Introduction of Video-CIM System to Pile Driving Construction at the Extremely Weak Ground

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ABSTRACT

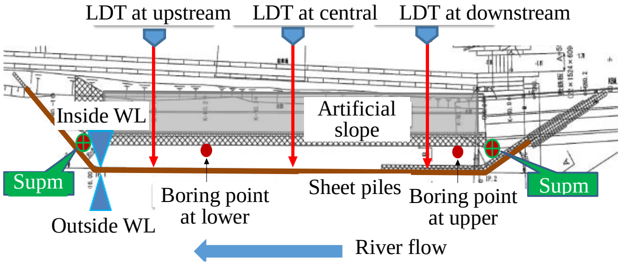
This report summarizes the results of the ICT construction executed at Daitourou area of the Shonai river located in Aichi Prefecture. Although self-standing type of steel sheet piles were penetrated into the ground of water side with the Silent Piler Method for building a cofferdam, a collapse of the penetrated piles was apprehensive because of the extremely weak soil of the river side and the fluctuation of water level due to the change of tide. In the project, the video CIM (Construction Information Management) system was implemented besides an automated measurement system of pile displacement to monitor both the progress of construction and the movement of piles. The possibility of implementing the visual information system in the pile driving construction was discussed with the results of both monitoring systems.

Key words: *ICT construction， self-standing type of steel sheet pile, Video CIM management, monitoring*

1. Introduction

Coastal revetment works for river improvement were executed at Daitourou area of the Shonai river located in Aichi Prefecture in 2017. **Fig. 1** and **2** respectively show the plane and the side view of the site. Although self -standing type of steel sheet piles were penetrated into the ground of water side with the Silent Piler Method for building a cofferdam, a collapse of the penetrated piles was apprehensive because of the extremely weak soil of the river side and the difference of water level between inside and outside of the sheet piles due to the change of tide.

In the project, the Video CIM (Suda et al., 2015; Kani et al., 2018) system was implemented besides an automated measurement system of pile displacement to monitor both the progress of construction and the movement of piles. **Fig. 3** shows an example of the video image obtained through a full circumference type camera. The possibility of implementing the visual information system in the pile driving construction was discussed with the results of both monitoring systems.



LDT : Laser Displacement Transducer, WL : Water Level

Fig. 1 Plane figure of the site

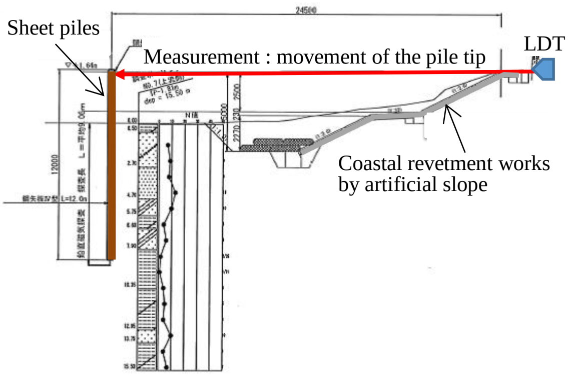


Fig. 2 A side view of the site

Fig. 3 View of the site through a full circumference type camera

2. Pile driving method and ground conditions

The Silent Piler Method was employed for driving steel type sheet piles into the ground at the side of the river. **Fig. 4** shows the process of the piling method. A steel pile was penetrated with a jacking machine getting the reaction force from the piles penetrated at the former process.

Fig. 5 shows a borehole log and the properties of the (1) Hanging work of a pile ground measured at the site. The ground was composed of alternation strata of weak clay and sandy soil. **Fig. 6** shows the record of the jacking force obtained when a pile was driven into the ground. It can be grasped that the weak area is distributed from the shallow part to the deeper part at the upstream area of the river.

3. ICT construction

3.1. Monitoring of pile behavior by transducers

A collapse of the piles was apprehensive because of the extremely weak soil of the river side, as mentioned in the previous section, and the difference of water level due to the change of tide. Thus, the behavior of piles and tide were monitored in the site. **Table 1** shows the monitoring items employed in the construction site.

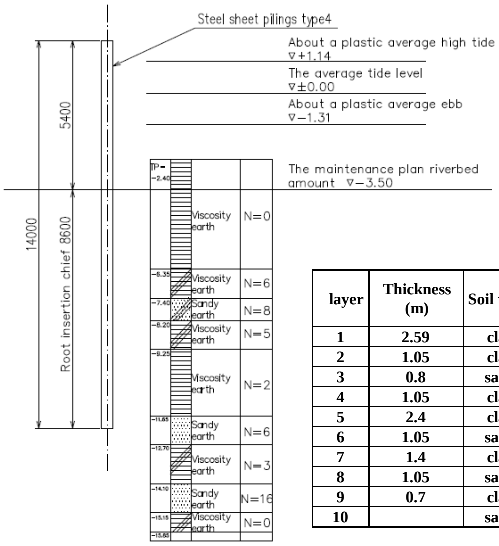
(1) Hanging work of a pile

(2) Setting of a pile

(3) Jacking operation

(4) Silent Piler machine

Fig. 4 Pile driving method by Silent Piler Method (GIKEN LTD, 2018)



layer	Thickness (m)	Soil type	N value
1	2.59	clay	0
2	1.05	clay	6
3	0.8	sand	8
4	1.05	clay	5
5	2.4	clay	2
6	1.05	sand	6
7	1.4	clay	3
8	1.05	sand	16
9	0.7	clay	0
10		sand	5

Fig. 5 Borehole log and properties of the ground

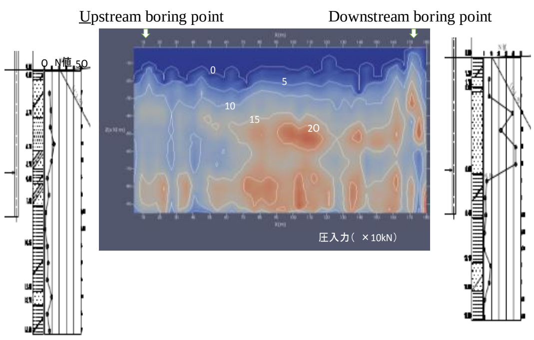


Fig. 6 Record of the jacking force

Table 1. Monitoring items

Measurement item	Measurement location
Horizontal displacement	Tip of steel sheet pile at 3 points (Upstream, Central, Downstream)
Strain of pile	One vertical siding
Strain of connecting rod	One horizontal siding
Water level	Inside and outside of temporary cofferdam at two points

The stability control of the steel sheet piles was mainly carried out by displacement measurement at the tip of a steel sheet pile. The vertical strain of a pile (longitudinal direction) was measured to grasp its deformation mode and the strain of a connecting rod which connected the neighboring piles with each other was also measured to check the connecting effect of the rod members.

The allowable horizontal displacement at the tip of piles was set to be not more than 120mm that was defined by 3% of the pile length following the art of design for river structure to keep the piles stable (Chubu Regional Development Bureau, MLIT:, 2016)

The water level was measured with the water pressure transducer both inside and outside of the sheet piles. The displacement of the pile tip was measured with an automatic measurement system by a laser type displacement transducer (see **Fig. 7**) for 24 hours. The laser displacement transducer was set at the shore side and the displacement of the pile was measured by the change of the distance between the transducer and the pile tip, as shown in **Fig. 1** and **2**. While the measurement data of the displacement of the pile tips were checked all the time during construction, as shown in **Fig. 8**, the alarm system was equipped to warn when the displacement exceeded the allowable displacement of 120mm. The data could be monitored and analyzed on the monitor page of the PC, not only at the site office but also at other offices by a remote monitoring system.

100mm Model: DT 500 - A 511
Measurement range: 0.2 to 70 m
Output: 4 to 20 mA
Measurement accuracy: ± 3 mm
Spot diameter (70 ｍ) 100 mm

Fig. 7 Laser type displacement transducer

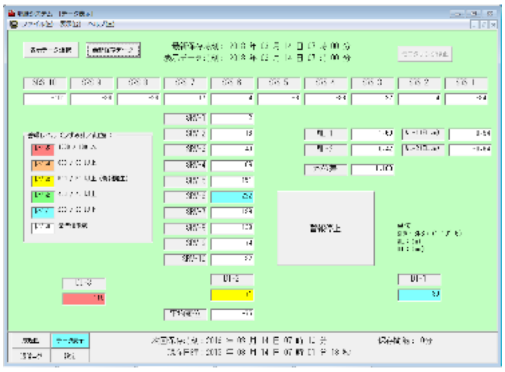


Fig. 8 Monitoring page on the PC

3.2. Monitoring of pile behavior by video system

Generally speaking, the video data has a possibility to draw out various information not only qualitative information concerning physical phenomena but also their quantitative data such as displacement, deformation, vibration or so on. A network camera system was tentatively introduced in the site for grasping the site conditions and monitoring the behavior of the piles, as shown in **Fig. 9**. The video image taken with the camera was shared among the engineers not only at the site office but also at other offices out of the site on the PC or the mobile phone through the telephone communication system. **Fig. 10** shows the video image monitored on the PC monitors of the head office. When the alarm system explained in **3.1.** section caught some irregular phenomena, the site conditions were immediately checked through the video image of past hours to grasp the reason of the alarm and some countermeasures were speedily taken not to lead to a serious trouble or accident.

Fig. 9 Video image of the construction site

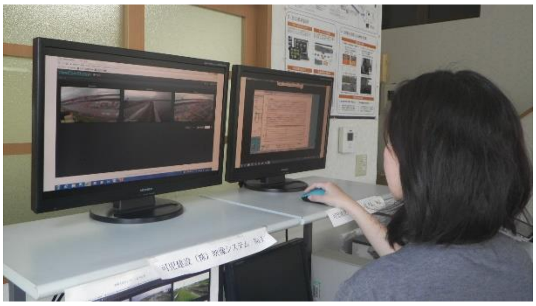


Fig. 10 PC monitor of the head office

4. Construction management

4.1. Fluctuation of water level

Fig. 11 shows the data of water level during the construction period. While the water level periodically fluctuated at outside of the sheet piles, being linked with the fluctuation of tide in the river, it kept almost constant at inside of the sheet piles due to the pomp up drainage for coastal revetment works after the middle of February.

Thus, the difference of the water level between inside and outside of the sheet piles also fluctuated periodically by 1 m around the average water level of 2 m. The difference of water level induced the difference of water pressure between inside and outside of the sheet piles and it acted on the sheet piles to possibly induce the displacement and deformation of the sheet piles.

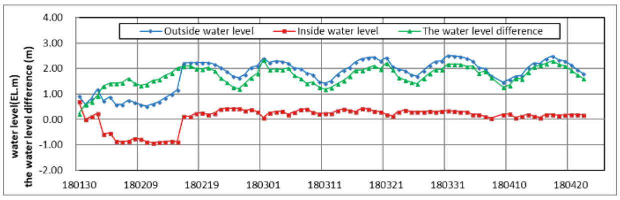


Fig. 11 Water level at inside and outside of the piles

4.2. Displacement at the tip of sheet piles

Fig. 12 shows the displacement of the tip of sheet piles measured at 3 points (upstream, central and downstream area) in the case where the maximum difference of the water level between inside and outside of the sheet piles (WL difference: maximum) was observed each day. **Fig. 13** also shows that in the case where the minimum difference (WL difference: minimum) was observed. It can be seen from these figures that the larger displacement was observed at the upstream area than the downstream area due to the extremely weak ground condition of the upstream area, as mentioned in the previous section. It is also made clear that the daily maximum displacement periodically fluctuated, being linked with the periodical fluctuation of the tide, while the daily minimum displacement showed comparatively small fluctuation. Therefore, the difference between the daily maximum displacement and the daily minimum one was thought to be induced by the periodical fluctuation of the tide.

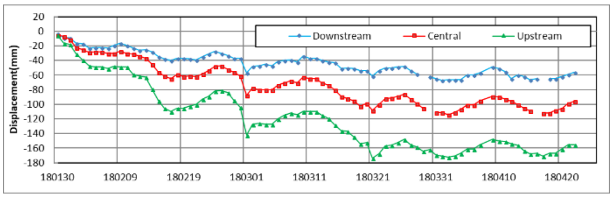


Fig. 12 Pile tip displacement (WL difference: maximum)

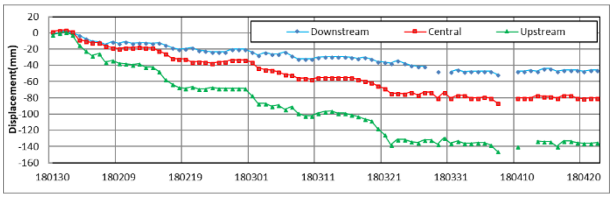
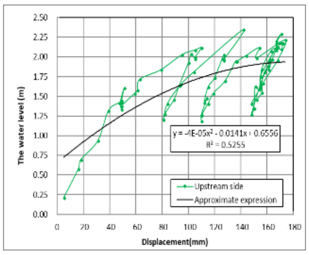


Fig. 13 Pile tip displacement (WL difference: minimum)

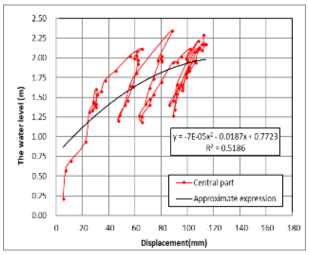
The pile tip displacement that exceeded the allowable horizontal displacement of 120 mm was observed at the upstream area of the river even in the case of the minimum water level displacement. It is thought to be induced by the soil condition weaker than that expected from the borehole investigation. The sheet piles had to be penetrated into the ground to a larger penetration depth than the design determined from the result of the borehole investigation. The construction was forced to be managed more carefully not to induce more displacement of sheet piles.

4.3. Deformation characteristics of the sheet piles

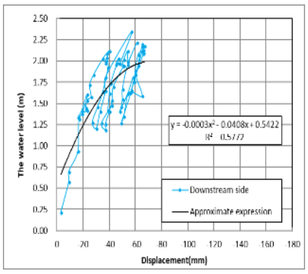
Fig. 14 shows the relation of the water level difference between inside and outside of the sheet piles to the displacement of the sheet pile tip. It is clearly observed that the pile tip displacement showed the typical behavior observed in the repetative process of loading and unloding, being linked with the fluctuation of the water level difference. It is also found that the plastic displacememnt obviously increased with the repetative loading process at the upstream area of the river, while the pile tip displacement showed the comparatively elastic behavior at the downstream area of the river. It can be said with assurance that the ground became gradually weak from the downstream to the upstream and the plastic difference was induced beyond the design condition at the upstream area of the river.



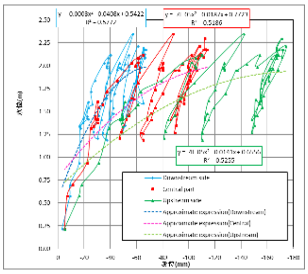
(1) Upstream



(2) Central stream



(3) Downstream



(4) All of three points

Fig. 14 Relationship between water level displacement and pile tip displacement

Fig. 15 Additional measure to prevent the sheet pile deformation with sandbags

Fig. 16 Drainage pomp to lower the water level inside the sheet piles

4.4. Utilization of Video image

The video image obtained by the camera was used for grasping the situation of the construction site, especially at the time when the larger displacement of the pile tip than the allowable displacement was measured by the displacement transducer. It was a quite effective system because the situation of the site could be grasped by engineers in charge of the project even if they were not in the site. They could give accurate directions for countermeasures against any undesirable situations. For instance, the situation of the sheet piles and the neighboring area in the site was checked with the video image shown on the monitor properly and some additional counter measures to prevent progress of the pile deformation by holding the piles with sandbags, or by removing the drainage pomp to reduce the effect of water level lowering on the piles, etc. **Fig. 15** shows an example of the holding works with sand bags. **Fig. 16** shows the drainage pomp moved from the closed area of the piles. Such rapid measures prevented a serious accident from happening in the site under the critical situation

Although the video image was effectively used in the meaning of the construction management, being combined with the digital monitoring system of transducers, it was not used for quantitative measurement of the movement in the site. The video image has a possibility to grasp various kinds of quantitative movement in the site such as the displacement of pile tip, etc. We analyzed the video image of the site with the image processing method and tried to extract the quantitative data of the displacement and inclination of the sheet pile or the deformation of the artificial slope. However, we have not yet succeeded in taking some accurate data from the video image. We are going to continue to build a method to collect the quantitative data from the video image data.

5. Conclusion

The ICT construction was executed at coastal revetment works for river improvement of the Shonai river located in Aichi Prefecture. A collapse of the sheet piles penetrated into the ground of water side for building a cofferdam was apprehensive because of the extremely weak soil of the river side and the fluctuation of water level due to the change of tide. The fluctuation of the water level of the river and the movement of the piles were monitored with the digital transducers. The measurement was made it clear that the water level difference between inside and outside of the sheet piles induced the difference of water pressure acting on the piles and that the displacement of the sheet piles fluctuated, being linked with it. Especially the ground around the sheet piles behaved in the plastic zone at the upstream area and the piles might fall into a dangerous situation of collapse, so some careful and precise management was required to prevent any accident in the site.

The video image of the site was also filmed by video cameras to grasp the situation of the construction. The video image has an advantage to be able to extract various information without any specific transducers. The rapid and accurate measures were done through comprehensive management system of the digital transducers and video image to prevent any serious accidents such as a collapse of the piles under a critical situation. Unfortunately, we have not yet succeeded in obtaining some quantitative data such as a behavior of the piles by analyzing the video image, we are going to continue to build a method to collect the quantitative data from the video image data.

The combination of the digital measurement with some transducers and the video image has a possibility to make more precise and accurate management of the construction site than just by digital measurement because additional information can be obtained depending on the situation of the construction site. This system is quite effective especially for comparatively small size of construction projects where the site had to be managed with a few engineers who manage other job sites at the same time. The research for extracting some quantitative information from the video image is expected to expand the usefulness of this method widely.

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