Protecting Our Waters

Company Helps Replace Bridge Without Making Dangerous Waves

By Harold B. Dreyer, President Gunderboom, Inc.

In 1999, Gunderboom, Inc. of Anchorage, Alaska, was asked by consultants working for the California Department of Transportation to play a key role in the Pile Installation Demonstration Project (PIDP), which was designed to acquire standard geotechnical information for the soon-to-be-considered replacement of the Oakland Bay Bridge.

Gunderboom's job was to come up with a way to lessen or eliminate underwater shock waves generated during the driving of large diameter steel piles for bridge foundations that could seriously impact marine mammals and fish in the area.

Gunderboom engineers indicated that a hybrid version of the Marine Life Exclusion System(tm) had been used successfully for underwater demolition projects to dampen underwater shock waves and prevent fish kills. Though technical data about specific reductions of shock/overpressure values was not recorded for these applications, theoretical calculations showed that shock/overpressure values were reduced by about 80 percent. These calculations were derived from publications, studies and patent work covering the basic concept of reducing damage to marine life and structures utilizing "air bubble curtain" techniques.

The template was taken to the staging facility so the curtain could be installed.

During the next several months, Gunderboom, Inc. developed a testing program from the basics of the MLES(tm), the "Boom Boom" system, which was to be implemented on the third test pile driven during the PIDP. Working with limited information, the company provided a quote for the system that was included in the bid specifications for the Pile Installation Demonstration Project, which went to bid in June 2000 and was awarded to the Manson/Dutra Joint Venture.

The Gunderboom Boom Boom(tm) integrates several techniques for the attenuation of a wide range of frequencies encompassing sound waves, shock waves and overpressures that are transmitted from underwater explosions, high-energy pile-driving projects and other construction-related activities. Historically, techniques that have worked well for mid-range and high frequencies have proven to be less effective with lower frequencies of 50 to 1,000 Hz traveling though a water column. The challenge is even tougher because lower frequencies tend to travel longer distances. Basically, techniques have been devised to attenuate certain frequency ranges with relatively good results but not over broad and varying ranges such as those that marine construction projects tend to develop. Quite often, especially in pile driving operations, these include the lower frequency ranges. Understanding the differing attenuation results at various frequency ranges provides the basis for the design and operation of the Boom Boom(tm).

The process by which this is accomplished is subject to patent rights held by Gunderboom, Inc. and pending patent applications. In addition, many aspects of the system are considered to be trade secrets. However, in general, the basic function of the Boom Boom(tm) system is to remove energy from and alter the shape of the acoustic shock and pressure waves emanating from the source. This is accomplished with phase boundaries; momentum transfer; scattering and dispersion at bubble interface; containment and control of the air-bubble curtain; maintenance of proper flux rate; turbulent flow fields; low frequency absorption techniques; and elimination of rarefication.

This is the template that was in use for the first two pilings, with no attenuation and then with the standard air bubbler curtain.

The Boom Boom(tm) system provides additional benefits to the typical marine-construction project:

★ It contains debris, jetsam and flotsam that is typically lost "over the side."

★ The system provides a completely sealed enclosure that prevents fish and mammals from entering the construction area. This is particularly useful because structures tend to generate marine growth quickly which, in turn, attracts fish looking for food.

★ The system contains incidental oil spills. The basic curtain material tends to absorb hydrocarbons. At the typical marine construction site, a certain amount of lube and hydraulic oil is inadvertently lost into the water and usually isn't recovered. However, since the Boom Boom(tm) creates a protected, encircled environment around the construction site, the oil is relatively easy to see and recover. Future applications might include oil-sorbent booms around the inside perimeter edges of the Boom Boom(tm).

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★ The system contains and controls sediments discharged during construction. Quite often pile installation projects require dewatering and removal of soils captured inside the piling. The Gunderboom system captures and retains suspended sediments – including contaminated sediments – that inadvertently enter the water.

After the bid was awarded to Manson/Dutra, Gunderboom, Inc. entered into a subcontract to design and supply a sound attenuation system for the PIDP. But it quickly became apparent that, for several reasons, the 46-foot-diameter floating boom system that Gunderboom had envisioned and quoted for the PIDP would not work with the approach the contractor had envisioned:

★ The dimensions for the boom template required for the project would exceed the diameter of the sound attenuation system. To be most effective, the sound attenuation system must completely envelope all structural elements that make contact with the piling being driven.

The curtain and template are lowered into position over the pin/locator pile.

★ The mooring configuration anticipated in Gunderboom's design for the floating sound attenuation system would conflict with the mooring array utilized for the construction barge and support equipment.

★ The weight of the piling and pile hammer required the crane to come within several feet of the template. A round boom floatation system, particularly at the diameter required to surround the pile-driving template, would keep the barge from getting closer than 10 to 12 feet.

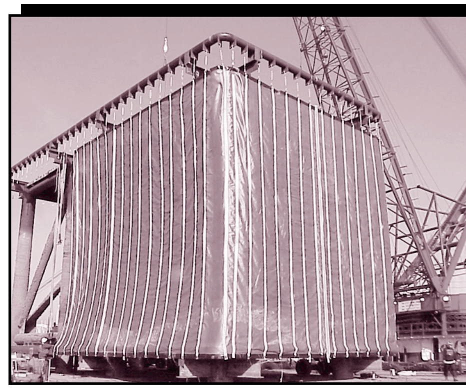
Gunderboom engineers went back to work and fit the sound attenuation system into the template design. The details were worked out with the contractor and submitted for approval to Caltrans.

The curtain assembly is 33 feet, 8 inches high and surrounds the template for a total length of 226 feet. It is attached to structural steel elements at the base of the boom and at the top, with turnbuckle arrangements for adjusting tension. The structural steel elements are suspended from outrigger arms welded to the template. A piping system to bring air between the two layers of the curtain and a second air bubbler ring system just inside the curtain perimeter were built into the template.

The contractor used the template for the first two pilings, one driven with no attenuation devices and the second driven with a standard air bubbler ring. After completing the second piling, the contractor removed the template from the project site and brought the assembly to the staging yard in Alameda, Calif., to fit out the Gunderboom system. Gunderboom, Inc. provided supervisory personnel to help install the curtain assembly onto the template.

The template, fitted out with the sound-attenuation curtain, was taken to the project site for installation at the designated location for the third piling. During the installation process, the contractor took preliminary soundings of the bottom depths at various points around the template. They indicated a distinct differential of depth from the East end to the West end of the template. After consulting with Gunderboom representatives on site, the contractor adjusted the template elevation to maximize the seal around the bottom without impacting the bubbler system's capabilities.

The system was designed for approximately 1 meter of bottom elevation differential, and installing the template to provide further intrusion into the bottom material might have caused damage to the bubbler system. More specific soundings after the template was installed showed a 3-meter elevation differential from East to West, possibly because the



The curtain takes shape around the template.

area was directly aligned with the existing bridge pier.

Once the contractor had the template in workable condition, Gunderboom technicians assembled the air manifold and delivery system, working from the contractor-supplied air compressor staged on the East end of the template. The air-manifold system provided connection points for four 3-inch hoses: two from opposing sides of the internal three-pipe bubbler ring and two from opposing sides of the attachment points for the attenuation curtain air distribution piping.

On Dec. 1, 2000, the first section of pile was stabbed into location, penetrating approximately 27 feet under its own weight. A Menck MHU 500 was rigged to the crane and placed on top of the piling. The weight of the hammer brought the piling down to its stops, so no pile driving was required for this phase of the project.

The contractor lofted the second section of piling and started the splicing operation. The Gunderboom technicians utilized several shifts of splicing time to make final adjustments and modifications to the flow rate gauging systems.

Two days later, pile driving on the second section got underway. The attenuation system had been aired up for about 20 minutes prior to driving. Driving encountered soft material and the hammer was used to tap the piling down. After about 48 minutes, the piling and hammer were down to the spotter and the compressor for the attenuation system shut off.

A visual inspection of the water surrounding the

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piling during driving revealed a surface disruption concentrated in an 8-foot radius on the West side of the piling only. Observations outside the curtain barrier revealed disturbances to the surface water 6 to 8 inches out from the curtain.

While the piling was being driven, Gunderboom technicians activated the sound attenuation system for specific periods of time to determine its effectiveness, and, according to Caltrans, a significant reduction in impact was verified in the preliminary review of the data.

Pile driving continued, with breaks for splicing additional segments of piling, and, on Dec. 11, the hammer was changed out to an MUH 1700 unit that develops approximately 1.2 million foot pounds of energy. While the piling was being driven with the larger hammer, Gunderboom technicians continued their routine of activating and deactivating the sound attenuation system. During this period of time, it was quite evident that with the sound attenuation system activated, there were no apparent fish kills. Within 20 to 30 seconds of deactivation, fish were seen floating on the surface on all sides of the template outside the boom. This process was repeated twice with the same results, indicating a significant reduction in sound and shock waves emanating from the energy transmitted through the piling from the large pile-driving hammer.

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The layout of the compressor, manifold and air lines.

After bringing the piling to grade with the large hammer, the project was completed, the template removed and the system returned to the shore-side facilities in Richmond, Calif.

An inspection of the Gunderboom Boom Boom(tm) curtain showed no sign of wear. The curtain basically was in the same condition as when taken from the mobilization yard in Alameda Nov. 28, 2000.

A mud line 2.5 to 3 feet above the bottom of the H beam supporting the bottom of the curtain was apparent on one end of the template. The mud line decreased and eventually disappeared toward the opposite end of the template.

Further inspection of the curtain showed that the outer armored layer had stretched 5 to 8 inches. There was some sag in the curtain above the bottom H beam. Where the mud line was apparent on the outside of the curtain, there was dried mud around and above the air lines inside the curtain.


The sound attenuation curtain inside during operation with inflated absorption cells and air flux.

A close inspection of the curtain showed no apparent wear of any of the systems or the top connections.

A close-up view of the bottom curtain connection to the H beam at a zipper connection showed no wear, some mud in the armor fabric materials and a secure zipper connection. This zipper connection was originally misaligned, causing a distortion of the connection, which was still apparent.

The only sign that the curtain had spent any time in the water was the rusting of the 7/8-inch bolts and associated washers used to secure the bottom of the curtain to the structural H beam.

The Boom-Boom(tm) system was effective in mitigating the damaging shock waves emanating from the pile driving operation. The PIDP also provided an opportunity for Gunderboom, Inc. to improve the system for future projects:

Contractor interface - Contractors must allow ample time in the bidding process for Gunderboom, Inc. to provide interface work plans with all contractors, which might require six to eight or even more different scenarios, depending on the contractor's equipment and approach to the project. What might seem like subtle differences – the radius of a crane barge, mooring array interference or elevation requirements, for example – can cause difficulties in implementing the Boom-Boom(tm) system.

Bottom contour alignment - The PIDP sound attenuation system was redesigned from a floating full-water-depth curtain to a fixed system attached to the template. It was anticipated that there would be (Continued On Page 4)

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The sound attenuation curtain bulging during operation.

up to 1 meter in bottom depth differential at the project site. When the system was installed, it was found that the bottom elevation differed approximately 3 meters from East to West. It is unclear exactly what effect this 1.5 to 2 meter gap had on the resulting test data, but a certain portion of the sound waves must have escaped through the void in the barrier system. Obviously, a complete seal is ideal.

Several options are available to solve these problems:

★ Complete and detailed bathymetric surveys of each location should be undertaken prior to design and implementation of the system.

★ Even with adequate and timely bathymetric information, it appears from observation that scour or subsidence may occur, particularly during an extended construction effort. Flexibility at the bottom of the Boom-Boom(tm) system is a good thing.

★ Either a floating system that can mold itself to the contour of the bottom and adjust for scour or a hybrid system affixed to the template at the top and allowed to freely adapt itself to the bottom contour at the bottom would solve the problem. Gunderboom is making design changes to accommodate this application.

Fendering system - Although not an immediate problem during the PIDP, several near misses with waterborne equipment indicate that a rudimentary fendering system around the Boom-Boom(tm) system might be advisable on long-term projects to prevent damage to the curtain.

Tidal current velocities - The system is designed for certain current velocities, and, in this case, the design current velocity was 2 knots, which, on several occasions, was exceeded. The safety factors designed into the system easily handled this over-current, but more detailed and site-specific current data should be developed for future installations. Since the load calculation on the curtain is an exponential formula, the maximum anticipated current velocity is critical in terms of designing a system that is adequate for the project and site. This is not necessarily a situation where designing for the worst case is financially prudent because the load factors increase significantly and directly bear on the cost of manufacture and implementation. In other words, an overbuilt system might add unnecessary costs to the project.

In addition, the shape of the system can help reduce costs. The PIDP required that Gunderboom design a rectangular system that could sit broadside to the current. In effect, this is the worst possible scenario. In a longer-term installation, a round configuration would be more appropriate.

Proprietary alterations - During the PIDP, Gunderboom technicians noted three modifications to the curtain system and material that would improve the effectiveness of the system. These alterations are now in the design stage and are expected to be incorporated into the next project.

Attenuation distance - The final design should provide for the sound-attenuation curtain to be placed no closer than 8 meters from the piling. This should assist with the tendency for the battered pile to project sound waves in a unidirectional manner.

Environmental considerations - Gunderboom, Inc. is making design changes to allow for a removable, internal, perimeter, oil-sorbent boom to further enhance the environmental attributes of the system. It is anticipated that future contract specifications will address the maintenance of a sorbent boom and removal of all floating debris captured inside the curtain before the template is removed.

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Gunderboom, Inc. provides systems for use in marine and aquatic environments for a variety of applications, including filtering power plant intake water, protecting beaches, reservoirs and aquaculture farms, and dredging and silt containment. The company uses a floating system that incorporates a curtain of permeable, non-biofouling material to contain or exclude silt, contaminated sediments, pathogens and aquatic life.

Gunderboom's sound attenuation system at work.