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ON-SITE VERIFICATION OF REAL-TIME CHECKING SYSTEM FOR IMPROVED RANGE BY HIGH-PRESSURE INJECTING GROUND IMPROVEMENT

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ABSTRACT: In contrast to the mechanical stirring method in which the ground soil and the modifying material are mixed and stirred by stirring blades and the improved body is formed in the ground, the high pressure injection stirring method is a method in which the improved diameter is changed due to soil condition and so on. There is a possibility that it can be changed with, and a method for easily confirming the shape, particularly the improved diameter, is highly desired. In this research, the authors propose and propose a method that can make "visualization" of this improvement situation and confirm the improved diameter in real time. Confirmation was made by measuring water quality in multiple items. From the results, it was confirmed that pH and the values of the other 5 items changed at the same time. And the change was due to the arrival of the cement slurry. Therefore, it can be said that real-time measurement is possible by visualization of improved diameter by water quality measurement conducted this time.

Keywords: Ground improvement work, High pressure injection, pH, Real-time checking system

1. INTRODUCTION

Currently as a measure against the Nankai Trough Earthquake, strengthening breakwaters is urgent in Japan. The main way of present reinforcement work is to strengthen the ground by making columns with cement. It is an invisible part that a soil-cement column is made, so it is important to check if the soil-cement column is made as planned. Particularly, in contrast to the mechanical stirring method, the high-pressure injection stirring method has a possibility that the improved diameter may change depending on the soil conditions and the like, therefore, a method of easily confirming the diameter is desired [1], [2]. In this research, the authors propose a method to confirm the improvement of the diameter in real time by "visualizing" this situation.

Experiments to confirm the state of improvement construction were carried out at the site where ground improvement is carried out. In this research, the authors focused on improved bodies with double pipe type high pressure injection stirring method. The high-pressure injection stirring method is a ground improvement method in which earth and cutting agent are mixed and stirred by cutting the ground by spraying hardening material and air horizontally from an injection nozzle attached to the tip of the injection rod [3], [4]. Normally, the injection rod is rotated and pulled up by several centimeters at regular time intervals to form a columnar improvement body. Although it is possible to make an improved body with a diameter of 2 to 5 m with a small boring, it is very important to confirm that the diameter of the improved body is made according to the plan as it depends on injection specifications and ground strength.

As an earthquake countermeasure, in addition to reinforcement of the tide bank, reinforcement of the pile foundation can also be mentioned [5]. However, because the reinforcement of pile foundations is in the ground and restrictions on sites and restrictions on heads, reinforcement methods are currently limited. One of the pile foundation reinforcement work performed under such conditions is Confining Pile Reinforcement Method. This method is a construction method that constructs a pile foundation structure resistant to earthquakes by improving the ground near the middle in the depth direction of the pile using cementitious materials. An improved body of the Confining Pile Reinforcement Method is also produced by the high-pressure injection agitation method, but there is a sound confirmation method as a method for confirming this form. The method is a method in which a guide pipe is installed at a planned position to be the outer peripheral portion of the improved body, a microphone underwater is inserted into the guiding tube, and the arrival of the solidified material is judged by the observed sound [3], [4].

However, in this study, the authors focused on confirming the arrival of cement directly, so the authors selected water quality measurement. Measurement was also conducted based on pH, which is strongly related to cement even among water quality.

2. OVERVIEW OF THE REAL-TIME CHECKING SYSTEM

2.1 Instruments

Water quality measurements were conducted twice on the site near a certain river in Osaka Prefecture using the portable multi-item water quality meter WQC-24 shown Fig. 1. This is an instrument that can measure multiple items simultaneously [6].

Figures 2 and 3 show the boring data of water quality measurement points.

The authors used following instruments for the real-time checking system.

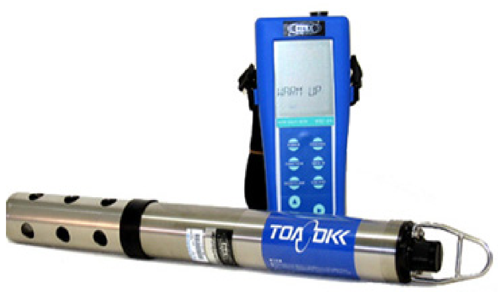


Fig. 1 Portable multi-item water quality meter WQC-24

(i) Sensor module (WMS-24-1)
(ii) Terminal (WQC-24-1)
(iii) Computer
(iv) Vinyl chloride tubes

2.2 Methods

The design of the improved body has a length L = 8.4 m and a diameter φ 3500 mm. First, the authors placed three vinyl chloride tubes of different lengths in advance as shown in Fig. 4 at a point 1750 mm away from the center of the improved body. In the vinyl chloride pipe, 17 holes with a diameter of 10 mm were installed between the length of 5 cm from the bottom, and the strainer portion was provided so that the cement slurry could enter. The measurement items were pH, dissolved oxygen, electrical conductivity, turbidity, salinity, and water temperature.

In the first measurement, measurements were made by placing three water quality meters throughout three vinyl chloride tubes. In the second measurement, one water quality meter was moved to another vinyl chloride pipe in accordance with the arrival of the injection, and measurement was carried out while using it.

The installation depth of the water quality meter for both the first and second times was set to three places: GL -9.0 m, GL -6.0 m, and GL -3.0 m. The notation was 1-CH, 2-CH, 3-CH in order from the deepest point. The groundwater level exists near 3-CH.

Fig. 2 The boring data (the first point of measurement)

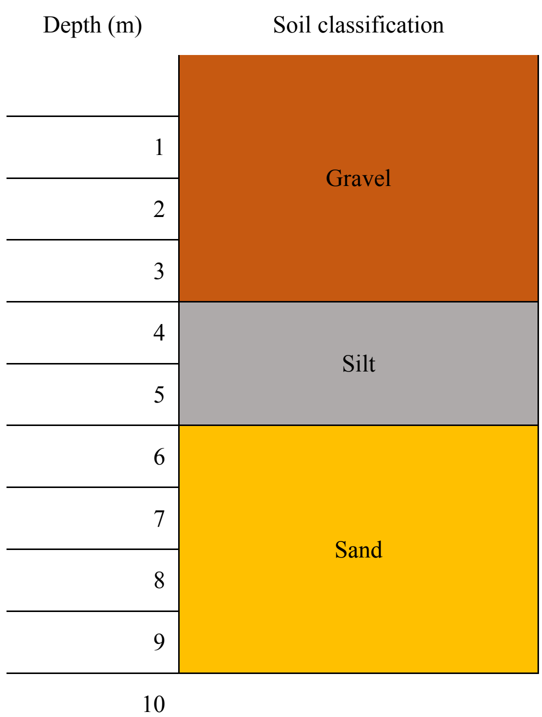
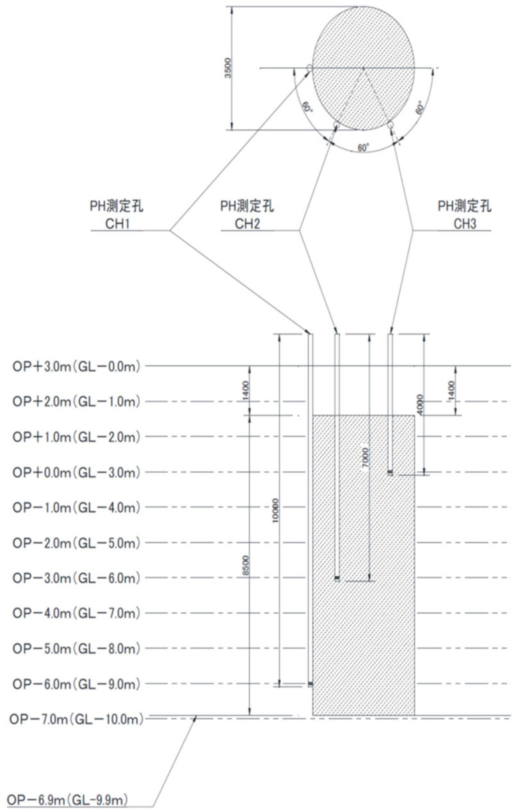


Fig. 3 The boring data (the Second point of measurement)



(OP: Osaka bay lowest sea level)

Fig.4 Arrangement of measuring instrument

3. ON-SITE VERIFICATION OF THE REAL-TIME CHECKING SYSTEM

3.1 The Measurement Results

The first measurement was pH only, the second measurement was six items of pH, dissolved oxygen, electrical conductivity, turbidity, temperature, and salinity, and a graph was prepared based on the pH measurement value. As expected results, it is difficult to predict dissolved oxygen, but for other five items the pH rises due to cement influence, electric conductivity is difficult to convey electricity by cement slurry mixing due to the properties of cement. As the cement slurry arrives, the turbidity rises rapidly, the temperature rises due to the hydration reaction between cement and water, and the salinity is almost sea water, so if the cement slurry mixes there, the proportion of salt decreases.

The results of the first water quality measurement are shown in Fig. 5. At 1-CH, no rise in pH was detected after the cement reached the measurement point. However, in 2-CH and 3-CH, increase in pH could be confirmed immediately after reaching the measurement point. 2-CH rose to about 11.3 to 13.4, and 3-CH rose to about 10.1 to 12.3.

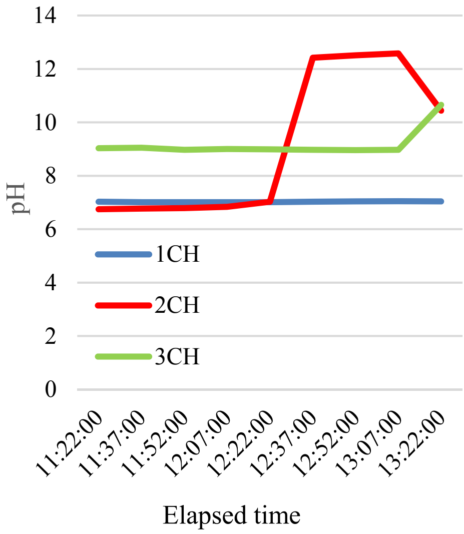


Fig. 5 The results of the first water quality measurement (pH only)

The results of the second water quality measurement are shown in Figs. 6, 7, 8, 9 and 10. First, when the change in pH is examined, the pH rises by about 3.0 immediately after the injection arrives in 1-CH. However, in 2-CH and 3-CH, only a small amount of increase in pH immediately after injection was confirmed. Examining the other items, the dissolved oxygen decreased in 1-CH, the electric conductivity decreased, the turbidity increased to the upper limit, the temperature increased and the salinity decreased. In 2-CH and 3-CH, because the rise in pH was small, other values were small changes accordingly.

3.2 Discussions on the Measurement Results

3.2.1 The reason why the pH of 1-CH did not change during the first measurement

In 1-CH, no rise in pH was detected after reaching the measurement location (see Fig. 5). The following can be considered as the cause.

(1) The solidified material injected at the time of making an existing refinement nearby reached the vicinity of the vinyl chloride tube following the underground water line and closed the tip of the pipe.

(2) The soil that remained in the ground when we dug a hole to stand vinyl chloride tubes closed the tip of the pipe.

3.2.2 The reason why the pH of 3-CH was high from the beginning

For Fig. 5, it is thought that the cause of the pH of 3-CH being high from the beginning is the gravel layer and the influence of the already improved ambient groundwater.

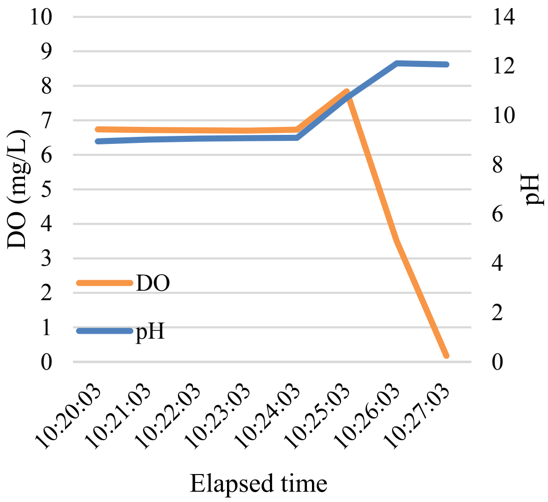


Fig. 6 The results of the second water quality measurement (pH and dissolved oxygen)

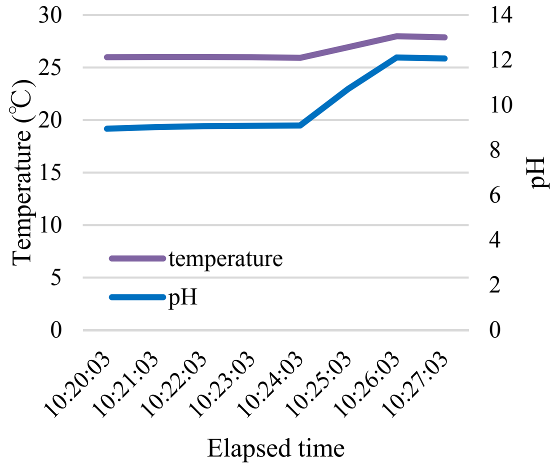


Fig. 8 The results of the second water quality measurement (pH and temperature)

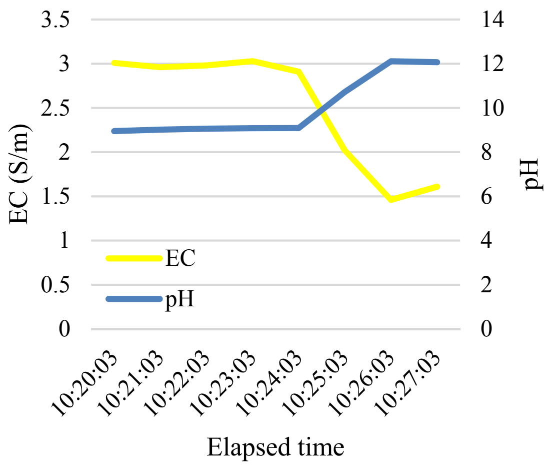


Fig. 7 The results of the second water quality measurement (pH and electrical conductivity)

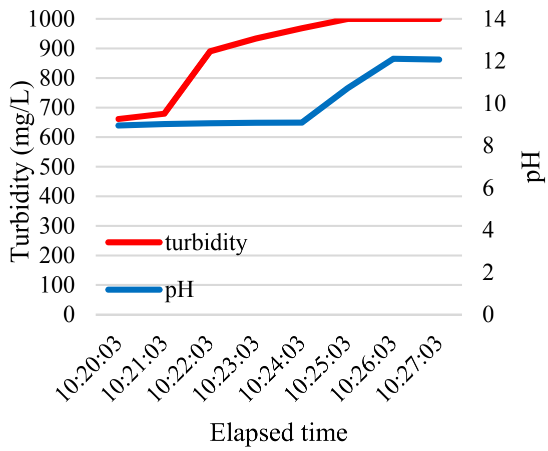


Fig. 9 The results of the second water quality measurement (pH and turbidity)

3.2.3 Summary of the results in the first measurement

No increase in pH could be confirmed with 1-CH. However, in 2-CH and 3-CH, an increase in pH could be confirmed. And in 2-CH and 3-CH, after vinyl chloride tubes was pulled out and the tip part was observed, it was confirmed by eyes that cement slurry adhered to vinyl chloride tube and high-pressure jet reached. Also, although we checked the diameter by excavating the upper part of the improvement body, we could also confirm that even here it was made almost as planned. From this, it can be said that visualization of improved diameters by pH measurement and real-time confirmation are possible because increase of pH due to arrival of cement slurry can be

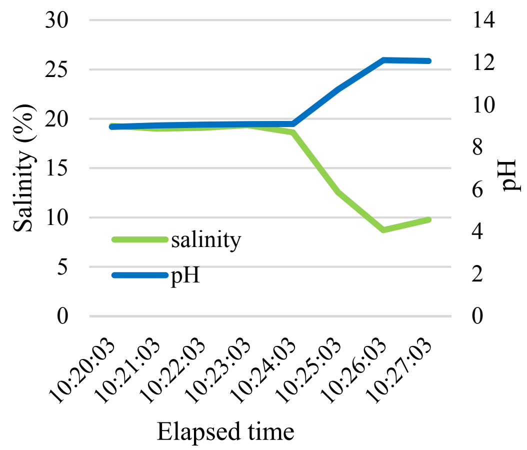


Fig. 10 The results of the second water quality measurement (pH and salinity)

confirmed in the first measurement.

3.2.4 The reason why the pH increasing of 2-CH and 3-CH is less than that of 1-CH in the second measurement

As shown in Figs. 6, 7, 8, 9 and 10, the pH rose by about 3.0 immediately after reaching the cement slurry in 1-CH. However, in 2-CH and 3-CH, only a small amount of pH increases of about 0.5 to 1.0 could be confirmed immediately after reaching the cement slurry (these results in 2-CH and 3-CH are not shown in in Figs. 6, 7, 8, 9 and 10). The reasons why the amount of increase in pH immediately after arrival of cement slurry at 2-CH and 3-CH was small may be as follows. Unlike 1-CH where the pH rose sharply immediately after reaching the cement slurry, both 2-CH and 3-CH had already started to raise the pH before cement slurry reached. As a result, the pH increases in 2-CH and 3-CH became gentler than the change in 1-CH, so the change immediately after arrival of the cement slurry became small. As a fundamental problem, it seems that the reason why the pH rise started before 2-CH and 3-CH before reaching is because a trace amount of cement slurry began to enter the vinyl chloride tube before reaching the cement slurry. This tendency is particularly strong in 3-CH because the increase in pH was more gradual than 2-CH. However, as mentioned in the measurement method, because the authors used only one water quality meter in the second measurement, it was not clear when cement slurry started entering. But This problem is thought to be avoidable by preparing the water quality meters for the number of tubes and always checking all the CHs at the same time, as in the case of the first measurement, instead of using one water quality meter at a time.

3.2.5 Items examined by the second measurement

Because the measurement results of 2-CH and 3-CH showed almost no change as described above, mainly the change of each item in 1-CH will be considered here.

Dissolved oxygen (DO) decreased significantly in 1-CH as shown in the Fig. 6. However, in 2-CH, the opposite result was obtained that the pH rises at a slightly rising timing. Because it is difficult to think that the value will drop to 0 as with 1-CH, dissolved oxygen (DO) is not able to say useful only with this measurement result alone.

On the other hand, electric conductivity (EC) and temperature can be confirmed to change according to the properties of cement (see Figs. 7 and 8), so it is useful as a confirmation item for visualization of improved diameter.

As turbidity was also confirmed to increase due to arrival of cement slurry and earth and sand (see Fig. 9), turbidity is also considered to be useful as a confirmation item for visualization of improved diameter.

Also, as in this case, when salinity is contained in groundwater, salinity is a useful confirmation item for visualizing the improved diameter (see Fig. 10).

3.2.6 Summary of the results in the second measurement

Although only few results were obtained in the second measurement, useful data could also be reliably obtained. From the results of this research, it is considered that particularly useful items are pH, electric conductivity and temperature. Because these are indices directly related to cement. Other items are not able to say useful because there are not enough samples or the available conditions are limited.

4. CONCLUSIONS

In this research, the relationship with the improvement situation was verified by measuring the water quality of six items of pH, dissolved oxygen, turbidity, electric conductivity, temperature and salinity by using the Portable multi-item water quality meter. From the two measurement results, it was confirmed that the timing at which pH and the values of the other 5 items changed, and that the change was due to the arrival of the cement slurry. Therefore, it can be said that real-time measurement is possible by visualization of improved diameter by water quality measurement conducted this time.

In this water quality measurement, visualization and real-time measurement are possible, but there is a possibility of measurement failure such as clogging of the detection tube in 1-CH of the first measurement. Therefore, the authors need to pursue measurement methods that can compensate for the above weaknesses in the future.

In this research, the authors focused on preparing an improved body by double pipe type high pressure injection stirring method, but this is not the only way to improve ground. Therefore, in the future, it is necessary to pursue measurement method that can be used not only for the double pipe type high pressure injection stirring method but also for confirming the situation of various soil improvement. In addition to being able to use it not only in various sites but also it must be made cheaply and easily.

5. REFERENCES

[1] Shen S.L., Wang Z.F. and Ho C.E., Generalized Approach for Prediction of Jet Grout Column Diameter, Journal of Geotechnical and Geoenvironmental

Engineering, Vol.139, Issue 12, 2013, pp.2060-2069.
[2] Eskişara T., Otania J. and Hironaka J, Visualization of soil arching on reinforced embankment with rigid pile foundation using X-ray CT, Geotextiles and Geomembranes, Vol.32, 2012, pp.44-54.
[3] Lunardi P., Ground improvement by means of jet-grouting, Ground Improvement, Vol.1, 1997, pp.65-85.
[4] Tomlinson M. and Woodward J., Pile Design and Construction Practice (Sixth Edition), CRC Press, 2014.
[5] Prakash S. and Sharma H.D., Pile Foundations in Engineering Practice, John Wiley & Sons, 1990.
[6] Rex Co., Ltd., Portable Multi-item Water Quality Meter (WQC-24), http: //www.rex-rental.jp/sui/wqc-24.html., 2016.