REACHING NEW DEPTHS
JWF’s Use of Vertical Shaft Machine Marks U.S. First

FOR ANY TUNNEL PROJECT, GAINING ACCESS TO THE UNDERGROUND IS A CRITICAL – IF SOMETIMES OVERLOOKED – COMPONENT. THE BUILDING OF VERTICAL SHAFTS IS THE MOST COMMON METHOD OF GETTING MEN AND MATERIAL INTO AND OUT OF THE TUNNEL, BUT SHAFT CONSTRUCTION IS NO EASY MATTER DUE TO CHALLENGING SOILS, THE PRESENCE OF GROUNDWATER, CONFLICTING UTILITIES AND RISK OF SETTLEMENT TO ADJACENT STRUCTURES.

In one recent project, contractor James W. Fowler Co. (JWF) introduced new shaft construction technology to the United States. JWF, an experienced heavy civil and tunneling contractor based in Dallas, Ore., used a Herrenknecht vertical shaft machine (VSM) as part of the Ballard Siphon Replacement project for King County’s Wastewater Treatment Division in Seattle, Wash.

Typically, constructing shafts consists of three steps: building the wall, often below the groundwater level; soil excavation, which may require the lowering of the groundwater level; and preparation and pouring of the base, usually in dry conditions.

With the introduction of VSM technology, Herrenknecht has introduced a method that enables all three individual operations to be performed safely and without lowering the groundwater level. The first two operations are performed in parallel followed by the pouring of the base. This leads to higher performance rates.

“The VSM allowed us to sink the shaft in a flooded condition so we did not have to dewater or impact the groundwater table outside of the shaft,” said John Fowler, executive vice president with JWF. “The VSM was the appropriate size and was well suited to the ground conditions on the Ballard project, and it was immediately available. Fowler has had a longstanding and very positive relationship with Herrenknecht that opened the door to the collaboration that led to the pairing of the Herrenknecht VSM 9000 and the Herrenknecht EPB2850 TBM.”

ABOUT THE PROJECT

The Ballard Siphon Project involves the replacement of a wooden sewer line under the Lake Washington Ship Canal built in 1935. Plans called for a new tunnel to be built 60 ft below the channel to provide additional capacity and accommodate future growth.

The project called for the construction of two vertical shafts in addition to the replacement siphon, which was built...
using the EPB TBM. For the excavation of the launch shaft, the VSM was chosen by JWF due to its advantages regarding safety, noise emission and cost efficiency, marking the first use of the Herrenknecht VSM in the United States. The 125-ft deep, 9-m inner diameter shaft was finished in about four weeks excavation time and the average excavated depth per shift was 6 to 7 ft (13 ft was the maximum achieved by JWF during the Ballard project).

The ground conditions encountered were soft soils including sand, gravel and clay coupled with a very high water table. The small overcut between the shaft wall and the soil is lubricated by a bentonite mixture and grouted after the shaft had reached final depth. The concrete base slab was poured with the lowering of the water table.

According to Fowler, the VSM provided the following benefits:

- Controlled sinking as the ground is excavated, the caisson is held plumb and true so it doesn’t bind.
- Controlled excavation, the VSM excavates and removes the soil from the shaft in a controlled fashion so that the operator knows that the caisson can remain plumb and true as it is installed.
- The VSM is perfectly suited to allow for the installation of a segmental, precast caisson so there is no delay due to forming, pouring, stripping and curing as there is with a traditional caisson.
- The VSM allows for the over-excavation of a bottom plug while the caisson is suspended, which allows for a bottom plug that is a larger diameter than the caisson so that the bottom plug can be locked into the caisson without putting divers in the flooded shaft.

Upon completion of the excavation, the VSM was recovered by the three shaft winches and dismantled within one week.

**HOW IT WORKS**

The VSM equipment consists of three essential components. First is the excavation unit, which systematically cuts the soil that can have strength of up to 80 MPa (11,600 psi) or more. Therefore the VSM is equipped with a cutting drum on a telescopic boom that allows excavating under the cutting edge and where required an overcut.

In one case, the VSM had to excavate through several meters of unexpected rock in the region of up to 200 MPa (29,000 psi). Although this is possible for the VSM, high cutter consumption should be anticipated.

The excavation process is carried out below the groundwater level and is fully
remote-controlled from the surface.

Second, a slurry discharge system removes the excavated soil. A submerged gravel pump is located directly on the cutter drum casing. It transports the water and soil mixture through a slurry line to a separation plant on surface. A centrifuge unit can be added to the separation plant to remove fine particles. This improves the transport of the excavated soil and ensures clean shaft water, which can be more easily disposed of when emptying the completed shaft.

The third component is the lowering unit. The lowering unit stabilizes the entire shaft construction against uncontrolled sinking by holding the total shaft weight through steel strands and hydraulic jacks. Only when the excavation under the cutting edge of the shaft is completed, the complete lining can be lowered uniformly and precisely.

The whole operation takes place from the surface and is controlled by the operator from the control container. All machine functions are guided remotely without the necessity to view the shaft bottom or the machine.

The shaft lining is installed at the surface and is in most cases made up with precast concrete segments. These are in general comparable with tunnel linings, however bolts and connectors can be handled from outside the shaft.

A second alternative is an in-situ concrete casting of the shaft walls. Here, the slower progress of works of lining is compensated by a “continuous” structure without joints and the possibility of integrating entire entry and exit structures for microtunneling activities in the walls of the shaft.

The VSM technology has been continuously developed since introduction in 2003. Start and target shafts for microtunneling activities have up to now been sunk within an internal diameter range of 6 to 10 m (21 to 33 ft) and to 85 m deep (279 ft). The entry and exit areas in the shaft wall can be prepared with glass fiber reinforcement if required.

**FUTURE**

Now that the VSM technology has been successfully used in the United States, other projects are looking to utilize its advantages. Its next endeavor is the Ala Moana harbor crossing project in Hawaii, which involves the construction of two 120-ft shafts 33 ft in diameter. “We were very impressed with the equipment, and we look forward to the opportunity to use our experience and the equipment on other projects in the future,” Fowler said. “We’re also pleased to see that our innovation has paved the way for other contractors’ in the industry to use the equipment.”

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**SOURCES FOR THIS ARTICLE INCLUDE** “NEW SHAFT CONSTRUCTION METHOD SUCCESSFULLY INTRODUCED IN THE UNITED STATES” BY PETER SCHMAH AND SEBASTIAN BERBLINGER (TRENCHLESS TECHNOLOGY) AND “FIRST USE OF VERTICAL SHAFT MACHINE TECHNOLOGY IN NORTH AMERICA” BY JOHN FOWLER (PACIFIC NORTHWEST TRENCHLESS REVIEW).