. All petroleum products are pollutants, according to the Clean Water Act.
3. Inherently biodegradable products take a long time to degrade.
4. Food grade products do not biodegrade, are toxic and are designed for light duty service.
5. Some biodegradable oils are better than others.
6. Most equipment manufacturers approve biodegradable oils.

With proper maintenance and routine monitoring, biodegradable fluids will provide a long useful life for the fluid and the equipment. No one wants a lubricant spill, but they are a fact of life. Biodegradable lubricants will more than pay for themselves in terms of reduced cleanup costs, fines, downtime and administrative costs.

Shari Miller is the director of marketing for Terresolve Technologies, Ltd. She leads the marketing, market research and quantitative analysis for the company. Curtis Scharf is the president and chief technical officer of Terresolve. He has been formulating lubricants and lubricant additives for more than 20 years and has developed more than 20 commercially available bio-based products. Mark Miller is the head of sales and chief executive officer of Terresolve. He has engineered, sold and marketed lubricants and lubricant additives for more than 20 years.

Driving Our Point Home

Professor Education Course Will Help Build Market Share

The future of the driven pile is hinged on education. Discussions with contractors, suppliers and engineers associated with pile driving always lead back to the need for education regarding driven pile foundations. Other suppliers in the deep foundation market have promoted their products extensively and their market share has increased considerably. Now the driven pile is taking center stage.

The PDCA is sponsoring the first College Professors' Piling Institute, July 22 through 26, 2002, in Logan, Utah. This historic education program will feature a number of industry professionals who will present the latest concepts in pile driving to an audience of 25 professors of engineering. During this intense, five-day program, professors will be introduced to all aspects of driven pile design and installation and be given extensive education materials covering these subjects.

A statically load-tested pile will be driven during the Institute and dynamic measurements will be made. Attendees will have the opportunity to: predict the pile capacity based on the subsurface information; predict the driveability of the pile; predict the pile capacity using dynamic measurements made during driving, together with an analysis using the CAPWAP program; and compare all of these results with field observations. This demonstration will highlight the advantages of the driven pile to those who determine design specifications for deep foundations.

The College Professors' Piling Institute is a monumental step forward for the pile driving industry, and the PDCA is funding virtually all the expenses for this labor-intensive seminar. The PDCA has several sponsorship opportunities available that can help make this event a memorable one for the professors and for the Pile Driving Contractors Association.

"Please consider helping regain market share for the driven pile industry by sponsoring one or more professors," PDCA Executive Director Stan Orr commented.

"I would like to thank those companies who have already sponsored professors for the Institute and hope to see more sponsorships going forward," he added. "The Board of Directors has committed to an annual Professors' Institute for the next five years. I believe the driven pile industry can recoup its lost market share as more and more professors learn and begin teaching about driven piles."

For more information about the Professors' Institute, contact the PDCA at (970) 945-1231 or visit the PDCA Web site at www.piledrivers.org.

Contribute To The Institute By Sponsoring A Professor

Depending on the sponsorship level, recognition for your donation could include complimentary banner ads at www.piledrivers.org, a complimentary ad in *PileDrivers.Org* magazine, a company profile in *PileDrivers.Org* and special recognition in the magazine, at PDCA meetings and in subsequent articles and press releases. Sponsorship options are:

☞ **A PDCA-Named Professor: $2,500**
PDCA will select a professor from the list of applicants, who will be funded in your company's name.

☞ **A Sponsor-Selected Professor: $3,500**
Select a professor from your favorite school or choose from PDCA's list of applicants. This professor will be funded in your company's name.

☞ **Multiple Professor Sponsorship: $4,000**
Sponsor two professors, either from the PDCA's list or one that you have selected, who will be funded to attend the Institute in your company's name.

Make a commitment by completing the Sponsor Acknowledgement Form on page 23.

"Building Market Share Through Professor Education"

Sponsor Acknowledgment Form

Yes! I want to do my part to build market share for the driven pile by endowing the future. I wish to sponsor a professor or professors through the sponsorships listed below.

❑ **A PDCA-Named Professor: $2,500**

I would like for PDCA to select a professor from a list of applicants to fund for the Institute in our company's name.

I understand that I will receive:

- A complimentary banner ad for three months at www.piledrivers.org
- Recognition on the PDCA home page, in a future issue of *PileDrivers.Org* and at future PDCA meetings

❑ **A Sponsor-Selected Professor: $3,500**

Please register the professor named below to the Institute.

Professor: ______________________

School: ______________________

❑ Send me a list of applicants and I will make a selection.

I understand that I will receive:

- A complimentary banner ad for six months at www.piledrivers.org
- Recognition on the PDCA home page, in a future issue of *PileDrivers.Org* and at future PDCA meetings
- A complimentary black and white half page ad in *PileDrivers.Org*

❑ **Multiple Professor Sponsorship: $4,000**

Sponsor two professors, either PDCA-selected, sponsor-selected or a combination of both.

Professor: ______________________

School: ______________________

Professor: ______________________

School: ______________________

❑ Send me a list of applicants and I will make a selection.

I understand that I will receive:

- A complimentary banner ad for nine months at www.piledrivers.org
- Recognition on the PDCA home page, in a future issue of *PileDrivers.Org* and at future PDCA meetings
- A complimentary black and white full page ad in a future issue of *PileDrivers.Org*
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Company name: ______________________

Contact: ______________________

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Please invoice me for my sponsorship:

Please charge my credit card for the sponsorship

Card type: ❑ Visa ❑ MasterCard ❑ American Express

Name as it appears on card: ______________________

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Who should we contact regarding placement of your complimentary banner ad or ad in *PileDrivers.Org*?

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Complete the information on this Sponsor Acknowledgment Form and return to:

PDCA Piling Institute

P.O. Box 1429 • Glenwood Springs, Colo. 81602

Phone: (970) 945-1231 • Fax: (970) 384-0512

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New Associate Members

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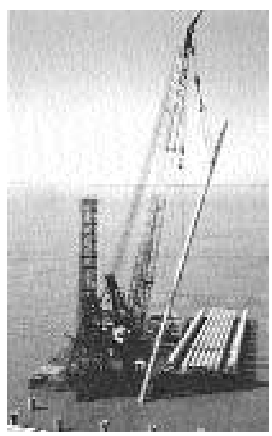


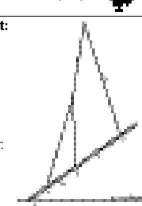
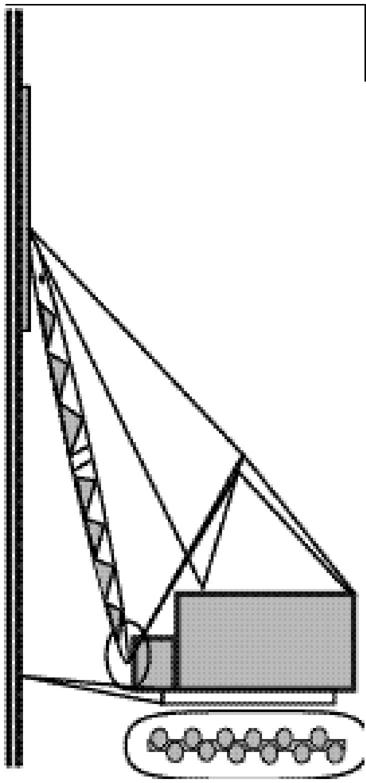


Diagram of this arrangement at a 35-degree angle



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(Continued on back)

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- ❑ Contractor
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Sponsored By:____________________________

Contractor Company Description

(check all that apply)

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- ❑ Deep Dynamic Compaction
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- ❑ Other ______________

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(check all that apply)

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- ❑ Plastic Pipe Piles
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- ❑ Wick Installation Equipment
- ❑ Sheet Piles
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- ❑ De-Watering Pumps
- ❑ Composite Pile
- ❑ Cushion Materials
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- ❑ H-Beam
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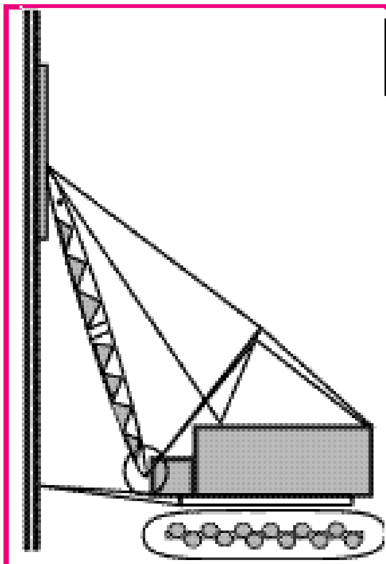
- ❑ Off Shore Leader System
- ❑ Wick Drain Supplies
- ❑ Drilling Supplies

Pile Hammers

- ❑ Vibratory
- ❑ Diesel
- ❑ Hydraulic
- ❑ Air/Steam

- ❑ Other________________
- ❑ Other________________
- ❑ Other________________
- ❑ Other________________



PDCA Membership Application

Technical Affiliate Company Description

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PDCA Sponsors Pile Demonstration

By George Goble and Manoj Chopra

The Geotechnical Institute Conference, held in Orlando, Fla., Feb. 14 through Feb. 16, provided the opportunity for the Pile Driving Contractors Association to offer conference attendees an extensive demonstration of pile driving and load testing.

The initial plan was to drive a pile for static load testing well in advance of the conference. This would verify pile driveability and hammer selection. Then, during the conference, the pile would be statically load-tested as a demonstration, and another pile would be driven during the conference. However, in the planning stage, it was decided to drive two piles in advance so both compression and tension tests could be performed.

As usual, the results brought several surprises. Data was obtained that provides a measure of the accuracy and reliability of some of the commonly used engineering tools for pile design.

Conference attendees were offered the opportunity to compete in predicting the pile driveability and the static capacity in both compression and tension. Prizes of $1,000 for the best driveability prediction and $500 for the best prediction of compression and tension capacity were offered by PDCA member American Piledriving Equipment (APE) of Kent, Wash.

Several PDCA members made large contributions to help make the demonstration a success. The Giken Company of Orlando provided a site reasonably close to the conference. Two borings with Standard Penetration Test (SPT) testing using a cathead and rope system were performed by Nodarse and Associates of Winter Park, Fla. These are shown in Figure 1. Energy measurements were made on the SPT operation by GRL Engineers of Cleveland, Ohio. The Cone Penetration Test (CPT) was performed by Ardaman & Associates of Orlando, and Seismic Piezocone penetration tests were performed by Georgia Tech on a truck supplied by Ardaman and Associates. All of this information was supplied to the predictors on the American Society for Civil Engineers (ASCE) Web site.

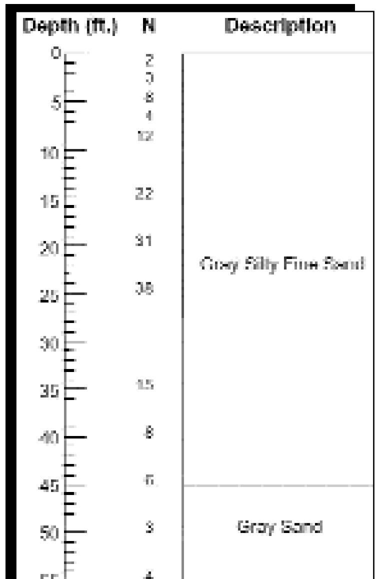

Figure 1 - Site Soil Boring

The soil profile is basically sand over the entire depth with a dense layer at about 15 feet. The test piles were 12-3/4-inch diameter, closed-end pipe piles with a 1/4-inch wall thickness. They were supplied by Mandal Pipe Company of Lilburn, Ga. Jacks used to conduct the static load test, both tension and compression, were furnished by Ellis & Associates of Jacksonville, Fla. Ed Waters & Sons Contracting Company, Inc. of Jacksonville, Fla., did all the pile driving and load testing.

This pile type and size was chosen since nothing could be left in the ground at the site after the demonstration. A penetration of 45 feet was selected. The first author (the guilty must be blamed) used the DRIVEN Program with SPT blow counts to predict the static capacity and GRLWEAP to predict driveability. Based on this analysis, an APE D-8-32 diesel hammer, supplied to Ed Waters and Sons by American Pile Driving Equipment, was selected. This relatively small hammer was selected to try to obtain blow counts at the end of driving that were not extremely low.

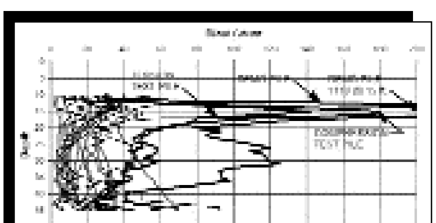
Figure 2 - Driving Records for the Test Piles (heavy lines) and Predicted Driving (light lines)

Two piles were driven on Nov. 26, 2001. The driving records are shown in Figure 2. Dynamic measurements were made with a pile driving analyzer (PDA) by GRL Engineers during the driving of both piles. The APE D-8-32, rated at 18.0 kip-ft., delivered from 7.3 to 8.6 kip-ft. average energy per foot during driving for the compression test pile. During the last foot of driving it delivered an average of 8.0 kip-ft., for a transfer ratio of 44 percent. This delivered energy performance places the hammer in the 80th percentile for open end diesel hammers on steel piles, according to the GRL Hammer Performance Database. All of the driving information on these piles was confidential.

Figure 2 shows the driving records for the two static test piles. They had blow counts at the end of driving of about 40 blows per foot. However, at 15 feet penetration the driving resistance was much larger (as much as 180 blows per foot). The hammer selection decision was reviewed, and the first author concluded that it would be better to stay with the APE D-8-32, even though the driving resistance became quite large at 15 feet. He felt that the reduced blow count of a larger hammer at the end of driving would be undesirable for the prediction symposium.

The contest pile drove considerably harder during the demonstration, as shown in Figure 2. The blow count at 15 feet was 1,110 blows per foot, and the pile driving demonstration continued during the entire demonstration period. The transferred hammer energy measured by GRL Engineers using a remote PDA (PAL-R) system for the demonstration pile was about the same as for the static test piles.

The method used in evaluating the driveability predictions emphasized the predictions at greater depth. The contest was won by Dr. Ameir Altaee of Urkkada Technology Ltd. All the predictions were low except for three that exceeded the demonstration pile driving resistance, but only near the end of driving. Only one predictor was close to the driving resistance at 15 feet. All of the predicted driving records are shown in Figure 2, together with the three

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Pile Demonstration

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observed driving records.

A wave equation analysis was performed for the driving at a penetration of 15 feet. The hammer operation was adjusted to match the measured hammer performance, (transmitted energy) and the pile capacity was determined for the observed end of driving blow count of the load test piles. This analysis gave a capacity of 250 kips at a blow count of 180 blows per foot. The same analysis indicated a capacity of 300 kips at 1,110 blows per foot. At high blow count the capacity increases slowly with large increases in blow count.

Dr. Frank Rausche of GRL Engineers ran the tension load test. The compression load test was performed after the demonstration by professor Gray Mullens of the University of South Florida. The load test curve is shown in Figure 3. The load test response was quite stiff due to the large shaft resistance near the top of the pile. At a load of 281 kips, the capacity of the load test system was reached. The load test curve has been extrapolated to the Davisson failure criterion at about 380 kips. Of course, such a large extrapolation is quite unreliable and it is probably a lower bound. The toe force, measured during the test, is shown on the curve.

The toe load was only about 10 kips at the end of the test, but it was beginning to increase rapidly. The structural pile capacity was about 500 kips. This pile would probably be filled with concrete so its structural capacity would not be limiting. In any case, the function of this exercise was to predict geotechnical performance.

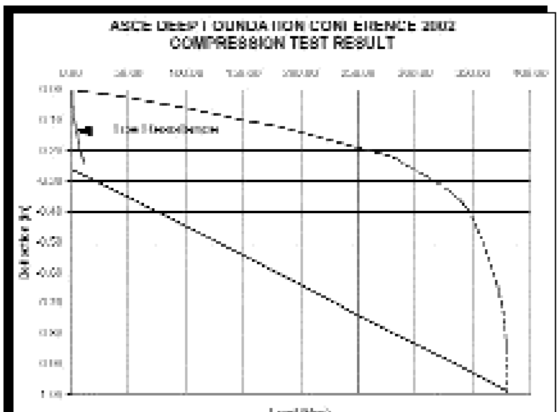

Figure 3 - Compression Load Test Curve With Extrapolation to Davisson Failure Load

Thirty-two conference attendees submitted capacity predictions ranging from 62 kips to 1,434 kips. A histogram of the predictions is shown in Figure 4. Two of the predictions were much larger than the others at 1,332 and 1,436 kips and are not included in the histogram. Only three other predictions were greater than the 380 kip extrapolated capacity.

It is useful to look at the prediction data statistically. For the 32 predictions, the mean value is 313 kips with a standard deviation of 304 kips (coefficient of variation [COV] 97 percent). If the two large predictions are dropped, the mean value becomes 242 kips, with a standard deviation of 120 kips (COV 49 percent). The mean of these capacity predictions is only 64 percent of the extrapolated capacity and that extrapolated value is probably low.

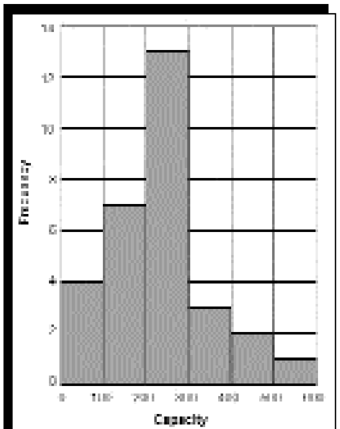

Figure 4

This data is useful for arriving at design factors of safety (or resistance factors) for deep foundations. Driven piles are usually installed to a blow count criteria that has been established using either a static load test, a PDA test, wave equation analysis or a dynamic formula. Prediction of pile capacity (or selecting a required pile length) based on subsurface investigation information has usually been very unreliable in granular soils, while the load tests or the dynamic methods are more reliable. This prediction event certainly confirmed that this problem still exists. Studies such as Dennis and Olson (1983), where load test data is collected with subsurface investigation information, have quantified the problem. In cases such as Dennis and Olson, a common judgment basis is used in evaluating and quantifying the subsurface investigation. In this prediction event, each predictor used a different experience base in evaluating the subsurface information and a different experience base in using the capacity prediction methods. Therefore, a large variability resulted.

Still one must ask why the capacity and driveability were so badly underpredicted. The subsurface investigation information was of excellent quality. For example, the SPT rig had been calibrated to 60 percent efficiency, the normal value. The CPT rigs were of state-of-practice capability. One should expect that the predictors were of above average competence, since they were at the conference. Two factors will be mentioned. At the time the subsurface information was collected, the water table was very near the surface. At the time of the conference, the water table was lower, perhaps by about five feet, although a measured water table is not available. It seems unlikely that this rather small change could have caused such a large increase in capacity. A second factor was presented by Antorena (1996). He collected data from a site in South Florida where CPT testing was performed before, during and after driving of a pile group. These tests showed that considerable densification occurred in the sands due to pile driving and due to the driving of adjacent piles. At this site, setup could be expected but the strength increase seems quite large. Some strength change must have come from densification of the sand.

Such exercises can prove to be of considerable value in understanding the challenges of deep foundation design. The data gives a good measure of current pile capacity prediction ability.

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Pile Installation Demonstration Project

New East Span Of The San Francisco-Oakland Bay Bridge

Photo by Barry Levin
The Imagery Group

By Roger Howard Jr., PE
Anthony R. Dover, GE
Saba Mohan, PE
Robert F. Stevens, PD, PE

This paper briefly describes the Pile Installation Demonstration Project (PIDP) and summarizes the findings and conclusions based on the installation of three large-diameter steel pipe piles in the San Francisco Bay as part of the San Francisco-Oakland Bay Bridge (SFOBB) East Span Seismic Safety Project. The PIDP was conducted to better understand pile handling, marine construction operations, pile driveability and pile setup associated with installing large-diameter, steel pipe piles into San Francisco Bay sediments. Three 2.5-meter (8 feet) diameter pipe piles were driven in the area between the existing Bay Bridge and the planned replacement bridge alignment. Additional details of the PIDP can be found in the Pile Installation Demonstration Project Geotechnical Report (Fugro-EM, 2001a) and in Howard et al. (2002) and Mohan et al. (2002).

Background

The San Francisco-Oakland Bay Bridge East Span Seismic Safety Project willl replace the east span of the world's busiest toll bridge and is the largest in the history of the California Department of Transportation (Caltrans). The existing east span of the SFOBB carries 10 lanes of traffic between Yerba Buena Island and Oakland. During the 1989 Loma Prieta earthquake, the east span of the existing bridge suffered considerable damage, including the collapse of a deck section. In 1995, the Seismic Advisory Board suggested replacement in lieu of retrofit. In June 1998, the single-tower, self-anchored suspension bridge structures and haunched concrete skyway structures were selected for final design. Final design of the chosen structure types and alignment was begun by the joint venture of TY Lin International and Moffatt & Nichol Engineers in the late fall of 1998, with the geotechnical site characterization and foundation engineering being provided by a joint venture of Fugro-West, Inc., and Earth Mechanics, Inc. (Fugro-Earth Mechanics).

Proposed Foundation Description

The foundation of the SFOBB main span-east pier and skyway structures will be founded on 2.5-meter-diameter, driven steel pipe piles that are approximately 70 meters to 95 meters (230 feet to 310 feet) long with non-uniform wall thickness schedules. The piles will be driven at a batter (1H:8V and 1H:12V), primarily to provide more lateral resistance and associated lateral foundation stiffness during ground shaking from a seismic event.

PIDP Project

Three piles were driven for the PIDP between Oct. 23 and Dec. 13, 2000, by Manson/Dutra (a joint venture of Manson Construction Co. and The Dutra Group) under contract to Caltrans. The piles were installed at two locations (designated the Primary Test Location for Pile Nos. 1 and 2 and the Pile No. 3 Test Location)

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Demonstration Project

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approximately 50 meters and 90 meters north of the existing SFOBB east span alignment.

The last three pile sections (B through D) were monitored during initial driving and during a series of restrikes by two pile driving analyzer (PDA) units. Case Pile Wave Analysis Program (CAPWAP) analyses were conducted for at least one hammer blow from the initial driving of each pile's D section and each restrike.

Pile Parameters

The piles were 2.5-meter-OD steel pipe piles with variable wall thickness (40 mm to 70 mm; 1.57 inch to 2.75-inch). Each pile was composed of four sections that were field spliced (welded). Section lengths ranged from 25.9 meters to 30.5 meters. The bottom pile section was designated as Section A, and the top section (driven last) was designated Section D. Pile wall thickness ranged from 40 mm along the lower part of the pile to 70 mm at the top, with a 62-mm-thick intermediate section. A 1.5-meter-long driving shoe with a wall thickness of 51 mm was welded at the bottom of each pile's Section A.

Pile No. 1 was a vertical pile. Pile Nos. 2 and 3 were battered piles with a designed batter of 1H:6V (angle from vertical of about 9.5 degrees). The specified pile tip elevation was El. -102 meters for all piles.

Driving Support Systems And Pile Hammers

Manson derrick barge DB-24, with a maximum crane capacity of approximately 357 tonnes (metric), was used for primary lifting during the PIDP. An eight-legged tubular steel space frame that measured about 20.1 meters by 7.3 meters in plan view and about 11.6 meters tall was used as a pile support template.

Two hydraulic pile driving hammers were mobilized to conduct the PIDP. A Menck MHU 500T (hereafter referred to as the MHU 500) with a maximum rated energy of approximately 550 kilojoules (kJ) (405 kip-ft.) (operated above water) and a Menck MHU 1700 (hereafter referred to as the MHU 1700), with a maximum rated energy of approximately 1,870 kJ (1375 kip-ft.) (operated above water). The MHU 500 weighs approximately 103 tonnes (metric) and the MHU 1700 hammer weighs approximately 292 tonnes. Menck MHU hydraulic hammers are double-acting hammers in which hydraulic fluid pressure is used to lift the ram and to help accelerate it during the down stroke.

Site Conditions

At the test locations, the mud line elevation ranged from approximately El. -7.0 to El. -8.9 meters. A detailed discussion of the SFOBB site conditions can be found in the Final Marine Geotechnical Site Characterization Report (Fugro-Em, 2001b).

Pile Driving Operations

Pile add-ons (i.e., Sections B, C and D) were hoisted into place using the stabbing guides to help position the pile over the previous section. The pile sections were field welded and inspected. Approximately 1.5 meters of pile were then cut off from pile Sections A through C.

Driveability

The PIDP provided significant insight into the driveability of the large-diameter pipe piles with large offshore hydraulic hammers into the soils near the proposed SFOBB east span replacement bridge. Some general findings applicable to pile driveability along the proposed east pier and skyway structures included:

- Each of the three PIDP piles was successfully driven to the specified pile tip elevation without excessive blow counts or pile damage.
- Piles had little difficulty penetrating to the specified pile tip elevation, and sand layers/lenses located above the identified Lower Alameda Alluvial sand (LAA-sand) did not significantly impede driving.
- Piles were driven well into the very dense LAA-sand at these two sites and most likely can be driven into similar soils across the alignment if the same or a similar large hammer (MHU 1700) is used.
- No significant differences were observed in the driveability of the two batter piles as compared to the single vertical pile.
- Piles cored through the soil during continuous driving, and the soil plugs moved up within the pipe pile during penetration.

Photo by Barry Levin
The Imagery Group

- As anticipated, the A sections of each of the three test piles ran through most or all of the soft bay mud.

Soil Resistance To Driving (SRD)

Estimates of SRD computed from PDA data [Case Method capacity (J) of 0.5] were compared with both CAPWAP and predicted SRD values. Two ranges of predicted SRD profiles were generated for each location. One range was based on the methodology presented by Stevens et al. (1982) and the other was calculated using a sensitivity-based method where unit skin friction values calculated using API 1993 procedures are incrementally reduced in clay by the inverse of the measured clay sensitivities.

The lower- and upper-bound coring case SRD profiles (based on both the Stevens and sensitivity-based methods) favorably

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Demonstration Project

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predicted the PDA-measured and CAPWAP-based SRD at the PIDP locations.

Blow Counts

The blow counts recorded during the initial driving of the three piles fell within a relatively narrow range (about 12 to 45 blows per quarter meter [bpqm]; 14 to 54 blows per foot) due to the fact that hammer energies were controlled by the contractor in an effort to maintain relatively consistent blow counts during initial driving of all pile sections.

Blow counts increased by a factor of two to three during the elapsed time between the driving of two sections. The increase in blow count is due to "setup" along the soil-pile interface as well as the tendency for the piles to act plugged at the very beginning of driving after a significant period of setup. After approximately 3 meters to 5 meters (about one to two pile diameters) of driving, the blow counts typically returned to values similar to those observed at the end of initial driving of the previous section.

The PIDP also provided a means to validate the driveability model that has been adopted for this project. Wave equation analyses were run with the selected pile, hammer and soil parameters (including SRD predicted from both the Stevens and sensitivity-based methods) at the measured hammer energies (from PDA data).

Below the relatively soft sediments encountered in the upper portions of the soil profile, the observed blow counts are generally bounded by the blow counts estimated using SRD from both the Stevens and sensitivity-based methods.

Overall, it appears that the method(s) used to estimate SRD and input parameters to the wave equation model were reasonable and can be used with added confidence to predict driveability of production piles.

Driving Stresses

Maximum measured driving stresses in the piles typically occurred at the pile toe at the end of initial driving and during restrikes when driving into the very dense sand of the Lower Alameda Alluvial sediments. The compressive stresses were as high as approximately 330 MPa (47.7 ksi) or 90 percent of the pile steel yield strength. As a result, thicker driving shoes will be used for the installation of the production piles.

Pile Setup

Data from the PIDP generally indicate that pile setup at the PIDP locations occurred faster than the original (conservative) predictions using the Bogard and Matlock (1990) setup curves. The PIDP setup data therefore provide a basis for revising the previously recommended approach for the timing of construction loads on piles. The PIDP data suggest that 65 to 70 megaNewtons (MN) (6,500 to 7,000 metric tonnes) of skin friction capacity were available approximately 30 days after the end of initial driving at the PIDP Primary Test Location (Pile Nos. 1 and 2). A comparison of the anticipated loads with the available capacity suggests that the allowable pile capacity (based on skin friction capacity with a factor of safety of 1.5 [FS=1.5]) will exceed the maximum anticipated construction pile load (Pier 8 Jack Span 4, about 45 MN) after approximately one month. At these load levels, monotonic pile-head load-deformation analyses predict about 20 mm (0.8 inch) of axial pile-head deflection. Predicted pile setup curves based on the Soderberg (1962) method also are provided on Figure 8.

Estimate Of Available Geotechnical Pile Capacity

The MHU 1700 hammer typically was not able to mobilize all the available skin friction during the restrikes. However, combined CAPWAP analyses (Stevens, 2000) were used to estimate the available static axial compression skin friction capacity at the time of each restrike. In combined CAPWAP analyses, the pile capacity is estimated using the largest resistance mobilized along a particular pile segment during initial driving or subsequent restrike(s).

After approximately 33 days of setup, the available skin friction capacity for Pile No. 1 was estimated to be approximately 70 MN (7,000 tonnes) (approximately 88 percent of the modified API [1993] static skin friction capacity).

In general, based on the available CAPWAP data and estimates of the magnitude and rate of pile setup, it appears that the PIDP piles will reach ultimate capacities that meet or exceed the required design capacities of the planned production piles.

Summary Of Conclusions

Three large-diameter, steel pipe piles were driven to final tip elevations at reasonable blow counts and without pile damage. The successful execution of the PIDP has:

- Reduced uncertainty associated with pile driving and foundation costs;
- Provided potential contractors with additional information that can be used when bidding on the project;
- Reduced the potential for schedule delays and claims by decreasing the likelihood of contractors attempting pile driving with a hammer that is too small;
- Clarified conservatism in the design of axial pile capacities;
- Established recommended minimum hammer size(s) and pile acceptance criteria;
- Established soil-pile setup criteria for the staged construction or loading of pile foundations;
- Helped to validate the methodologies used to

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Demonstration Project

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predict SRD and blow counts for pile driving into the soil of San Francisco Bay.

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