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Efficiency examined of hands-free Cone Penetration Testing using the SingleTwist™ with COSON

Etude de l'efficacité des essais de penetration statique CPT sans manipulation de l'opérateur, grâce au système SingleTwist™ utilisé avec le COSON

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ABSTRACT: As a working environment, the Cone Penetration Test (CPT) cabin, built on trucks, crawlers or Track-Trucks® will more and more develop from a workshop into an office. Before, operators were mainly dealing with manual operations to keep the production going. Nowadays, and in the future, it can be increasingly expected that time "on board" will be spent on design or other office-related work next to performing CPTs. This paper describes a system that has been designed to support this market development. The new system, COSON-ST, enables a fully automatic and hands-free CPT cycle by combining the patented ST-technology with the hydraulically driven COSON pushing system. With just one push of a button, the cycle is started in which the CPT string, with measuring instrument (CPT cone), is pushed into the soil in one continuous movement. This CPT string is built up automatically from a reel with separate, but interconnected, ST-rods. After reaching the final depth, the pushing movement will change into a pulling movement and the string will be automatically disassembled and rolled onto the reel. This paper describes the efficiency of this technology. The City of Rotterdam, the first owner of a Track-Truck with COSON-ST, deployed their system in different projects. One project is chosen to further elaborate on its advantages and experience in practice.

RÉSUMÉ: l'environnement de travail des cabines d'essais de pénétration statique (CPT), qu'elles soient montées sur un camion, des chenilles ou sur un système combiné camion chenille (Track-Trucks®) va se transformer de plus en plus d'un atelier en un espace de bureau. Auparavant, les opérateurs étaient essentiellement occupés par les manipulations permettant la continuité des essais. Désormais, et plus encore dans le futur, on s'attend à ce que les opérateurs soient plus occupés au traitement ou à la rédaction de résultats des essais, qu'à leur réalisation elle-même. Cet article décrit un système qui a été développé afin de soutenir cette évolution de la profession. Le nouveau système, COSON-ST, permet de réaliser un cycle complet d'essais CPT automatisé et sans manipulation, en combinant la technologie brevetée ST avec le système de poussée à commande hydraulique COSON. Avec une seule pression sur un bouton, un cycle complet démarre, au cours duquel le train de tiges CPT, avec son instrument de mesure (le cône CPT), est poussé dans le sol dans un mouvement continu. Cet ensemble est constitué de tiges de type ST interconnectées, disposées sur une bobine. Lorsque la profondeur finale est atteinte, la poussée se transforme en traction, et le train de tiges est automatiquement désassemblé et enroulé à nouveau sur la bobine. L'article démontre l'efficacité de cette technologie. La vile de Rotterdam, la première à posséder un pousseur CPT COSON-ST monté sur camion-chenilles, l'a utilisé dans plusieurs projets. Un de ces projets a été choisi pour développer les avantages de ce système, et en décrire l'utilisation pratique.

KEYWORDS: continuous CPT, onshore pushing system, hands-free, automatic, CPT-rods on reel

1. INTRODUCTION

Changing requirements and regulations are spurring continuous development of CPT systems. The need for increasing operational efficiency requires systems that can start up more quickly and run without further intervention or control. These systems are expected to have a simple human-machine-interface to monitor the process and receive system alerts in the event of imminent quality loss or maintenance requirements on the equipment or data acquisition system. These expectations focus on obtaining better CPT data, performed in a shorter time and with less effort.

Smart and dedicated technology is required to meet these needs. A combination of digital data processing, an accurate system feedback and a simple and robust design delivering excellent quality, safety, long service life and easy maintenance is needed to face the increasing demands.

The answer is "back-to-basics". The CPT rod, the most simple and robust part of the CPT system, has become the core of a new development. The CPT rod is the connecting link between the measuring cone and the pushing system. More than 90 percent of the time required for a cone penetration test consists of handling the CPT rods. Far reaching efficiency improvements can be found in a creative approach towards these rods. This paper presents the SingleTwist (ST)-technology as the result of such a creative design process. The introduction of this new technology is preceded by an overview of pushing systems developed over time and is concluded with a description of a practical application. This new insight will ensure a changing working environment inside the CPT cabin: a shift from operator to engineer or from manual to hands-free operations and from manual labour to data processing, assessments and design work.

2. DEVELOPMENT OF CPT PUSHING SYSTEMS

To performing a CPT soil investigation, it is necessary to push a measuring cone into the soil over time. We can see that the development of pushing systems has kept pace with that of measuring cones. The first systems used in the 1930s were suitable for testing with mechanical cones. The power source used was often the operator's muscle strength, a jack was used for power transmission and the maximum pushing force was limited to 50 kN. With the arrival of the electrical cone in the

1950s, higher demands were also placed on the pushing device. Soil investigation at larger depths required higher pushing forces. A continuous speed also became important and an electrical connection to the cone was required to show measurement data in real time. Due to increasing demands for comfort, the pushing device had to be set up in a closed and conditioned cabin.

The following subsections describe the pushing systems developed at A.P. van den Berg for onshore soil investigation. The specific A.P. van den Berg trade names are indicated in brackets.

2.1 Onshore CPT pushing systems

The range of pushing systems varies from a single light weight pushing cylinder for hand carried CPT solutions to heavy duty pushing devices built on trucks and on large crawlers.

2.1.1 Light weight systems

Light weight CPT systems (HYSON LW) are very suitable for installation in hand carried applications and on light vehicles such as mini crawlers. The pushing system has a single hydraulic cylinder with a maximum pushing capacity of 100 kN. Due to its low weight and small size it can easily be applied in basements, back yards and on dikes.

The LW system has an intermittent pushing movement with a stroke of 700 mm and can handle 500 or 1000 mm CPT rods. The pushing force is transferred by means of a ball pushing clamp or a pushing piece. The LW system is powered by a hydraulic power pack and is only available with manual operation.

The advantages of a LW pushing system are the compact size and low weight in combination with sufficient pushing capacity to perform a reliable CPT. For sufficient reaction force, it is necessary to secure the system with ground anchors.

Figure 1. HYSON 100 kN in Mini CPT Crawler

2.1.2 Heavy duty systems

Heavy duty CPT pushing systems (HYSON) are very suitable for installation on crawlers (see Figure 1) or inside the CPT cabin of a truck or a truck with tracks (Track-Truck®) as shown in Figure 2. Stand-alone CPT systems mounted on a frame can be used as a skid system onshore or on a barge or jack-up rig for near-shore applications. The pushing system has two cooperating hydraulic cylinders which are interconnected by an upper and a lower beam. A maximum pushing capacity of 300 kN is feasible, but in many cases for reasons of maximum vehicle weights, this is limited to 200 kN.

The heavy duty system has an intermittent pushing movement with a stroke of 1200 mm and is able to handle 1.000 mm CPT rods. Depending on the degree of sophistication of the system, the pushing force is transferred by a ball pushing clamp, a mechanical clamp or a hydraulic clamp, mounted on the upper beam. Optionally an automatic rod screwing device can be added to the hydraulic clamp to ease the work for the operator. The heavy duty pushing system is powered by the truck PTO or a separate power pack. Hybrid systems with partly electrical mode are already available.

The advantages of the heavy duty pushing system are high efficiency, great ease of use and sufficient pushing capacity for every type of soil investigation.

Figure 2. Track-Truck with HYSON 200 kN inside the cabin

2.1.3 Heavy duty continuous systems

The continuous CPT system (COSON, see Figure 3) is a further development of the above described systems with intermittent stroke. In fact, it is a dual pushing system, built on top of each other. This pushing system is equipped with four cooperating hydraulic cylinders, provided with two independently moving hydraulic clamps. This allows a continuous movement of the CPT string when pushed into the soil. The maximum pushing capacity is often limited to 200 kN.

The continuous pushing system is able to handle 1.000 mm CPT rods. Because of the continuous movement of the CPT string, the cohesion with the surrounding soil is less, so a greater penetration depth can be achieved with the same pushing force.

The advantages of the continuous pushing system are increased production, greater CPT depth at the same pushing force and no interruptions due to discontinuous pushing movements.

Figure 3. COSON 200 kN inside cabin CPT vehicle

2.1.4 Heavy duty automatic ystems

The continuous CPT system as described above was very suitable for a further automation of the handling of CPT rods (AUTOCOSON, see Figure 4). This system consists of a continuous CPT system supplemented with a carrousel system that automatically feeds the CPT rods. The cable for data transfer was replaced by light conductors inside the CPT rods for wireless data transfer (Optocone).
The automatic pushing system can run a full cone penetration test without intervention of the

Figure 4. AUTOCOSON 200 kN inside the cabin

operator. As a result, the tasks of the operator shift to monitoring and administrative work. In fact, a part of the office work can be prepared or even performed in the CPT cabin.

The advantages of the automatic pushing system are increased operator comfort resulting in less absenteeism, less machine work and more time for processing CPT results, and a reduction in working hours per CPT performed.

2.2 Offshore CPT pushing systems

Unlike onshore pushing systems which are used on land or above the water surface, offshore pushing systems are intended to operate under the water level. This imposes special demands on the equipment towards reliability and durability and use of material that are suitable for marine conditions.

In offshore CPT systems we can distinguish between wireline systems for use in drill pipes, and seabed systems for performing a CPT from the seabed. Both systems require specific facilities on board of a ship.

The wireline CPT system (WISON-APB) is a pushing system specially developed for use on geotechnical vessels with drill tower and moon pool as shown in Figure 5.

The advantages of the wireline pushing system are the simplicity of the tools, which are easy to use and maintain. Furthermore the large water depth up to 3.000 m that can be achieved and the ability to quickly switch between CPT and sampling with different tools.

Figure 5. WISON-APB at a drilling vessel

The seabed CPT system (ROSON) is a pushing system that is deployed from a vessel with an A-frame from the rear deck or with a crane through the moon pool or over the side. Depending the water depth requirements, the winch is supplied with a cable length from 200 up to 4.000 m. The advantages of the seabed pushing system are the proven high reliability, robust design and the ability to quickly switch between CPT and sampling with different tools.

3 PATENTED SINGLE TWIST™ (ST) TECHNOLOGY

The fact that being involved with onshore as well as offshore developments can foster cross-fertilisation is proven by the development of the SingleTwist (ST) technology. Initially, the ST-technology was developed for the ROSON seabed CPT system. By incorporating the patented folding ST-rods in the seabed system, a compact, safe and easy to handle ROSON-ST (see Figure 6) is created.

Figure 6. ROSON-ST seabed CPT system

Later it turned out that this technology is also suitable for onshore CPT, which has resulted in the development of the COSON-ST. By integrating the patented ST-technology in a CPT cabin with the COSON continuous pushing system, an automatic and hands-free CPT machine is created. On the Track-Truck, the workplace of the CPT operator is turning into an office environment. The assembly and disassembly of the CPT string takes place fully automatically, so the CPT operator can engage in other (desk related) activities.

Chapter 3 will give an explanation of the ST-parts for onshore application and in Chapter 4 the experiences with the COSON-ST is described.

3.1 ST-rods: the foldable CPT string

The ST-rod is the smart element which makes up the CPT string. In the next subsections the interconnection of the ST-rods, the transfer of measurement data through the ST-rods and the storage of ST-rods on the Folder are described in more detail (see Fig. 7).

Figure 7. Folder, Sprocket, Twister, ST-rods and data transfer

3.1.2 ST-rod connection

By using a multiple bayonet thread, an extremely strong and reliable connection has been invented that can be quickly fastened and loosened. The most striking external characteristic of the ST-rod connection are three separate threaded areas. Each of these areas covers 1/6th of the circumference of the rod, so that the inner thread of the female part can be directly aligned with the outer thread of the male part. This important feature of a bayonet coupling makes it possible to fix the connection with a very short 1/6 turn. The seven thread runs in combination with the high quality hardened SS material ensure a very strong connection with a maximum holding force of 420 kN. At the front end of both the male and female threads a slope is provided, so that the rods slide into each other easily.

The optimal design has been obtained with computer aided design, strength calculations according to the finite element method and computer aided manufacturing. The theoretical specifications have been confirmed with exhaustive laboratory and field tests.

3.1.3 ST-rod data transfer

A CPT rod not only ensures the transfer of the pushing and pulling force, but also the transfer of data. Most common is a connection between cone and data logger by means of a cable. A cable is very reliable, has a large bandwidth for data transfer, can be applied both onshore and offshore, and requires no further supporting equipment. However, the cable is vulnerable especially at rod connections, which must be taken into account particularly when used in automated systems.

The light conductor is a proven technology in CPT and also a good option for data transfer. There is no continuous cable running through the rods, which makes handling a lot easier. This is a useful feature especially in automated systems. However, data transfer with light conduction has a limited band width and is not very suitable for an offshore environment.

For data transfer in the ST-system it was decided to use a 4-core flexible cable with a small diameter. Because only digital cones are used, the number of cores can be limited to four. The requirement for applying ST-technology offshore, was an important consideration for choosing this cable. To protect the cable it is fully integrated into the ST-rods and the intermediate ball joints at the rod connections. This minimizes the risk of damage. Furthermore, the cable must be able to compensate for the change in length during assembly and release of the ST-rods. This has been solved by using a flexible spiral cable.

3.1.4 ST-rod storage and maintenance

The foldable ST-string is stored on a reel called the ST-Folder as shown in Figure 8. The Folder has a diameter of 2 m and is provided with spacers at the circumference. This allows the ST-rods to be precisely positioned in 13 rows. The total storage capacity of the Folder is an ST-string of maximum 70 m length. To easily reel up the string, the ST-rods have a length of 350 mm.

The Folder is powered by an electric motor. This motor is electronically coupled to the Sprocket wheel, which feeds the ST-string to the pushing system. In this way the Folder keeps pace with the movements of the pusher. To perform maintenance, the foldable string can be replaced completely or partially. The foldable string is made up of 2.8 m sections that contain 8 ST-rods. Connectors on both ends of the cable inside a section allow for the electrical connection between sections. Each section can be replaced with a new one by (dis)connecting the ball joints and connectors.

Figure 8. Folder, storage of the ST-rods

3.2 Twister on continuous pushing system

The Twister (see Figure 9) realizes the transition of the foldable ST-string into a solid CPT string. The Twister is mounted on the upper beam of the continuous pusher system (COSON). Both are described in following subsections.

3.2.1 Twister

The purpose of the Twister is to connect and disconnect the ST-rods. Therefore the Twister is arranged on top of the upper beam of the pusher. The rod to be tightened is hydraulically clamped by the Twister. The other rod that is already part of the CPT string is held by the COSON clamp of the upper beam. As soon as the rods are correctly positioned, an electrically driven rotation of the Twister follows, providing a maximum torque of 350 Nm.

To ensure a good connection between two tightened rods, the Twister checks both the rotation angle and the torque. At least an angle of 50° and a torque of 250 Nm must have been reached. If not, a new attempt is made to tighten the rods. In the case of three unsuccessful attempts, a process stop will occur and a message will appear on the screen.

Figure 9. Twister, to connect the ST-rods

The angle and torque are also an indication of the thread quality. If the angle becomes larger in combination with a lower torque, this may indicate wear of the thread. If this occurs repeatedly with the same rod, a message is shown for replacement. For a balanced wear of the rods, it is best to change parts of the string periodically. This is possible by emptying the Folder, disconnecting the middle part of the string and exchanging the last part with the first part. Then the string can be reeled back onto the Folder.

3.2.2 Continuous pushing system

The continuous pushing system (COSON, see Figure 10) has been used in the ST-concept for the following reasons. First, with a continuous pusher the Folder can also move continuously, which is an easier process to control adding and removing rods. Furthermore, the small installation height provides sufficient room for a Sprocket wheel on top, without special roof requirements. Finally, the rod length of 350 mm is chosen to match the stroke of the continuous pusher, so each rod is clamped and (un)tightened at the same position by the Twister.

Figure 10. Continuous pushing system

The pushing system also comprises the following components. First, a length measurement system to determine the position of the clamps and the pushing length and pushing speed of the string. Furthermore the pusher is equipped with clamps for fixing casing tubes and a scraper mechanism for cleaning rods and casing tubes when retracted out of the soil. The COSON continuous pushing system is a proven technology with a track record of more than 20 years.

3.3 Sprocket wheel for connection

The Sprocket (Figure 11) is the connecting link between the Folder and the Twister. It ensures the correct position of the ST-rods in relation to the Twister. It also ensures the correct feeding speed, so that a smooth cooperation between Folder and Twister is guaranteed. Finally, the Sprocket ensures that the rods are pushed together in order to twist them properly. And vice versa, that the rods are pulled apart directly after they have been loosened. These functions are described in following subsections in more detail.

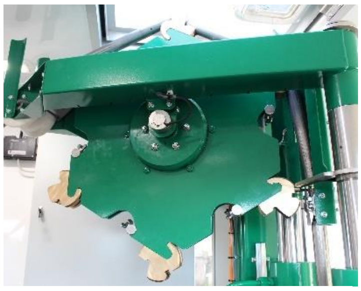

Figure 11. Sprocket, wheel for connection

3.3.1 Correct positioning of ST-rods

The electrically driven Sprocket is mounted on the static part of the pusher. There are six guiding blocks on the sprocket that precisely position the rods. These blocks also make it possible to apply a small pretension during pushing or pulling, so that the Sprocket can precisely follow the movements of the pusher.

The Sprocket also ensures a free hanging string between Folder and Sprocket, so that potential positional differences between both systems will be absorbed.

3.3.2 Right supply speed of ST-rods

Because the Sprocket exerts a constant push or pull load on the string, the average Sprocket rotation speed is exactly the same as the pusher speed. During a CPT the pusher moves at a continuous speed of 15 to 25 mm/sec. During retraction, this movement is non-continuous with an average speed of 70 mm/sec.

3.3.3 Smooth twisting of ST-rods

For tightening the bayonet coupling of the ST-rods, it is necessary that the seven thread runs are exactly opposite to each other. This is achieved by the constant push load of the Sprocket. The rods to be tightened are pushed together, so a connection is established properly. When loosening the rods, it is important that they are pulled apart quickly. This prevents the bayonet coupling from being re-assembled again. The Sprocket also ensures this by applying a constant tension to the string.

3.4 Operation and HMI

The ST-system enables a fully automatic and hands-free CPT cycle. The operator just has to bring the ST-system to the correct condition to start or continue a cycle. This is done with the clear push / pull and speed symbols on the left side of the screen (figure 12). After positioning, the cycle is started with just one push on the start button. The effect of an action is made visible within this image of the system on the right side of the screen, by changing colours or moving component parts.

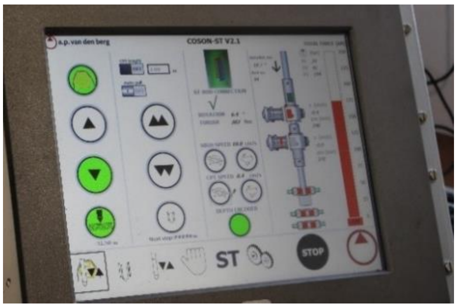

Figure 12. Touch screen for operation and real time presentation CPT data

All movements of the different clamps, the pusher, Twister, Sprocket and Folder can be operated separately. Important process variables are continuously displayed, such as the CPT speed, the angle and torque of tightening rods, the angular position of the sprocket wheel and the oil pressure and temperature. Furthermore, it is possible to set alarm values for the maximum reachable total push load and inclination of the cone.

4 PRACTICAL APPLICATION

The VLG, the Engineering Department of the City of Rotterdam procured the first COSON-ST pushing system built on a Track Truck. Since early 2019 the company in the Netherlands has used this CPT system successfully in various projects. For example the company executed more than 300 CPTs on projects in Amsterdam and 32 CPTs and 30 magneto measurements with the Icone Magneto click-on module on a project in Rozenburg (the Netherlands). Their typical workday is filled with two to eight CPTs at multiple locations. One project was selected to share as typical example in the following sections.

Compared with more traditional CPT systems, the VLG confirms that the COSON-ST automated system has removed the causes for physical strain. The operators do not have to lift, guide and screw CPT rods anymore.

Secondly, the ST-system is timesaving. Preparation takes less time, as there is no need to raise a hatch and to place an end set including inner casing. The operator just has to prepare and install the Icone. The timesaving in the CPT cycle is mainly achieved during pulling. It is proven that a complete 50 m CPT can be performed approximately ten minutes faster with the COSON-ST with two hydraulic clamps than with the HYSON with one clamp. On top of that, after one push on the button, the operators 'hands are free to prepare the next test or perform other (engineering) activities.

With the application of thicker CPT rods, 40 mm instead of 36 mm, the risk of buckling and breaking is much smaller and that provides the VLG with a lot of confidence. The company has regularly pushed with a total force of more than 15 tons without any problems, whereas with previous CPT systems the VLG was already on guard with respect to breakage at lower pushing forces. Due to these rods, the time-consuming use of casing for lateral support is also required less often.

This all results in an average production of 10 CPTs of 40 m in a working day at one project location. On longer days with favourable conditions, the company has even reached 17 of these CPTs. The maximum CPT depth of 70 m with VLG's CPT string size has also been realized.

The selected project concerned the geotechnical investigation required for the design of new bridges that are part of the Polder path in Schiebroekse polder in Rotterdam, The Netherlands. This is a cycle link between the city of Rotterdam and the Schie nature reserve. Eight Cone Penetration Tests were performed.

4.1 Purpose investigation bridges Polder path

The main purpose of performing Cone Penetration Tests was to:

- Calculate the load capacity for prefab concrete piles, for the determination of the pile lengths.
- Indicate the preconditions required to prevent the potential bursting.

4.2 Equipment used

Figure 13. Track-Truck with COSON-ST in the cabin

The VLG uses the Track-Truck with COSON-ST as a standard in order to execute CPTs, because the working environment is ergonomically optimized and the production rate is increased by at least 10%. In order to build new bridges (part of the Polder path in Schiebroekse polder) in Rotterdam, the CPTs were performed with the Track-Truck with COSON-ST (20 ton CPT truck with tracks) as well. A Track-Truck can run on the highway as an ordinary truck with its tracks retracted. After lowering the tracks, the Track-Truck does not get stuck in soft and hilly terrain such as the location where the new bridges will be built. Inside the cabin of the Track-Truck the COSON-ST pushing system is integrated. This matches with the safety, physical load and efficiency requirements of the VLG, the Engineering practice of the City of Rotterdam. A digital 15 cm^2 piezocone (Icone) was used as the measuring instrument. The modules Seismic, Conductivity, Magneto and Vane could be used along with the Icone, but additional parameters were not requested in this project.

4.3 Test method

The bearing capacity of the piles has been determined with the help of a special D-foundation computer program. The pile point level must be chosen in such a way that the requirements of the NEN EN 9997-1+C2:2017 Geotechnical design are met. The piles are calculated for pressure loads.

4.4 Test results

The Cone Penetration Tests performed with the COSON-ST and 15 cm² Icone for the design of new bridges part of the Polder path in Schiebroekse polder in Rotterdam, The Netherlands, gave a good image of the soil for the foundation advice. An aquifer was found at circa 12 m depth with the 6th and 7th Cone Penetration Test (see figures 14 and 15 on the next page).

In this respect, the risk for the development of wells, when digging in the (unfavourable) area at two bridges, has been checked. This check indicates that there is no bursting risk of the soil when excavating for the abutments of these two bridges.

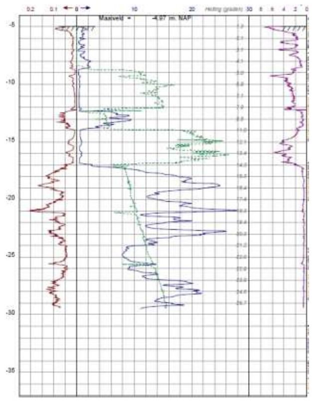

Figure 14. CPT nr. 6 including pore water pressure: showing an aquifer between clay layers at 12 m depth

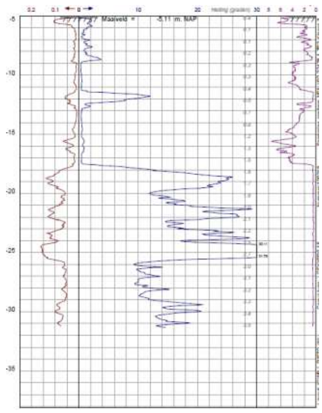

Figure 15. CPT nr. 7 without pore water pressure: showing an aquifer between clay layers at 12 m depth

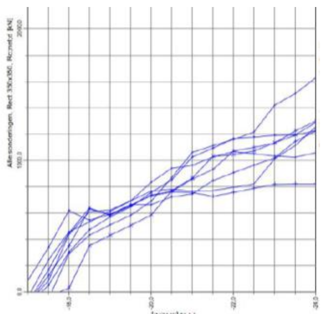

Figure 16. Output D-Foundations indicative calculations piles bearing capacity

The Cone Penetration Tests are used to calculate the bearing capacity of precast concrete piles for a pile level at a depth of 20 m. Of these indicative calculations is the D-Foundations output included in Figure 16.

5 CONCLUSIONS

Cone Penetration Testing (CPT) is a recognized and widespread method for efficiently performing in-situ soil surveys, for e.g. foundation advice. Over the course of time, CPT has been improved by integrating digital electronics inside the measuring cone. Also the pushing system needed upgrades, because soil investigation is carried out at increasing depths which requires higher pushing forces. In addition, developments have also focussed on operational efficiency and an ergonomically optimized work environment.

The Cone Penetration Test cabin as working environment, built on trucks, crawlers or Track-Trucks, will more and more develop from a workshop into an office.

The most prominent development is the ability to perform automatic and hands-free Cone Penetration Tests using the patented SingleTwist™- technology with the COSON pushing system. With a single push of the button, the automatic CPT cycle is completed. The CPT string, with the measuring instrument (cone) fitted at the tip, is pushed into the soil in one continuous movement. This string is built up automatically from a reel with separate, but interconnected, ST-rods.

The so-called COSON-ST has proven to be a robust CPT pushing system providing reliable data about the soil and ensuring the operational efficiency which is increasingly expected. The COSON-ST has more than proven itself and the VLG feels confident to let the system do its work. VLG experienced a production rate increase of at least 10%. The system works faster than standard CPT pushers, as it can start up more quickly and runs without further intervention or control. It does not require any manpower during the push/pull cycle of a CPT. The operator only has to provide the start/stop signals. Another advantage which is proven according to VLG is that the working environment is ergonomically optimized, because manual actions near the moving system are almost unnecessary. Indeed time "on board" is spent on design or other office-related work next to performing CPTs. An additional advantage of the COSON-ST is that the depth range is increased because of the continuous CPT push. CPTs are realized faster and in addition to the already shorter preparation time, this continuous movement results in a faster pushing and pulling process with a higher production rate as a consequence. Furthermore the ST-rod is designed in such a way that the risk of breakage and the associated downtime and costs are limited.

Based on the input from VLG we can conclude that the COSON-ST is a welcome contribution to the expected change of the working environment inside the CPT cabin. A shift from operator to engineer and from manual operation to data processing and assessment will occur.

In addition to the onshore application described in this paper, the ST-technology can also be used offshore. This results in a ROSON-ST that is immediately operational and can perform a CPT fully automatically from the seabed in a very safe and timesaving way.

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