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THE ADVANTAGES OF THE USE OF GPS BASED LOGGING SYSTEMS FOR VERTICAL DRAIN INSTALLATION PROJECTS

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In the recent years a sound, GPS based, logging system has been developed by Cofra B.V. The logging system is used for the registration of, amongst others, the drain coordinates, push forces at selected intervals and maximum depth of the vertical drains. The system has proven itself to be of added value for both the contractor as well as the client and can be used on projects upon the request of the client. Examples are given showing the advantages of this system over the traditional logging system without coordinates and advanced screen for the operator. As the GPS system is capable to load and show AutoCAD drawings to the operator, valuable information can be provided to the operators. These include the locations of underground infrastructure or levels of installation. When strict levels of installation are requested, the operator is given the ability, on specific base units, to choose an option to automatically stop installation at chart datum levels reducing the specific risk for the client. When unforeseen deviations are encountered, the data is shared with the client to investigate the effect on the consolidation process and mark the locations for predrilling. The registered data is also loaded into a GIS system to generate overviews or perform data analysis.

INTRODUCTION

This paper discusses the advantages of the use of a GPS based logging system during and after the installation of prefabricated vertical drains (PVD). During the installation of PVD the system can, for example, be used to prevent damage to underground infrastructure, map any obstructions and predrilling locations or determine sand thicknesses. The measurement of the level of the working platform enables us to install up to chart datum levels. After installation, the data can be used by the geotechnical engineer for a better understanding of the subsoil and help with the prediction of the (residual) settlements. In the next chapters specific advantages and observed features at various projects where the system was used will be discussed.

PREFABRICATED VERTICAL DRAIN INSTALLATION

PVD, also known as wick drains, are one of the most commonly used techniques to make soft compressible subsoil with a low bearing capacity constructible. The prefabricated vertical drains are installed using a wide range of stitchers. The heaviest rigs are capable to penetrate qc = 20MPa sand layers. The principal of the installation of the vertical drainage is based on the insertion of a steel mandrel with a drain inside. This mandrel is moved up and down through a system of cylinders and winches, which in turn are propelled by the excavators' hydraulic system. The drain section at the bottom of the mandrel is connected to an anchor plate which closes off the opening to prevent soil from entering the mandrel. The mandrel then takes the drain to the desired depth. When the mandrel is at this depth, it is withdrawn and the resistance created by the anchor plate upon retraction ensures that the drain remains in place at the right depth. After the mandrel is back above the surface, the drain is cut and a new anchor plate is connected to the bottom of the next drain. The principle is shown in Figure 1.

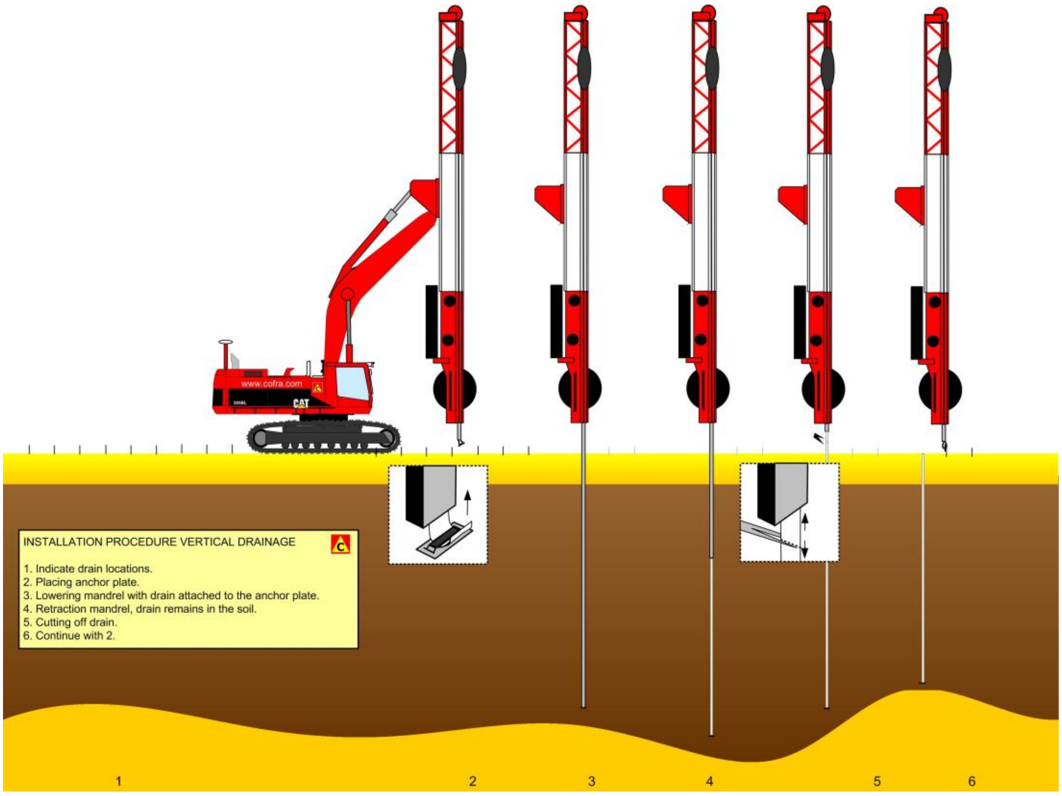

Figure 1. Principle of prefabricated vertical drain installation.

QUALITY CONTROL

The installation process is monitored by the operator on a screen in the cabin, see Figure 2. The screen is divided into a section showing a GPS referenced AutoCAD top view and a section with the real time data of the installation. The uploaded AutoCAD drawings can provide the operator with all the information required, such as drain depths, underground infrastructure, limitations on height and other restrictions. This system was specially developed for Cofra B.V. and includes the knowledge of several decades of PVD installation.

The real time data section shows amongst others:

- The stop criteria.
- The surface location of the PVD in x,y,z coordinates.
- The push force per depth intervals between 0.1m and 1.0m.
- The actual depth of the mandrel.

During the installation, a pressure profile with depth is shown to the operator in order to check the installation process, potential development of bedrock level and, for safety purposes, a check of the thickness of the working platform. When the platform is too thin the bearing capacity of the platform could become insufficient causing instability of the equipment. This is mainly caused by mud boils or mud waves below the platform when dredged sand is used.

Figure 2. View of the operator screen with on the left the section showing a top view and on the right the real time installation data

The registered push force is influenced by the tip resistance, the friction along the mandrel, the friction of the mandrel inside the stitcher and the pretension in the winches. This pretension is required in the cables to prevent slippage of the cables over the sheaves. In very soft soils the required push force is often lower than the pretension, making it, on the basis of the logger data, impossible to differentiate between peat and soft clay. When the required push force becomes higher than the pretension, the measured push force is the actual tip resistance and friction of the mandrel. Stiff clay layers and granular layers generate most often resistance profiles that are higher than the pretension and resistances will be visible in the logger data. Examples of soil profiles and use of the data will be given in following sections.

DEPTH OF INSTALLATION

The depth of installation can easily be determined from the logger data. It is mainly of interest when deviations occur from a fixed installation depth or when projects are executed on the basis of a maximum push force. A map, showing this maximum depth, is given in Figure 3 and Figure 4.

Reclamation project with off shore PVD installation
On the project data shown in Figure 3 the PVD was installed up to a depth of 35m below the water level into very soft material which strengthened below -20 to -25m CD. The initial dynamic probes, locations are marked as white diamonds in the figure, showed a variable image of the installation depth and top of bedrock. The maximum depth obtained from the probes coincided well with the installed depths of the PVD. However, during installation it was found that the top of the bedrock level varied even more than anticipated and a large section had a very thin clay layer. This high bedrock level was missed by the site investigation campaign. This was of major impact to the settlement behavior of the area. With the use of the logger data the client was able to optimize the fill during consolidation and make use of the data to place the settlement markers.

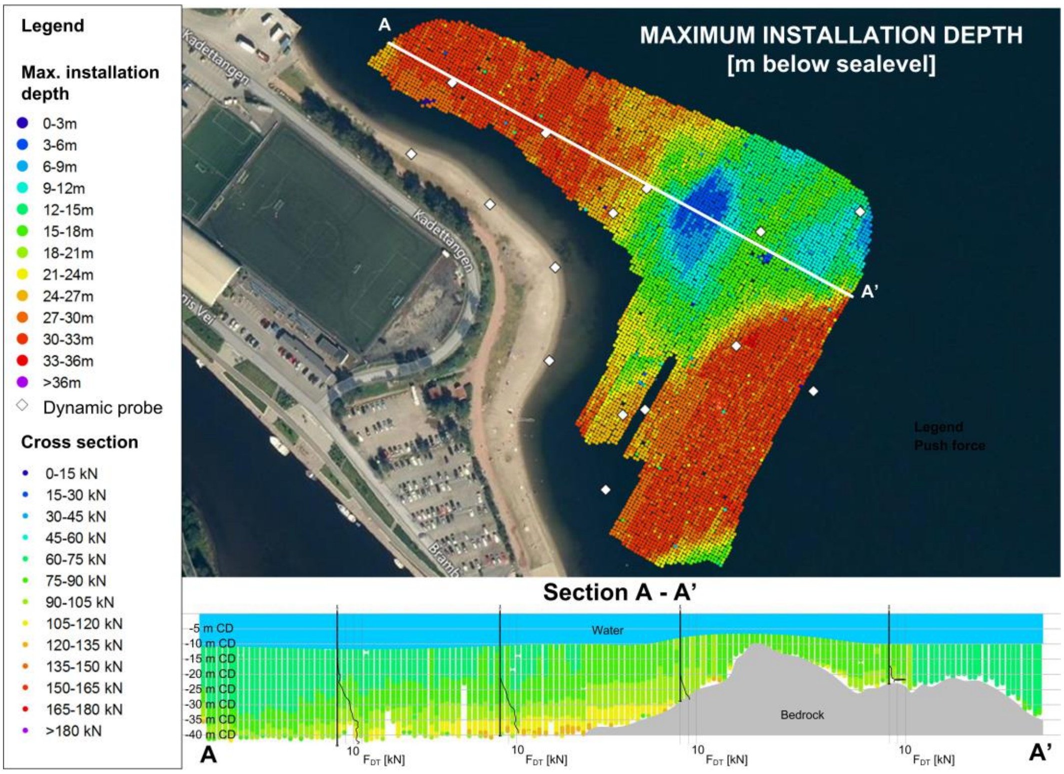

Figure 3. GIS compilation of the logger data showing maximum installation depth and a cross-section through section A-A'

Breakwater project with off shore PVD installation

Figure 4 shows the data of the installation of the PVD underneath a new breakwater. The cross section of the logger data shows a gradually increasing push force towards the maximum depth, especially from a depth of -14m. At the anchoring depth of the drain a sand layer is present, visible by the red colors in the push force in the given section. On the project only 6 boreholes and 6 CPT's were performed. From this data a theoretical installation profile was created. The initial profile is shown in Figure 4 as anticipated bottom of soft clay. It can be observed from the image that there is a large difference visible in the actual installation depth and the predicted depth. It is therefore advised, when no limitations are present for installation up to a certain push force, to use the push force as a depth boundary. When using such a criterion, there should also be a minimal installation depth or rules for hitting obstructions far above the anticipated depth of installation. A GPS based logging system is in this case of advantage to map the push force profile and overview of the installation depths.

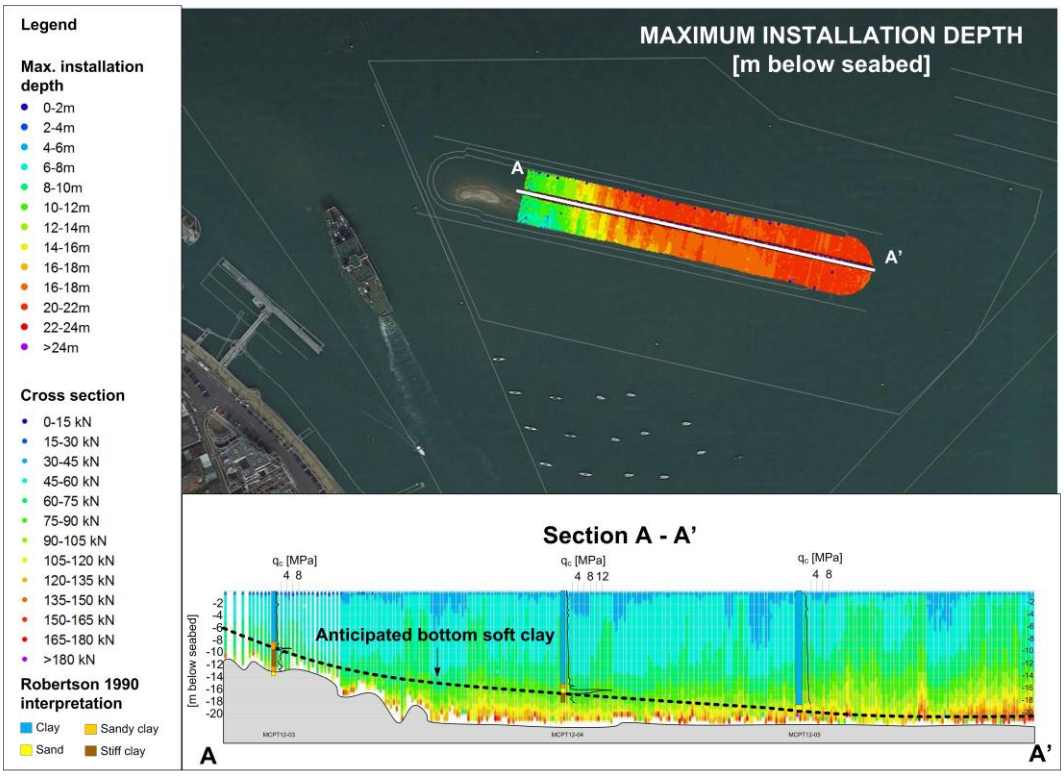

Figure 4. GIS compilation of the logger data showing maximum installation depth and a cross-section through section A-A'

REQUIRED PUSH FORCE

Reclamation

On projects where dense sand layers or man-made soils are encountered, the use of GPS loggers proved to be very useful, especially when refusals are encountered. The locations where refusals were encountered can be predrilled using a GPS based map without any markings on the ground. A project example is given in Figure 5. This project involved the reclamation of a harbor for a tank terminal. On this project several medium strength installation rigs were used to meet the tight time schedule. Only one machine was equipped with GPS and was used to install the drains on the areas where obstructions were expected. Before the reclamation was placed, jetties were present on a part of the area. The piles were removed after the placement of the fill by pulling and vibrating. Due to the vibrations the sand at these old pile locations was densified significantly to such levels that the rigs were not able to push through. The locations of the piles are shown very well in the depth overview of Figure 5 by the blue circles. The old jetties are shown in the inserted picture in the top view. These locations were afterwards predrilled to make the installation of the PVD possible.

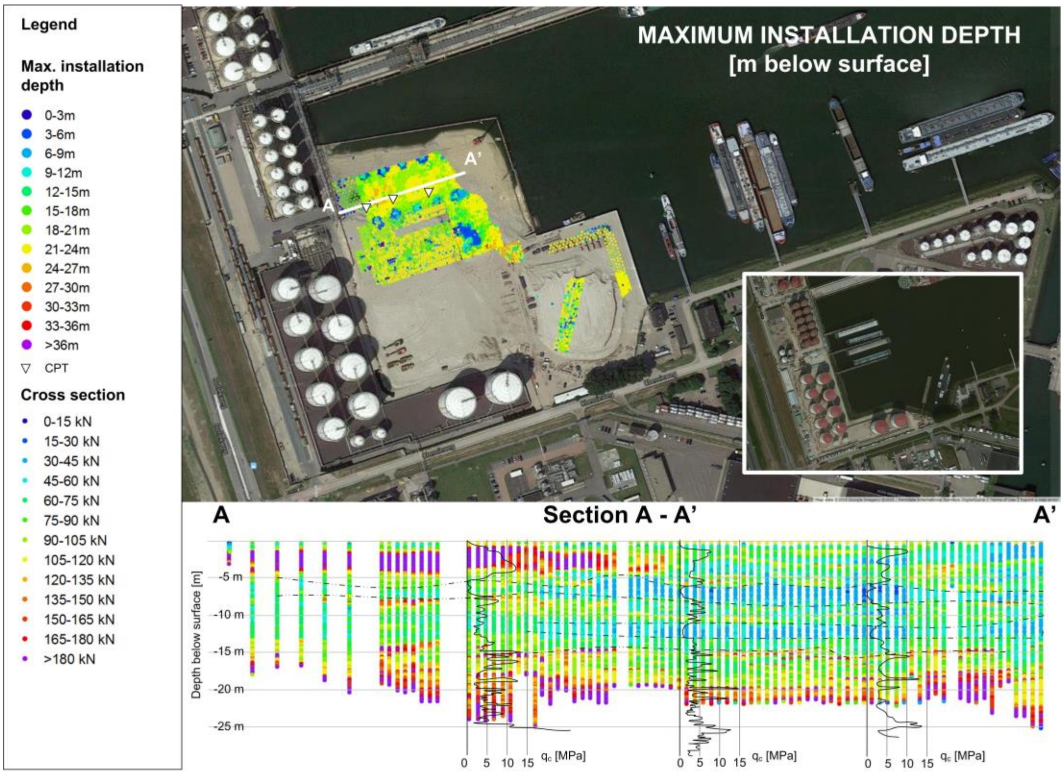

Figure 5. GIS compilation of the logger data showing maximum installation depth and a cross-section through section A-A'

The local soil profile can also be clearly distinguished from the cross section shown in Figure 5. The purple colors indicate dense sand layers with cone resistances of over 10 MPa. The two blue colored section between -5m and -15m indicate soft compressible clay layers. It is also visible that there are more clayey sections present in the tidal deposit starting from -15m below the surface. This example shows the advantage to be able to plot the push force in a cross section. It can be used to map geological features.

Push force map at specific depth

Another possibility that is available from the registered logger data is the plot of the push force at a specific depth. Figure 6 shows the plot of the push force at two meters below the working platform. The purple line in the figure seems to be an in-filled channel with very dense material. After consultation with the project coordinators on site this feature was actually an old haul road present at site before placement of the working platform, see infill in Figure 6. In this case this feature is not of influence to the consolidation process. When, for example, this feature would be sand channel, the map can be used in the design of the surcharge or placement of the monitoring equipment. This can prevent unexpected differential settlements within the project area.

Another feature shown in the map is the installation till a fixed depth of in this case 15m (blue colors in the right bottom map of Figure 6) and the installation till refusal (green-orange colors in the right bottom map in Figure 6). This led to major depth differences in the project with maximum PVD depths up to 50 meters deep.

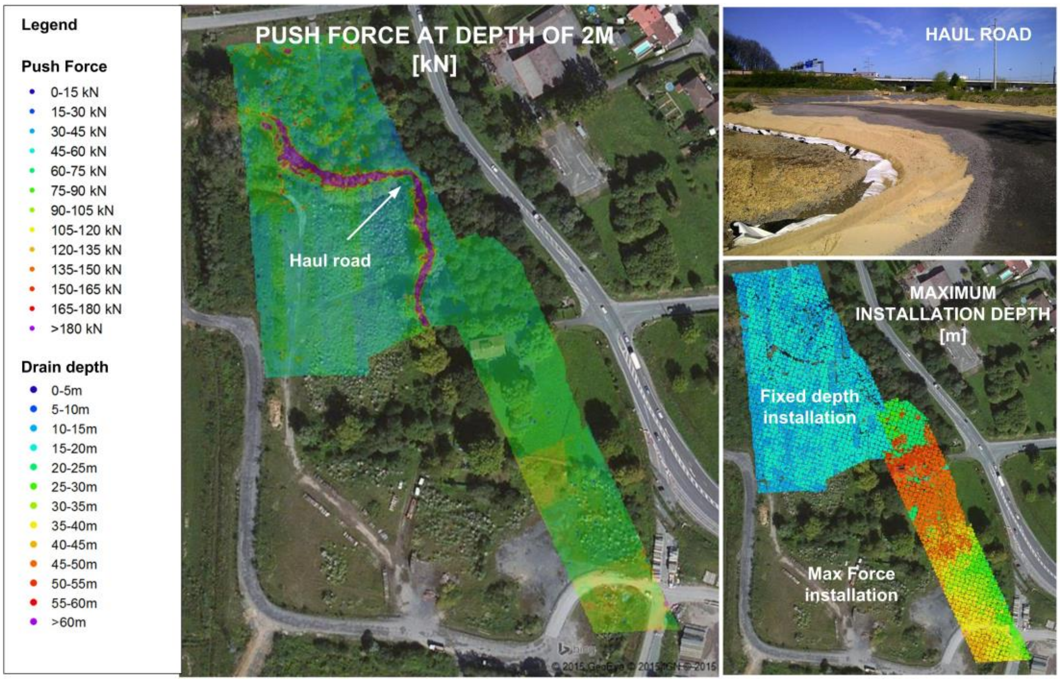

Figure 6. GIS compilation of the logger data showing the push for at 2m installation depth and the maximum installation depth over the project area.

ACCURACY OF INSTALLATION

Figure 7 presents a top view of a road construction project in the Netherlands. The enlargement of the top view clearly shows the high accuracy of the installed locations of the drains. See also Figure 9 for a photo of the PVD that was installed with the use of the GPS without pre markings on the ground. On the road construction project, the GPS positions were used to determine the exact location of the piezometers, ideally positioned at 2/3 of from the distance between the center of the points – within a drain pattern – and the drain to measure an average pore water pressure development, see Figure 8 for a graphical explanation. This gives a better estimation with respect to the conservative value measured in the center between the drains. This makes monitoring more reliable as there is less risk on having a connection between the piezometer and the PVD, influencing the pore water pressure measurements.

Figure 7. GIS overview of PVD installation depth and installation accuracy.

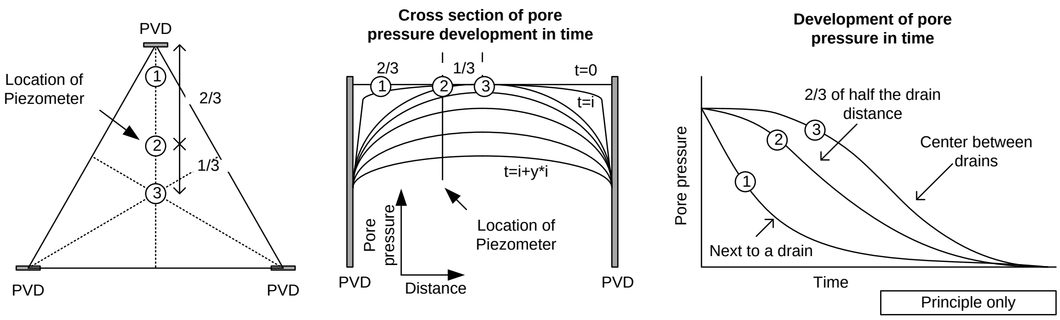

Figure 8. Principle of effect of placement of piezometer

Figure 9. Example of GPS based installation of PVD without the use of pre marking on the ground.

CONCLUSION

The GIS images presented in Figure 3 to Figure 7 show that the use of GPS based logging can provide additional information to the geotechnical engineer and the client, especially when siff clay layers or sand layers are present. With the use of this system, push force profiles can be constructed which can be used to map geological features. It can also be used to generate an overview of the installation depths over the installation area. Both can help during the monitoring phase in the assessment of the lateral variations within the site, placement of the settlement markers, piezometers and ultimately limiting differential settlements by adjusting fill heights. This makes monitoring more specific and reliable.

The GPS based system can be used without pre-marked locations on the platform with a high accuracy as is shown in Figure 7 and 9. With the use of this system impenetrable obstructions can be mapped for further action.