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Gaining traction

Antonio Marinucci and Vincent Jue discuss the use of Soilmec's displacement and traction compaction tooling

Above: Soilmec's displacement tool has both cylindrical and conical variants

Drilled displacement piles (DDPs) are cast-in-place concrete piles that are formed with little or no soil removal from the ground. This is a specialised technology in which a pile is constructed using a process in which a specially designed tool is advanced into the ground using both rotation and downward thrust (crowd force) to displace the soil radially outward into the surrounding formation. Concrete is then injected and steel reinforcement (if required) is inserted to fill the created hole and construct the structural element.

DDPs have been used as structural foundation elements and for ground improvement and offer numerous advantages that have contributed to their increased use, especially for construction in urban areas, in contaminated environments (landfills and industrial facilities), in congested spaces and in close proximity to existing structures (around buried structures and utilities). As long as the soil can be displaced and compacted, this technique is suited for a wide spectrum of soil conditions ranging from loose/soft to medium-dense/firm and from sandy gravel to clay (relative density ≤ 65%; undrained shear strength < 2,000psf).

In applicable ground conditions, the installation process results in increased unit values of side shear and no relaxation compared with non-displacement piles. Therefore, the load-displacement response of a DDP is stiffer than that of a comparable non-displacement pile, which, consequently, enables DDPs to achieve a given load resistance at a shorter length. Some of the benefits of DDPs include:

- relatively rapid construction from high daily production;
- minimal amount of soil removal (spoils);
- no need for stabilising fluids (slurry) or steel casing;
- reduced environmental concerns – minimal noise and ground vibrations compared with impact-driven piles;
- lowered risks and costs associated with transport and disposal of (contaminated) spoils;
- cleanness of the working area – reduced risk of injury to onsite personnel;
- lower concrete overbreak than with conventional piling methods; and

Displacement tools

Soilmec's cylindrical (Cilindrico) displacement tool is well suited for soft ground conditions (loose to medium-dense sands, soft clays and organic soils); whereas the conical (Conico) displacement tool is well suited for stronger ground conditions (medium-dense to dense sands and stiff clays).

These tools comprise four main sections: a drilling tip, a lower section with partial auger flights that move the soil upward toward the displacement body, a central cylindrical body that stabilises and displaces the soil, and an upper section with partial auger flights that move the soil downward toward the displacement body.

Soilmec manufactures and provides the conical tools in modular form to optimise productivity. Cylindrical and conical displacement tools are able to form boreholes with diameters ranging from about 350mm to 600mm.

The general requirements for a drill rig capable of constructing displacement piles include a rotary head capable of delivering rotation of about 20-25rpm, a rotary head capable of delivering 200-250kNm of torque, a pulldown system with a crowd force of at least 200kN and a pull-up system capable of providing an extraction force of at least 200kN. In Belgium and the Netherlands, where the DDP technique has a long history, drill rigs with double this amount of torque and crowd are used to achieve the greatest productivity.

- increased unit side friction and end-bearing resistance achieved through the compaction of the surrounding soil, resulting in lower cost per tonne of load.

TRACTION COMPACTION TOOL

In general, the maximum achievable diameter and depth are limited by the type of tooling and the capabilities of the drill rig: the push/pulldown force (crowd), the pull-up/extraction force, the maximum available rotary torque and the height of the drill mast. For conventional DDPs, the soil is compacted during the drilling or penetration phase, thereby requiring the use of a large, heavy, powerful drill rig to provide the crowd force and torque needed to achieve the desired diameter, depth and displacement.

Soilmec patented a DDP technique using the traction compaction tool (TCT), where a large proportion of the compaction occurs during the extraction/concreting phase instead of all of the compaction occurring during the drilling phase. During drilling, the tool and drill string are rotated clockwise and penetrate the ground using the single rotary drive and crowd force provided by the drill rig, resulting in partial compaction and causing much of the material to remain in a coiled mass as the tool moves downward. When the desired depth is achieved, the TCT is rotated counter-clockwise and the central element of the tool shifts to full displacement during the extraction and concreting phase.

Because the total volume of the displaced soil is compacted during both penetration and extraction, the peak friction between the TCT tool and the in-situ soil is reduced, so wear and heat are minimised. Therefore, the torque, power and crowd force required to turn the TCT and penetrate the ground is greatly reduced by utilising this different work cycle.

Soilmec's SR-80 with displacement tooling

Moreover, since the drilling rig is utilised during drilling and extraction, it is operating more efficiently and productively than rigs used to construct conventional DDPs. Consequently, a smaller drilling rig can be used to achieve a comparably sized DDP.

On a site in Illinois, US, contractor Hayward Baker (HBI), a member of the International Association of Foundation Drilling (ADSC), has been using a Soilmec SR-75 fitted with a 400mm-diameter TCT to install DDPs through overburden and clay of varying strengths into the firm clay layer to depths ranging from 40ft to 45ft (12-14m). Using the SR-75/450mm TCT at this site, HBI has achieved 2,000LF of production (completed piles) per day, about double its bid estimate.

FLEXIBILITY

Displacement piling construction does not require a dedicated specialised drill rig. The new Soilmec product lines for hydraulic rotary piling rigs, ADV (advanced) and HIT (high technology), can be utilised for the installation of various deep foundation techniques using a single platform. Conversion kits facilitate quick changeover between different techniques spanning from large-diameter piles (LDP), continuous flight auger (CFA), cased auger piles/cased secant piles (CAP/CSP), drilled displacement piles (DP), turbo-jet (TJ) soil mixing and for low-headroom (LHR) conditions. ▼

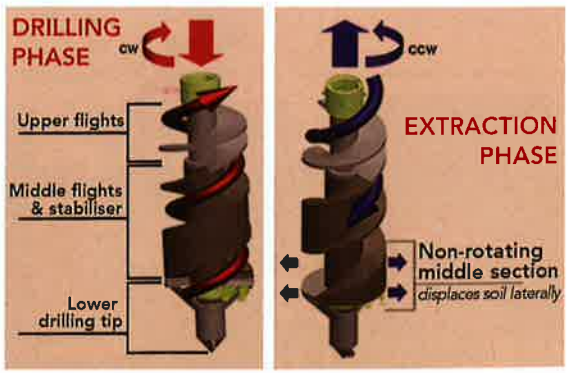
Quality control

It is essential to monitor and control various parameters during construction that affect the integrity and performance of a DDP. The different equipment and drilling/engineering parameters can be monitored and recorded continuously using the Soilmec automated Drilling Mate System (DMS), which is integrated directly into each of the Soilmec drilling rigs.

The DMS is a high-tech, fully integrated, interactive tool whose interface is located in the rig cabin, which allows the operator to monitor and accurately control the machine in real time. Data from an array of sensors recording the different parameters is transmitted to the cab, can be displayed on an easy-to-use touchscreen interface, can be stored on a flash drive, or can be streamed via cellular networks to a remote computer.

Some of the important drilling/engineering parameters include the drilling depth, penetration speed, rotational speed of the tool, inclination of the rig mast, rotary torque, crowd force, lifting speed, extraction force, concrete pressure, concrete flow and total volume of pumped concrete. Controlling and monitoring the various parameters during drilling and concreting assists with ensuring that the quality of the finished product consistently meets project specifications.

By maximising the drill equipment operability with the traction compaction tool, smaller drilling rigs can be used to achieve the desired diameter and depth of the DDPs, resulting in reduced operating and transport costs without sacrificing quality and productivity. Specific advantages of constructing DDPs using the TCT include the construction of larger-diameter elements (up to 800mm), the use of smaller/lighter drill rigs, high rates of daily production, lower operating and transport costs (compared to conventional DDPs and non-displacement piles), and enhanced quality of the finished element.



How the traction compaction tool displaces and compacts the soil

This article was written by independent consultant and researcher Antonio Marinucci, Ph.D., MBA, P.E., and Vincent Jue, president of Champion Equipment Company