Installation of fully grouted piezometers

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ABSTRACT

In the planning and design phase of the E16 Sandvika – Wøyen road project in Bærum Municipality in Norway, NGI installed a large number of piezometers using the "Fully grouted" installation method. Because of layered soil conditions, with soft clay overlaying very hard moraine, traditional "push in place" installation method was not feasible for a large number of the planned sensors. Instead, a method that could ensure that sensors installed in both the clay and the moraine at the same locations had to be used.

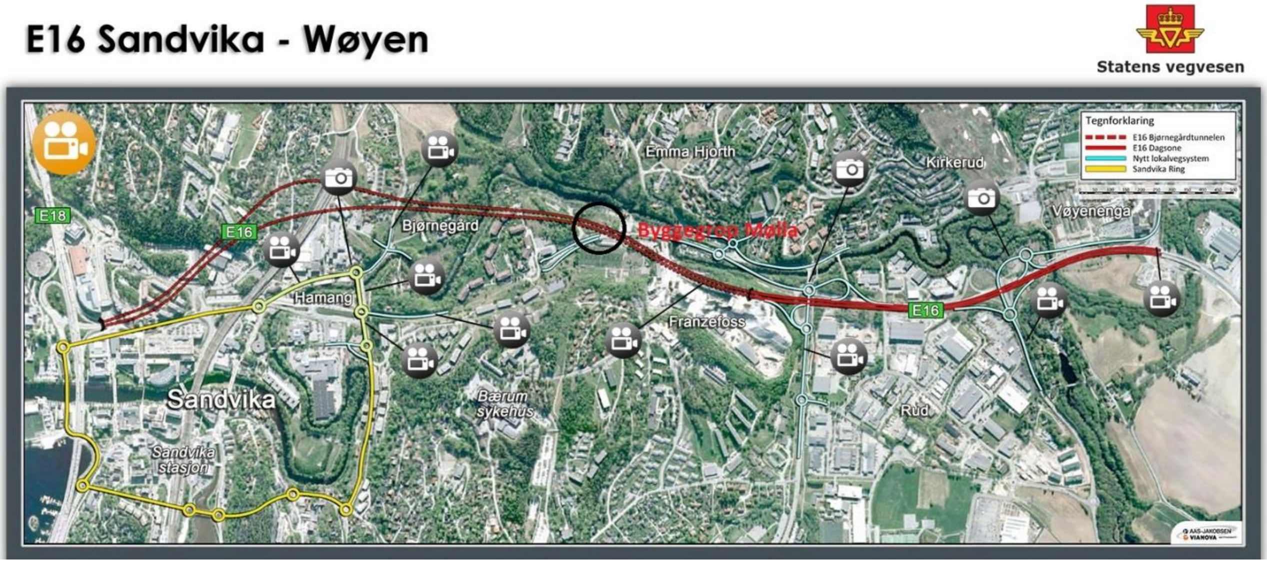
In total, 35 sensors were installed using the grout in place method, and two sensors were installed in the clay as control. The results from a pumping test performed in close proximity to the installed sensors, confirm that the installation method was successful, and that the sensors respond rapidly to changes in the in situ pore pressure.

Keywords: Piezometers, grout, groundwater, pore pressure,

1 INTRODUCTION

The Norwegian Public Road Administration is building a new 4 lane road between Sandvika and Wøyen in Bærum municipality in Norway. Aas Jackobsen AS designs the project with Geovita AS as geotechnical design engineers. NGI have performed geotechnical site investigations in the field and lab based on the specifications made by Geovita AS.

The project consists of several tunnels in rock as well as excavation and cuts in both soil and rock. At several sites in the project sheet pile walls or secant pile walls are planned. Within the project there is a building site named Mølla that is in the focus in this paper. An overview of the project is shown in Figure 1. Building site Mølla is marked by a black circle.

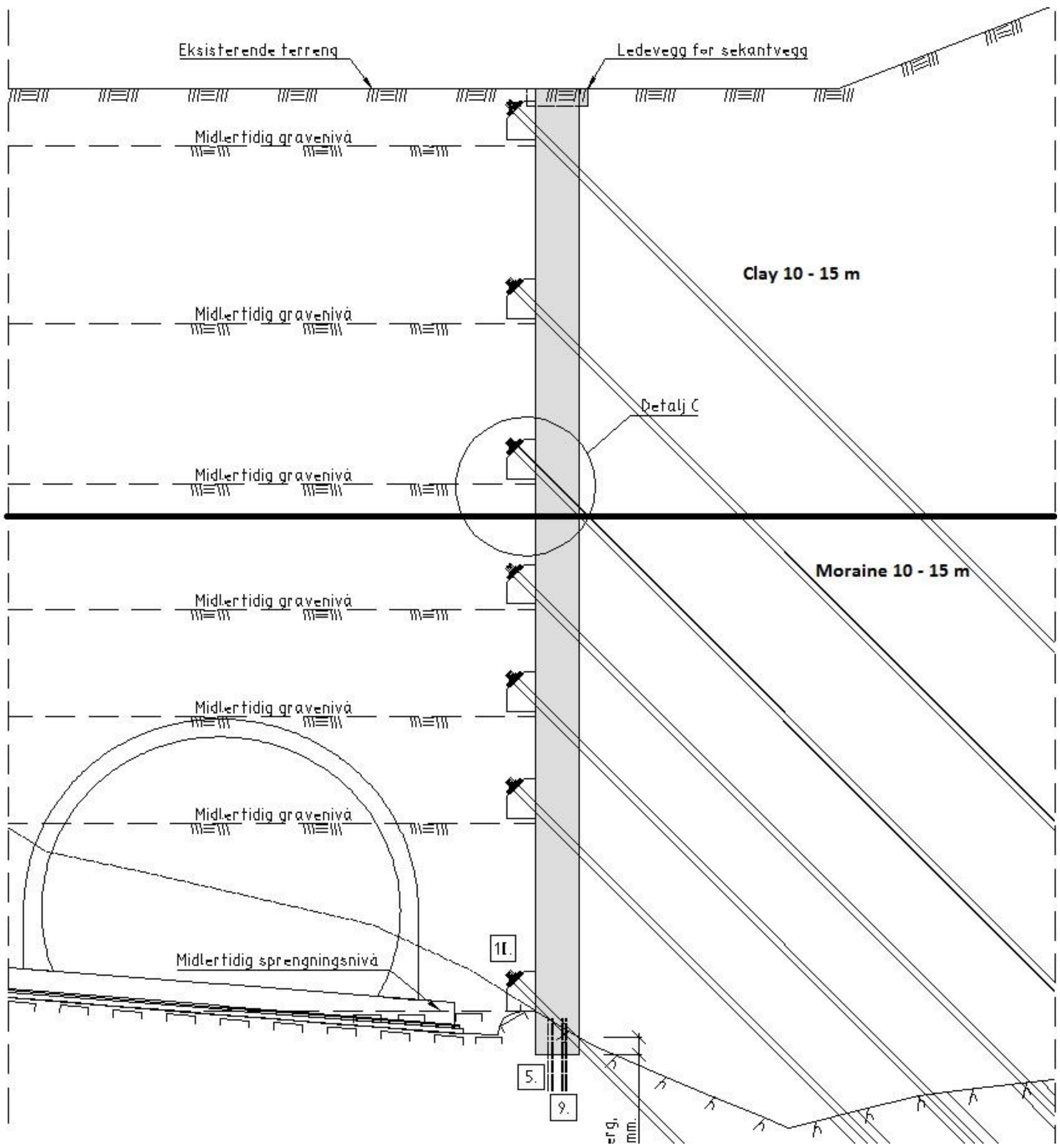


2 GROUND CONDITIONS AND CHALLENGES IN MEASURING PORE PRESSURE

At the planned site at "Mølla", a one sided construction pit is under construction. A cross section of the planned secant pile wall is shown in Figure 2. The wall is up to 25 m high at the highest point and 125 m long. The wall is retained with 5 – 7 levels of tieback rods, depending on the height of the wall. Figure 2 show a cross section through the planned secant pile wall, and the planned tunnel at the bottom.

The ground conditions consist of 10 – 15 m of soft clay on top of 10 – 15 m of very hard moraine. The thick black line in Figure 2 show the transition between clay and moraine. This level is varying in the whole area, as does the depth to bedrock. There are two separate ground water tables at the site, one in the clay and one in the lower, and more permeable moraine. The pore pressures in the moraine was known, from previously installed hydraulic piezometers, to vary with precipitation.

The design of the wall required that the pore pressures in both layers to be measured in real time, and that sensors in the moraine had rapid response to changes in the pore pressure in the surrounding soil. This was because lowering of the pore pressures in the moraine through pumping during the construction phase, would be desirable for the design of the wall.



To make sure that lowering of the pore pressure in the moraine was possible, a pumping test was performed. This pumping test had to be monitored in several locations and with several sensors in each location, to make sure that the pore pressures was lowered sufficiently during the pumping, and that the response in the pore pressure in both soil layers was as expected.

To accomplish this, a monitoring programme was designed by Geovita AS, for installation by NGI. If the program was successful, the same set of sensors was to be used to monitor the construction phase. The monitoring program consisted of a total of 35 sensors in 6 different locations. Each location had a sensor every 5 m depth, regardless of whether the type of soil was soft clay or hard moraine.

3 FULLY GROUTED PIEZOMETERS

It was decided to use the "Fully grouted" piezometer installation method, proposed by Mikkelsen & Green, 2003, to install the piezometers at Mølla, as this made it possible to install sensors in the same borehole, regardless of the soil type at the sensor location. The method uses a cement/bentonite/water grout, This grout is pumped into the annum between the sensors and the soil around the borehole, to fully enclose the sensors.

Some other options for the installation was considered:

1. Installing the piezometers in clay with the normal push in place method normally used in soft soil in Norway.
2. Installing the sensors in the moraine by predrilling with a drill bit, and hoping that the borehole in the moraine wouldn't collapse. This would require one borehole for each sensor in the moraine.
3. Drilling casings down in the moraine, and placing sandfilters around each sensor and bentonite seals to isolate the sensor levels in the traditional way to install piezometers in hard soils.

Figure 3 show the difference between installation of fully grouted and traditional piezometers.

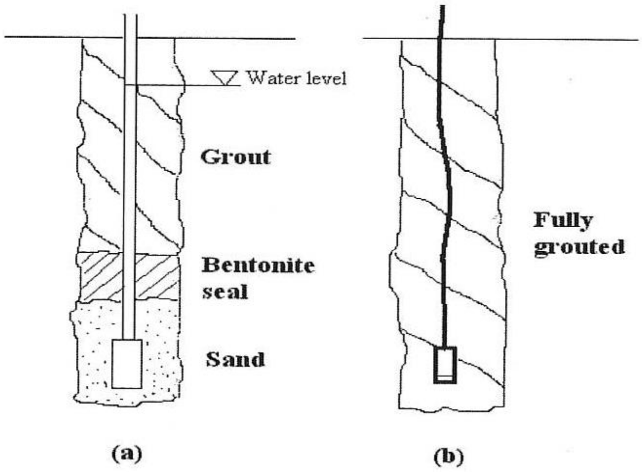


Figure 3: Traditionally piezometer and fully grouted piezometer, Mikkelsen & Green 2003

Installation of the sensors in the clay would not be an issue, but option 2 and 3 had large contained risks of vertical leakage between sensor levels and also contained a larger amount of work and number of drilled boreholes in the very hard moraine. This made the "Fully grouted" method seem attractive, as only one borehole was necessary at each sensor location, and all the sensors in the single borehole would be installed simultaneously.

As described in Mikkelsen & Green, 2003; as long as the piezometer used is of the electrical diaphragm type, the permeability of the grout can be low and the response to changes in the in situ pore pressure will still be within minutes. Figure 4 show the relationship between permeability and response time, for different type of piezometers, after Terzaghi & Peck, 1968.

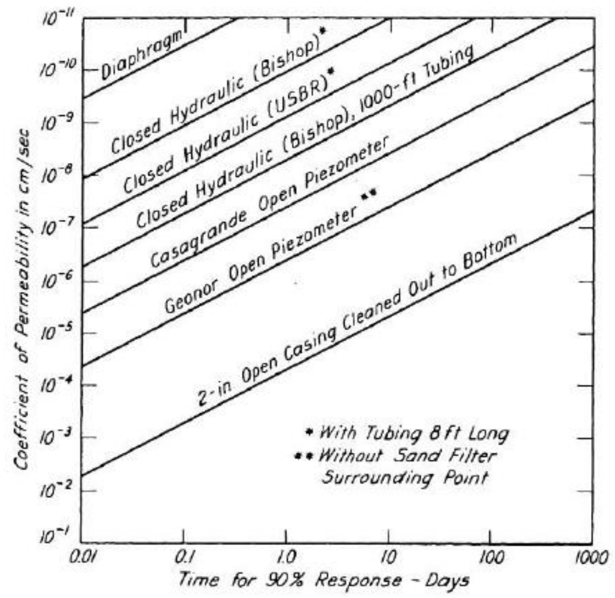


Figure 4: Response time for different piezometers

4 ADVANTAGES WITH THE FULLY GROUTED METHOD

The fully grouted method has several advantages compared to the traditional method with a filter and bentonite seal:

- The grouting can be completed quickly, as it just requires a tremie pipe into the borehole to pump in the grout.
- Several sensors can easily be installed at different depths in the same borehole.
- The filter and bentonite seals can be skipped, and this leads to lower probability of hydraulic leaks due to errors during the installation of the sand filter and bentonite seal.
- The strength/stiffness of the grout can be adjusted to mimic that of the soil at the site.
- Other measuring systems, like inclinometers, can easily be installed in the same borehole since the grout is in contact with the surrounding soil in the borehole.

As long as the soil is too hard in order to use the push in place method, the best way to install piezometers will probably be with the fully grouted method, as there is not a lot of disadvantages, as long as the correct equipment is avaliable.

5 DETAILED DESCRIPTION OF THE INSTALLATION METHOD AT E16 MØLLA

At Mølla the following steps was executed to install the sensors.

1. A cased borehole was drilled down to 50 cm below the level of the deepest sensor using ODEX drilling system. The inner diameter of the casing was either 76 mm or 92 mm.
2. The bottom of the borehole was cleaned thoroughly through water flushing.
3. The drill string and drill bit was retrieved from the casing.
4. The casing was kept full of water after retrieving the drill string to make sure that the sensors were fully saturated when installed.
5. The sensors were attached to the outside of a steel tremie pipe that was lowered down into the casing. A sensor was attached every 5 m depth, with plastic strips, the wires to the sensors was fastened every meter. Figure 5 show the sensors fastened to a central pipe.
6. During the lowering of the tremie pipe with the sensors attached, the sensors were checked continuously, to verify that the sensors were working.
7. When the tremie pipe was installed, the grout was mixed according to the ratios listed in Table 1, and pumped down to the bottom of the borehole. As the grout is heavier than water, the water in the borehole is displaced out of the top of the borehole.
8. When the borehole was completely filled with grout, the casing was pulled out of the borehole. Grout was added to the borehole to replace the volume of the casing being pulled out, to keep the borehole full of grout.
9. The real time monitoring system, developed at NGI, was installed and data was transmitted through the mobile phone network. An general description of the system shown in figure 6.

Table 1: Mixing ratios for the grout used at E16 Mølla.

Material	Ratio	Ratio by weight
Cement	1	9
Bentonite	0,1	1
Water	2,1	18,9

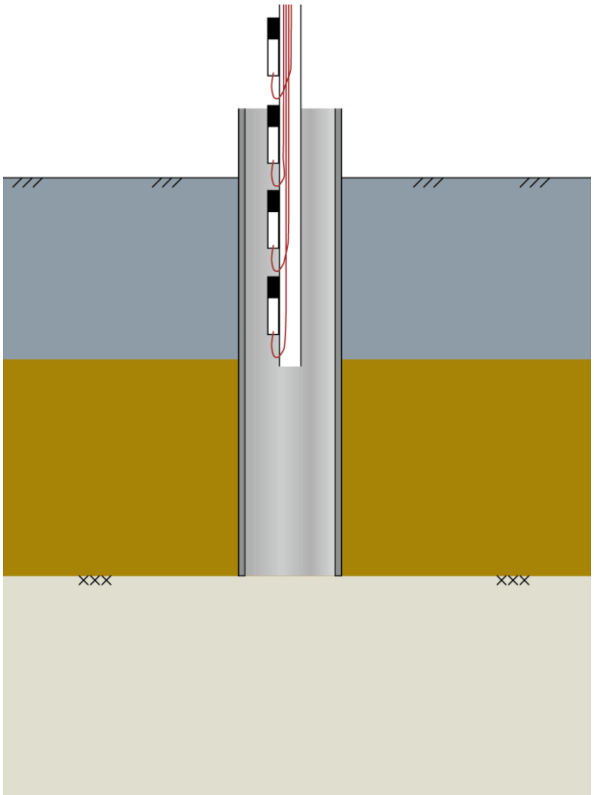


Figure 5: Sketch of cased borehole, with a pipe and several sensors under installation.

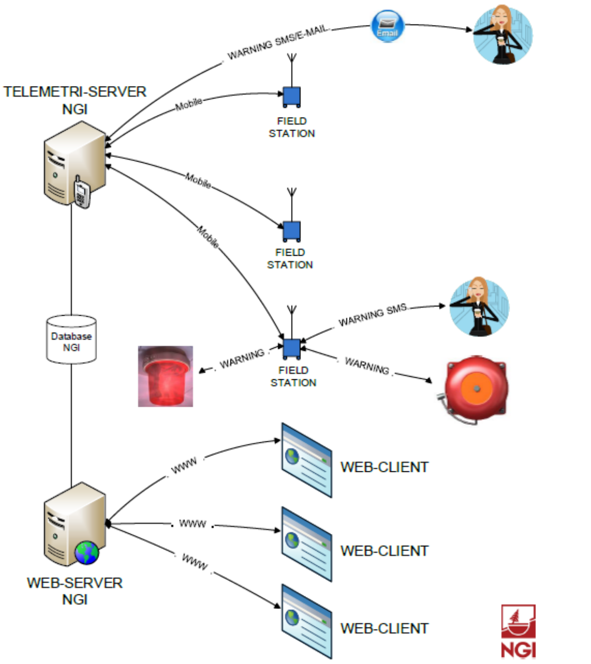


Figure 6: NGI's remote monitoring system.

6 CHALLENGES DURING THE INSTALLATION

Installation at the site was carried out by using 2 geotechnical Geomachine 100 drill rigs to install the casings. Two types of drilling systems were used, Atlas Copco Odex 76 mm, and Atlas Copco Odex 90 mm. The size of the drilling systems was chosen to make sure that the horizontal distance from the sensor out to the in situ soil was as small as possible. With these systems, the distance from the filter of the sensor to the in situ soil would nominally be 38 and 45 mm. The drill rigs were selected based on availability.

There was challenges with the drilling of the consuming a lot of time with both drilling systems when drilling in the hard moraine at the site. It was known that the moraine at the site was hard, but it was harder than expected, and in combination with the geotechnical drill rigs top hammer drives the penetration rate was not satisfactory. In retrospect, to use well drilling rigs, with down the hole hammers would probably have been more efficient, but this would probably have required an increase in the casing size to 4 1/2 ". The use of a symmetrical drilling system, with a ring bit and pilot bit, could probably have improved the penetration rate when drilling.

7 PUMPING TESTS AND RESPONSE TO THE CHANGE IN PORE PRESSURE

To verify that the pore pressure in the moraine could be lowered, two pumping wells were installed close to three of the installed sets of piezometers.

Two casings, diameter 219 mm, were drilled down to bedrock. A slotted filter with a diameter of 114 mm and 0,3 mm large slots was installed in the moraine. The length of the filter was 15 m. Through the clay layer on top, an unslotted pipe was used.

Filter sand was backfilled around the slotted filter in the borehole and the casings were pulled up to the transition between the clay and the moraine.

A pump was installed at the bottom of each filter, and water was pumped out of the borehole at a rate of around 0,8 m^3/hour in one well, and 1,6 m^3/hour in the other. The pumps were kept running over a period of four days, and the pore pressures in all the sensors were continuously monitored in this period.

Figure 7 show the monitored pore pressures in monitoring location ST_312, where four sensors where installed in the moraine (Pink, light green, purple and blue lines), and one sensor (dark green) was installed in the clay.

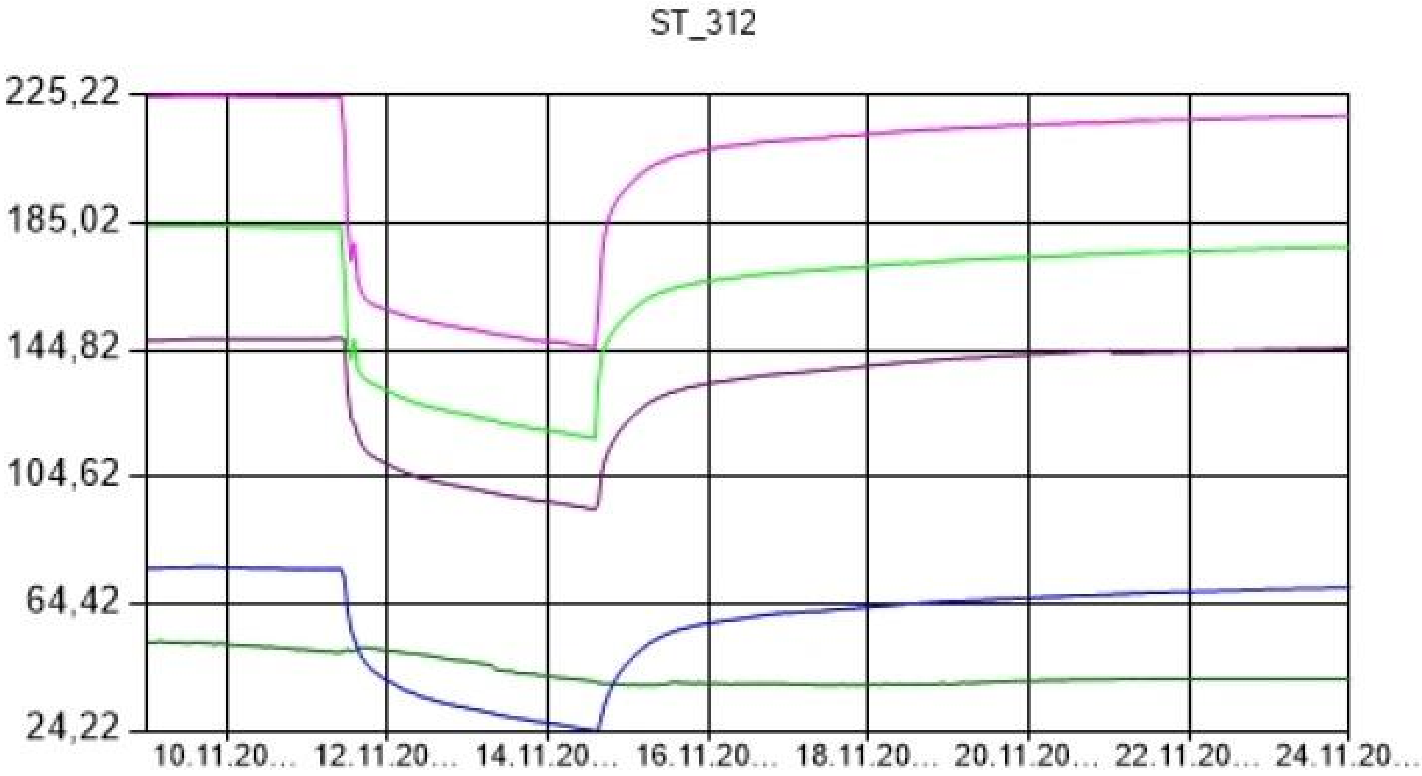


Figure 1: Logged pore pressures vs time in borehole ST_312 during the pumping test.

The logging show an immediate response to the pumping in the permeable moraine layer where the water was pumped out. One can also see that after the pumps are turned off, the pore pressure rapidly increases. The sensor installed in the clay have almost no response – and the pore pressure is actually increasing in the beginning of the pumping test – indicating that the grout has worked as a hydraulic seal between the sensors.

8 CONCLUSION

Even though the drilling of the casings proved to be time consuming in the hard moraine at Mølla, the installation of the sensors with the tremie pipe and the following grouting was a lot faster than installing several levels of sand/gravel filters, bentonite seals and grout in the same borehole.

The results show that the grout in place piezometeres worked as intended and the measured pore pressures are as expected. The response during the pumping test show that the grout has a permeability that lets the sensors measure rapid changes in pore pressure, and that there is no leakage between sensor levels.

The author would recommend the fully grouted piezometer method in all applications where electric piezometers needs to be installed in hard soil that requires drilling a borehole with casing.

9 ACKNOWLEDGEMENTS

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Geovitas AS, especially geotechnical engineer Amund Auglands, contribution, through both design of the testing programme and the idea to use the fully grouted method is greatly appreciated. Without them, the method would probably not have been proposed at all.

10 REFERENCES

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