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Construction of anchor piles for mooring bank by Skip Lock Method

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ABSTRACT: In the Shizuoka Prefectural Port Project, a wharf was necessary to be improved as a cargo passengers quay which can cope with simultaneous port calls with 2 large ships of 150 thousand GT class and cargo ships of 30 thousand DWT class. For this improvement, a retaining wall of steel tubular piles with anchors was adopted under following site conditions: 1) Noise and vibration should be minimized for the existing buildings. 2) The working space was limited. 3) The piles were required to be installed into stiff ground though a rubble mound. In order to overcome these conditions, the "Gyropress Method" in which a steel tubular pile with cutting ring bits is rotated to penetrate underground obstruction/stiff ground, and the "Skip Lock Method" which can install piles with intervals were selected. This paper introduces a case study of installing steel tubular piles as anchor piles for rehabilitated wharf.

1 GENERAL INSTRUCTIONS

1.1 *Place*

Shimizu Port's Hinode Wharf (hereinafter, Shimizu Port) is a port located in Shimizu Ward, Shizuoka City, capital city of Shizuoka Prefecture. This port is planned to be used as an international logistics base for export-oriented companies such as automobiles, motorcycles and musical instruments, as well as for advanced technology companies such as semiconductors. It has also been attracting attention as a port inviting international cruise ships, triggered by the World Cultural Heritage Registration of Mt. Fuji. (Figure 1).

On the wharf, there are existing buildings and a quay wall (Figure 2), and a construction method was required not to impact them during the construction.

1.2 *Background and objectives of the project*

The Shimizu Port is divided into the north and south sides (Figure 3). The north quay, both a 30,000 DWT class cargo ships and a 150,000 GT large international passenger ship can berth together. On the other hand, the south quay was not possible to call 2 large passenger ships and cargo ships at the port. In recent years, the number of calls by international passenger ships has been increasing, and further increases are expected in the future. In order to improve the shipping acceptance and deterioration of mooring bank, -this construction order has been placed.

2 STRUCTURAL TYPE AND PILLING METHOD

2.1 *Site condition*

Since the available space on the existing wharf is limited (see Figure 4 and 5), it was necessary to save space and to shorten the construction time as much as possible in order not to disturb other loading and unloading works. In addition, the construction method was required not to loose the existing ground close to the buildings and quay. Furthermore, it was a condition that steel tubular piles could be installed even if the spacing of the piles was not constant.

2.2 *Ground condition*

Figure 6 shows the seabed of the location of steel tubular piles. The layer from the seabed to a depth of 9.0m is consisting of approximately 400mm wide diameter rubbles, as shown in the photograph.

From around 9.0m to 18.5m in depth, a silt layer with the SPT *N* value of about 4 and a gravel layer thereafter (max. SPT *N*-value is 47) were confirmed from the borehole log (Figure 7).

It was required that the use of Gyro Piler which enables steel tubular pile to penetrate into hard ground by rotary cutting press-in, because it is difficult to carry out the pile installation by other methods such as the press-in piling with water jetting or the vibratory hammer method.

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Figure 1. Shimizu Port Hinode Wharf (Map: https;// google.co.jp/maps).

Figure 2. Existing buildings and a quay.

Figure 3. Call port status before the construction Hinode Wharf (Map: https;//google.co.jp/maps).

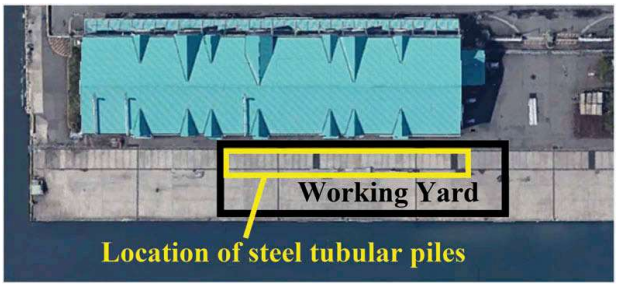

Figure 4. Call port status before the construction Hinode Wharf, (Map: https;//google.co.jp/maps).

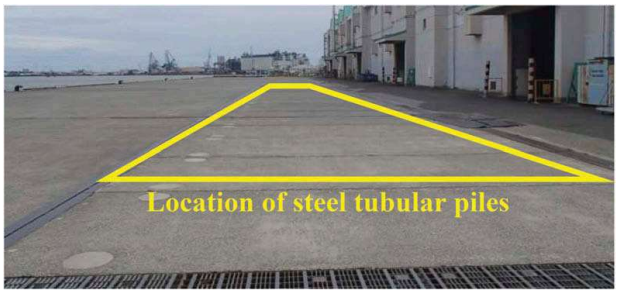

Figure 5. Working Yard before removal of pavement for the installation.

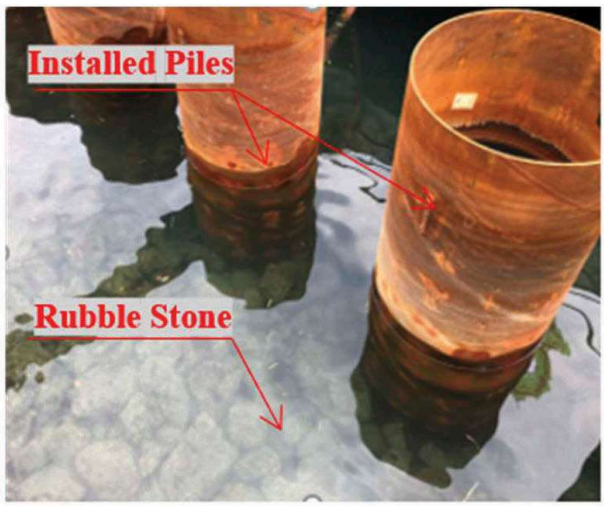

Figure 6. Rubble stones on seabed and installed piles by Gyro Piler in this project.

2.3 *Structural type*

The mooring quay constructed in this project consists of an interlocking tubular pile wall of 1000mm in diameter and 25.0 to 28.0m in length, and steel tubular piles of 1200mm in diameter and 21.5 to 23.5m in length, which were cast into fillers (sand, stone).

2.4 *Piling selection*

As the rubble mound does not exist on the sea side, the steel tubular piles with interlocks were planned to be installed by the vibro hammer method using water jets. On the other hand, the anchor piles through the rubble mound were planned to be installed by the Gyropress Method. The Gyro Piler is a piling machine which can install a steel tubular pile with cutting ring bits into the ground through underground obstruction (*i.e.* reinforced concrete) by static load while rotating, without noise and vibration (Figure 9). The pile installation by the Gyro Piler that can realize all of "pile installation to rubble mound", "piling work in narrow space", "Noise and vibration-free piling method" and "pile installation

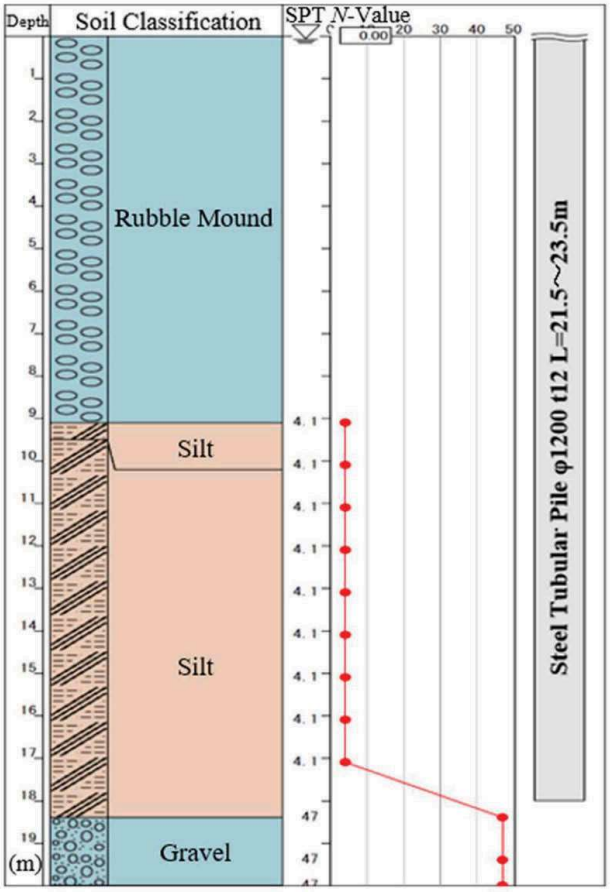

Figure 7. Borehole log.

in a short period", which are problems in this field, were adopted. The internal drilling method was also considered when selecting the piling method, but it was not adopted due to the impact on the existing buildings and quay wall, and the heavy machine size.

2.5 *Skip Lock Method*

The steel tubular piles as anchor piles should be installed with 3,000mm intervals from center to center, which cannot be applied for the standard Gyro Piler. Therefore, the Gyro Piler with the Skip Lock Method was adopted. Before the development of the Skip Lock Method, the Gyro Piler had difficulty installing steel tubular piles with over 250mm intervals. Therefore, dummy piles between permanent piles were essential for self-walking on the installed tubular piles, however, extracting the installed dummy piles was a problem of this method. The Skip Lock Method was developed to solve this problem.

There are two ways to perform this method: a method of using a Gyro Piler together with a set of Skip Lock attachments, and a method using a "modified Gyro Piler for Skip Lock Method" (refer to Figure 10). When a set of Skip Lock attachments is used, the interval between the pile centers is unchangeable [Pile diameter (mm) × 2.5]. Since it was necessary to handle 2,176mm and 2,496mm

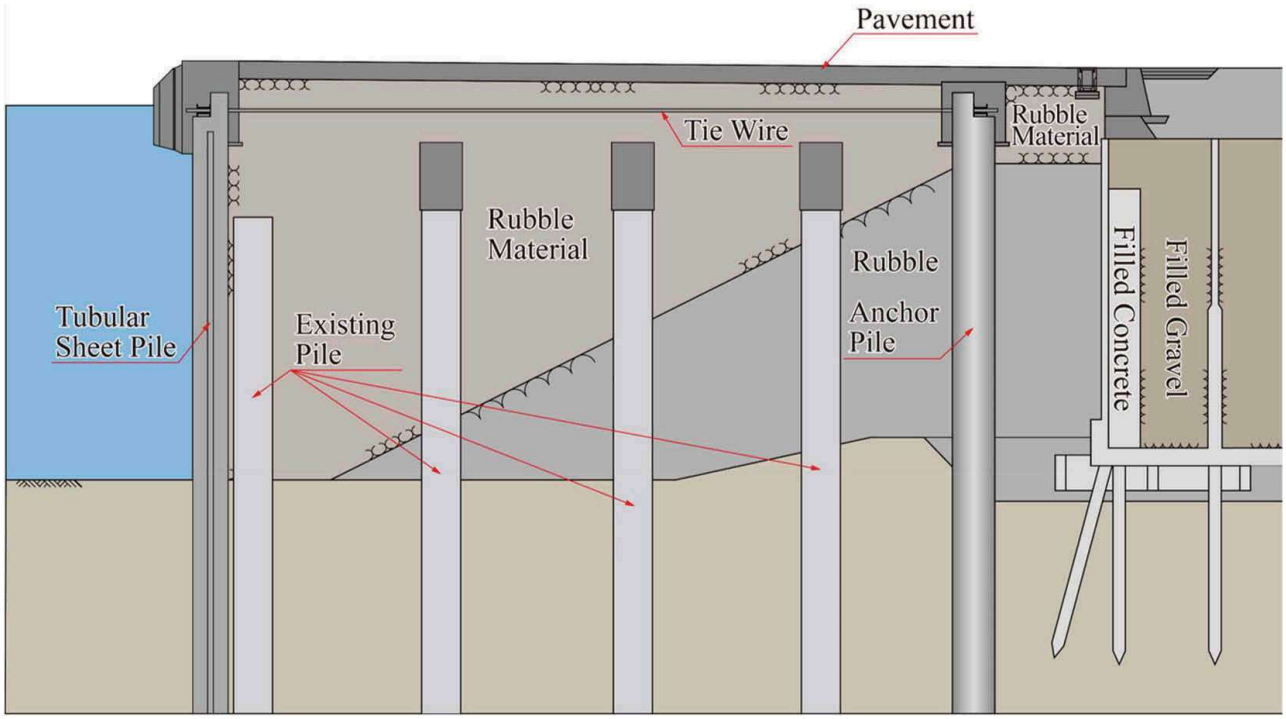

Figure 8. Cross section of mooring bank.

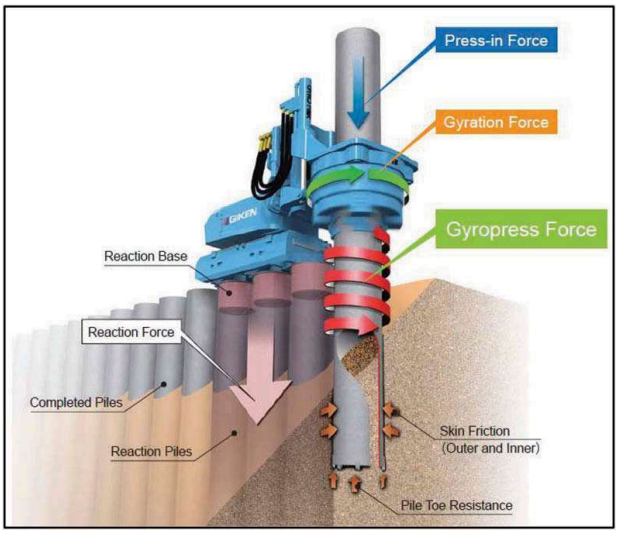

Figure 9. Gyropress method.

intervals between the two pile centers in this site, "modified Gyro Piler for Skip Lock method" was used.

Figure 11 shows the procedure of tubular pile installation.

3 PRESS IN PILING

3.1 *Machine layout*

A service crane works alongside the specified pile line for unloading steel tubular piles from lorries and pitching a pile into the Gyro Piler. For improving the workability and productivity, all piles were placed at the liftable location by the crane before the press-in operation. (Figure 12).

3.2 *Cross section*

Since only one crawler was available for the Gyro Piler in the yard (the Gyro Piler is on the installed piles), the pile installation did not disturb any accesses of lorries for other works (Figure 13).

3.3 *Productivity*

The steel tubular piles were installed by the Gyro-press Method in two sections: the first section took five months from December 2019 to May 2020 including the winter and spring holidays, and the second one is expected to take two and half months from September to December 2020.

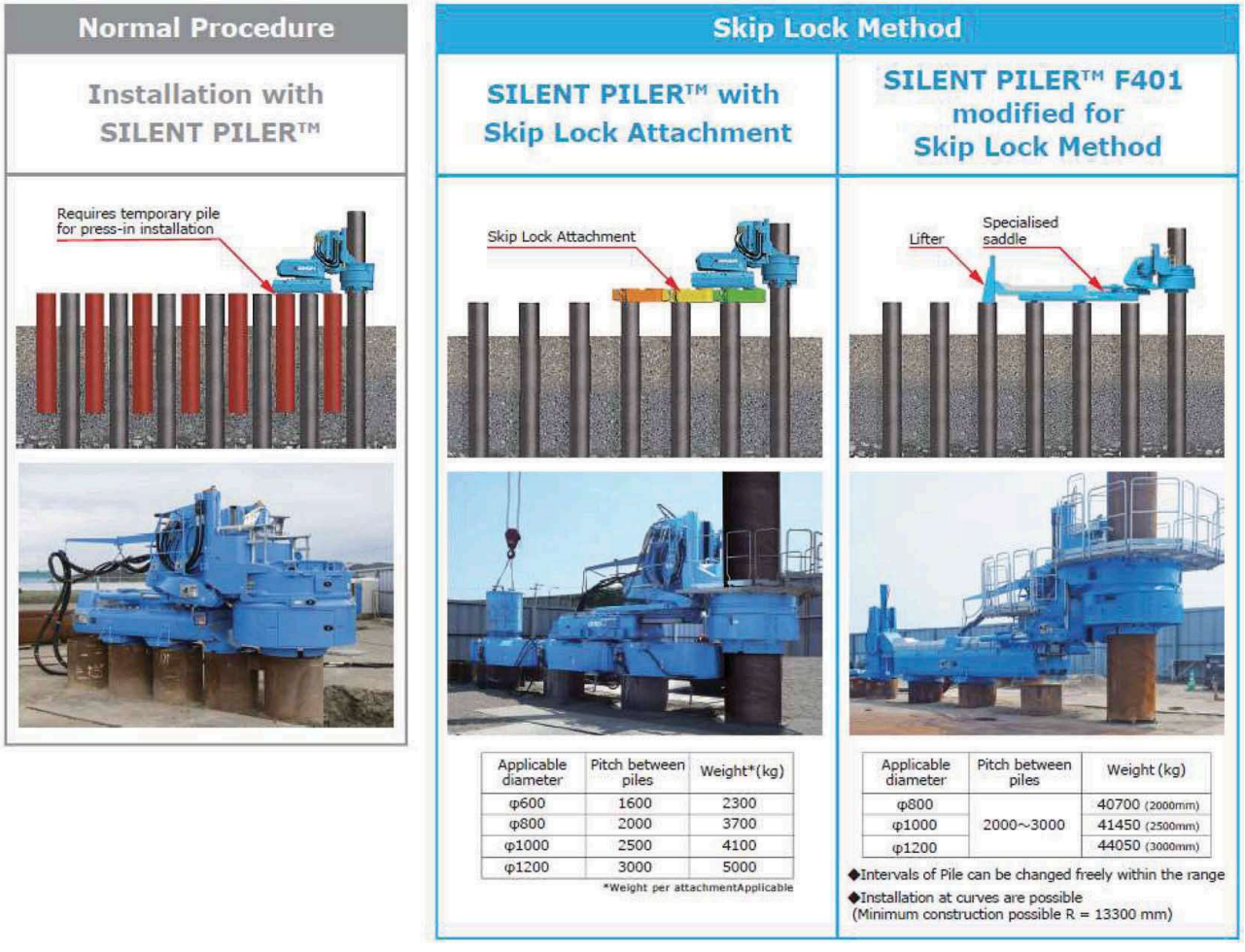

Figure 10. Skip Lock Method.

Figure 11. Procedure of the piling operation.

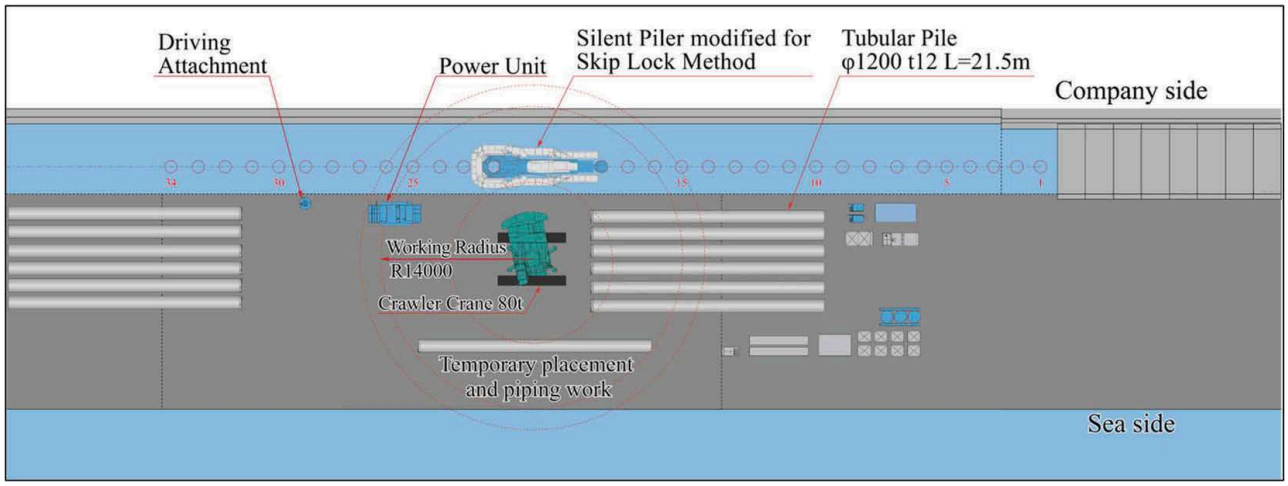

Figure 12. Plan view to show system layout.

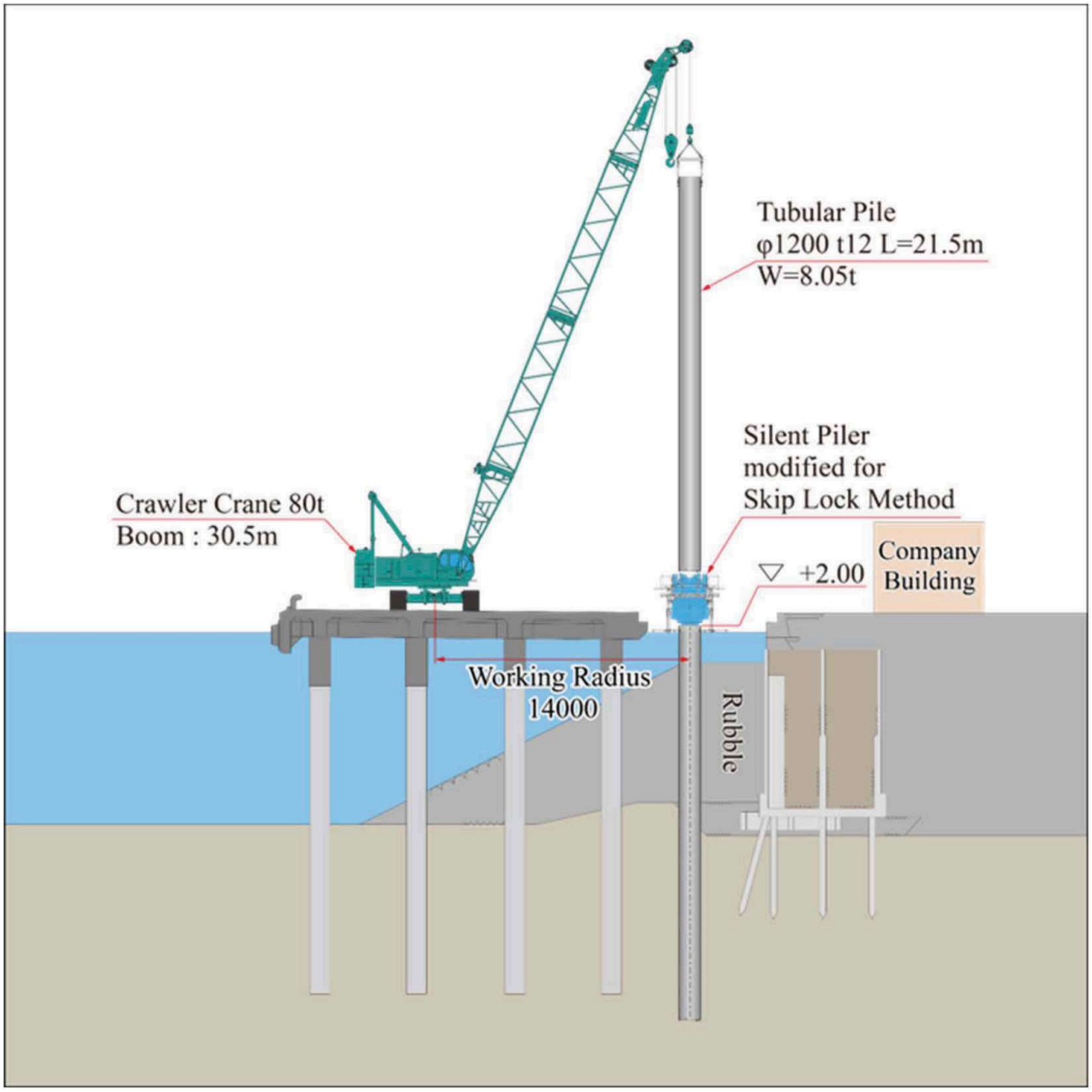

Figure 13. Cross-sectional view to show system layout.

Table 1. Productivity of installing a steel pile.

Material	Specification	Number of Piles	Average Cycle Time per Tubular Pile
Tubular Piler	φ1200, t12mm, L=21.5~23.5m, Joint less	34piles	294min

3.4 *Press in data monitoring system*

The Gyro Piler can collect press-in data (press-in force, rotational torque, press-in time, *etc*.) in which the piling situation is recorded for each steel tubular pile, and the operator is able to confirm the press-in data, utilize for the analysis of ground condition and so forth, while operating the press-in piling machine. From the data collected at this site (Figure 14), it can be checked that the torque rotational force decreases from around 9.0m depth. It is assumed from the data that the pile toe of the steel tubular pile reached the silt layer through the rubble mound.

In addition, since the torque-rotation force increased from 17.0m depth, it can be anticipated that the pile toe reached the stiff ground layer. In the soil investigation, the borehole log is the result of measuring the "point" in the field. On the other hand, the press-in data, in which steel tubular piles are installed continuously, can confirm the soil condition as a "line". The use of press-in data is an effective tool that can confirm whether the required penetration depth has been ensured for the supporting layer assumed at the design stage.

One cycle of the pile installation including pitching a pile and self-walking took approximately 294 minutes, and the penetration time assumed on the rubble mound was 180 to 240 minutes.

Comparing it with using a set of Skip Lock attachment, the relocation time of a piece of Skip Lock attachment could be reduced about 30min in one cycle. It means that one cycle time per pile was dramatically reduced.

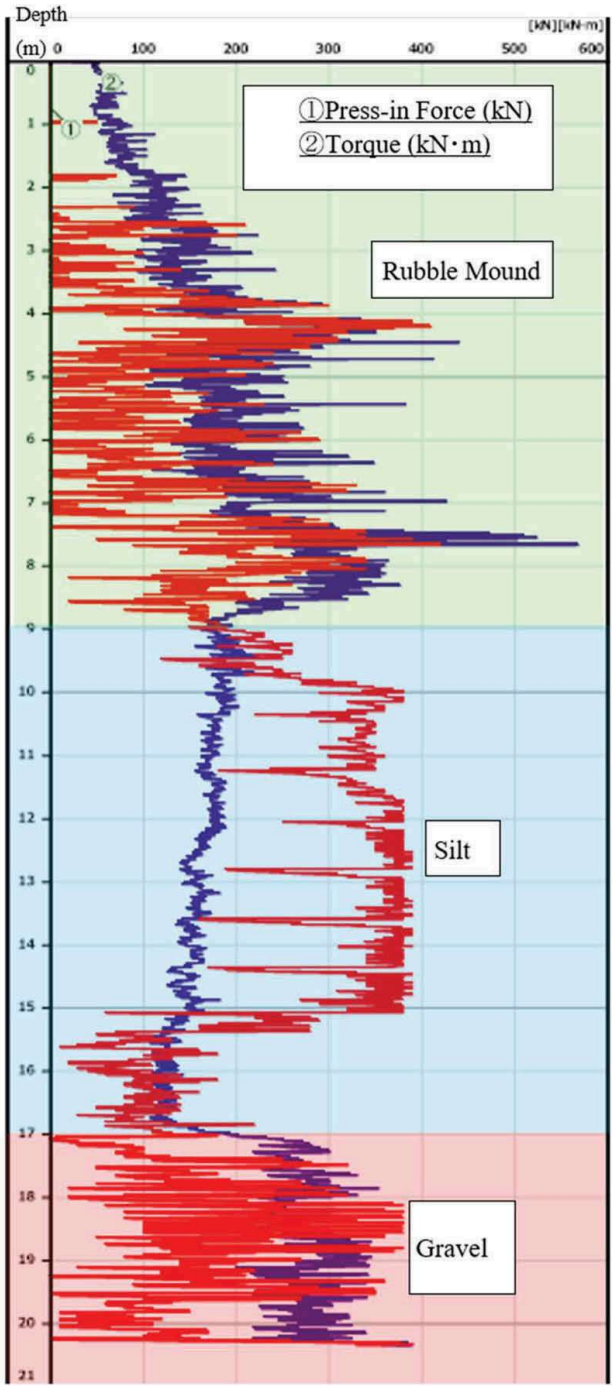

Figure 14. Press in data.

4 CONCLUSIONS

This paper shows the piling application of installing anchor piles by the Gyropress Method and the Skip Lock Method, for steel tubular pile quay wall (Figure 15).

In the result of comparing the Gyropress Method with the Skip Lock Method with the vibro hammer method using water jets after the removal of rubble mound, the Gyropress method was adopted because it can keep a good balance of the "five construction principals" which consists of environment protection, safety, speed, economy and aesthetics. In particular, a large-scale plant is not necessary and steel tubular piles are directly installed without removing the rubble mound, which contributes a great deal toward reducing the total cost and shortening the construction period without disturbing other works.

Figure 15. Construction site.

In addition, this project is the first application of using a modified Gyro Piler for the Skip Lock Method. This is a remarkable case in which it has become possible to construct with various pile pitches that are about 2 to 3 times the diameter of the pile, which was considered difficult by the standard method. By utilizing the experience obtained from this project, improvement of work efficiency of the Skip Lock Method together with the auxiliary equipment and items, shortening of cycle time, and omission of process will be realized, and the degree of completion as a piling method will be improved.

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