

Torpedo pile anchors enter the GoM

Innovative mooring anchors developed by Petrobras will soon be installed in a new region.

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Petrobras Brasileiro SA has licensed Acteon company InterMoor Inc. to produce and install its patented torpedo pile anchoring system in the US. The first installation of the torpedo piles is expected to be in the Gulf of Mexico (GoM).

The torpedo pile dynamically penetrates the soil by the free-fall velocity attained by the effects of gravity. Stabilizing fins, a conical tip, ballast, and an omni-directional chain attachment on the pile top distinguish these piles, but once in place, they behave in the same manner as a conventionally installed crown loaded pile.

Since 1996, when Petrobras was awarded its Brazilian patent, the company has successfully installed more than 1,000 torpedo piles for anchoring deepwater flowlines and facilities offshore Brazil. InterMoor has been licensed to use the US Patent on the technology awarded to Petrobras in 2000 in applications outside Brazil.

Technology development

Torpedo piles were first conceived as an inexpensive, easily installed anchor for riser flowline restraint. Restraint is needed as floating production facility movement caused by environmental loads produces cyclic loading in the risers followed by flowline displacement on the seabed. Another need



The torpedo pile dynamically penetrates the soil as a result of free-fall velocity attained by the effects of gravity. (Images courtesy of InterMoor)

for flowline restraint comes from the effects of thermal walking loads — the one-way displacement of flowlines across the seafloor resulting from repeated heating and cooling of the lines during sequential operational periods — and planned or unplanned shutdowns.

With torpedo piles meeting their expectations as flowline restraints, Petrobras realized their potential application as mooring piles for mobile offshore drilling units (MODU) and floating production, storage, and offloading (FPSO) vessels.

Testing of torpedo mooring piles started in December of 1999, and R&D continues today with the development of ever larger torpedo piles for FPSOs. Petrobras has acquired a large database of installation information over the years as the first torpedo piles were fully instrumented with accelerometers and inclinometers. Data gathering continues to this day for FPSO installations.

Although torpedo piles can be designed for specific loads and soil

conditions, over time, de facto torpedo sizes have developed for differing applications. T-24 torpedo piles typically are used for flowline restraint, T-43 for MODUs, and T-98 for FPSO permanent anchors. The number following the “T” indicates the dry weight of the anchor in metric tons.

Application

Torpedo piles are suitable for deepwater mooring applications for the same reason driven piles, suction piles, drilled and grouted piles, and plate anchors are. They are all vertical load-capable anchors.

The need for vertical load-capable anchors became evident in the 1990s as taut-leg moorings with synthetic line sections started to replace the traditional all-chain and chain-wire catenary mooring lines. Not only did the taut-leg systems improve performance, the vertical load component at the vessel's attachment point was much lower, reducing the mooring system's impact on vessel payload.

No anchor is ideal for all applica-

tions, and the torpedo pile is no exception. It works best in the soil conditions that work well for suction piles and plate anchors, such as soft to medium clay soils. Sands are best handled with driven piles, and rocky soils with drilled and grouted piles.

In evaluating types of anchors for specific applications, the torpedo pile's advantages over the alternatives include ease of installation, low-cost fabrication, and small footprint. For example, driven piles require a large, costly hammer spread for installation; suction piles require relatively large diameters in order to keep the embedment pressures under control leading to higher fabrication costs and a larger footprint; direct-embedment plate anchors require a large suction pile (known as a follower) for installation; and drilled and grouted piles require a drilling rig.

Drag-embedded plate anchors can be an effective competitor, but only if final anchor location and depth are not critical. Drag embedded anchors in general are not found to be suitable for congested fields with a lot of seabed infrastructure in place.

A sizing and cost evaluation would likely find a fabrication cost advantage for a torpedo pile compared to an equivalent suction pile, and an installation cost advantage compared to driven piles, drilled and grouted piles, and direct-embedment plate anchors since a hammer spread, drilling rig or suction follower is not needed for installation. Gravity does all of the work.

A typical torpedo pile has a conical tip and a tubular body made of line pipe, fins and an omni-directional chain attachment point at the pile top. To prevent fluttering and resultant unacceptable vertical tilt angles after penetration in the soil, it is necessary to insert ballast into the bottom portion of the pile to keep the center of gravity low. This is generally accomplished by



A torpedo pile awaits installation.

use of lead ballast near the tip, a section of cast iron above the lead, and optionally, concrete above the iron. The size of the fins depends on the use. T-24 piles need very small fins; only enough to keep them from rolling on the deck. Very large fins are used on the MODU and FPSO anchors to increase holding capacity. The omni-directional anchor attachment point is a special casting.

Installation

Torpedo piles are typically installed from the stern of an anchor-handling vessel (AHV). Their construction allows them to be easily deployed over the stern roller and positioned over the target zone. The smaller torpedo piles such as the T-24 might be held 400 ft (122 m) above the seafloor while the heavier T-98 requires only 100 ft (30.5 m); a sufficient height to ensure the torpedo reaches its terminal velocity before striking the seafloor. The pile attachment chain can be held by the AHV's shark jaws or, better yet, a special release device called a Pelikelo. A loop of chain longer than the pile's height above

the seabed and estimated penetration depth is provided in the mooring line so that the gravity penetration can proceed uninhibited. If for any reason the installation is unacceptable, for example if the pile tilt or position is out of tolerance, the pile can be recovered and re-installed up to a day after its first installation.

After gravity installation, the top of the pile is typically 30 to 50 ft (9 to 15 m) below the mudline. Once the mooring line is loaded to cut in the embedded anchor chain, the chain forms an "inverse or reverse" catenary shape in the soil. This shape reduces the horizontal load on the top of the pile increasing its lateral capacity. The large fins used on the T-43 and T-98 torpedo piles also greatly increase the lateral pile capacity and vertical capacity. Vertical capacity is a combination of pile weight and soil adhesion to the external surface of the pile and fins. As with conventional piles, the vertical capacity of the torpedo pile increases over the course of time and regains most of the strength lost during installation in approximately 90 days, depending on the soil type. **EXP**