Example of Construction of Sheet Pile Walls for Anti-Seismic Reinforcement of Railway Embankment

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ABSTRACT

A construction of anti-seismic reinforcement of railway embankment was performed near Hirai Station in the JR Sobu Line. The site was located in a densely populated residential area. The working space was limited to the width of the slope of the embankment. Each pile was cut by four and carried in by medium duty trucks for Koshin site. On the other hand, a storage space for pile materials was prepared in Hirai site by using L-shaped sheet pile walls and excavation.
The standard press-in method was adopted for Koshin site in the preliminary design. But, since it was difficult to carry in additional equipment after press-in work had processed, it was decided to use a versatile machine, ECO400S, in preparation for the probable hard ground which consisted of buried and abandoned materials in the embankment. For Hirai area, at the first pressing-in for temporally sheet piling, at 30 cm below the surface of embankment, the pile was blocked by rubbles. As a result, crush pilers were used to construct both temporally and real structure of sheet pile walls. The GRB system was used to perform sheet piling in narrow working space at the both Koshin and Hirai sites effectively.

Key words: *GRB System, Narrow Space, Weld Joint, Versatile Piler machine*

1. Outline of the project

1.1. Place

Hirai is located in the east part of Tokyo. **Fig. 1** shows the location of the construction site. It is a densely populated area centering on Hirai Station in the JR Sobu Line. That is a main train line which connects Chiba to Tokyo, and many commuters use it. Along the railroad, a residential buildings stand close together densely and are packed to the side of embankment. Except the main roads, the large-sized vehicles were regulated in this area.

1.2. Background and objectives of the project

Because the site was narrow, slender, and slope terrain, heavy machinery could not approach the piler. The GRB system with using a clamp crane, a unit runner and a pile runner was indispensable to the works.

As mentioned above, it was difficult to carry in sheet pile materials in sufficient length. Piles were carried in by divided materials. In Koshin site, because large-sized vehicles were regulated, each pile was cut into 4 pieces by length less than 6.5 m. It was necessary to joint them by welding during press-in procedure and there was a concern that this would prolong the installation time. In order to overcome this situation, working space for lateral welding was prepared to joint upper pile with upper middle pile, and lower middle pile with lower pile. Number of welding joints during the press-in procedure for one sheet pile decreased from 3 to 1.

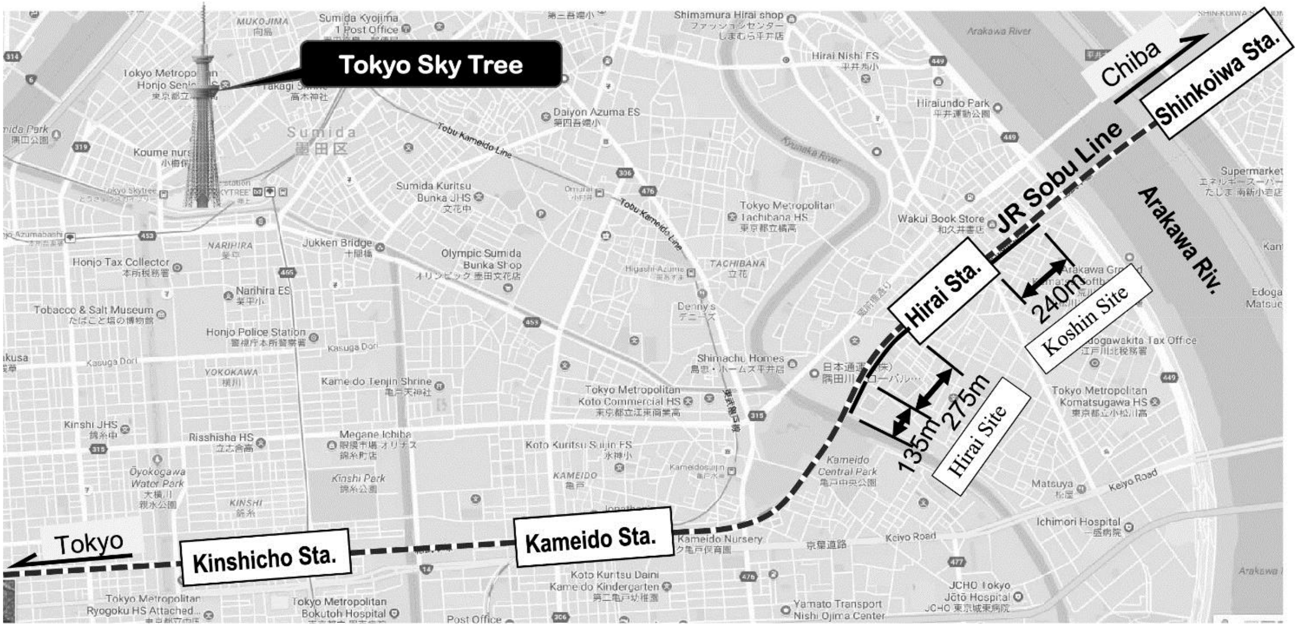

Fig. 1 Location of Construction Sites

2. Structural type and piling method

2.1. Site condition

In this site, the construction was performed adjacent to the railway in service. A distance between the railway center of the inbound line and the planned sheet pile line is 5.1 m as shown in **Fig. 2**. Safe operation of the train was the top priority. A clamp crane, CB-3, was provided with swing limit control to prevent over turning toward the railway. However, every crane movement was restricted only for one minute before the train passage. Trains passed at intervals of three minutes during the rush hour.

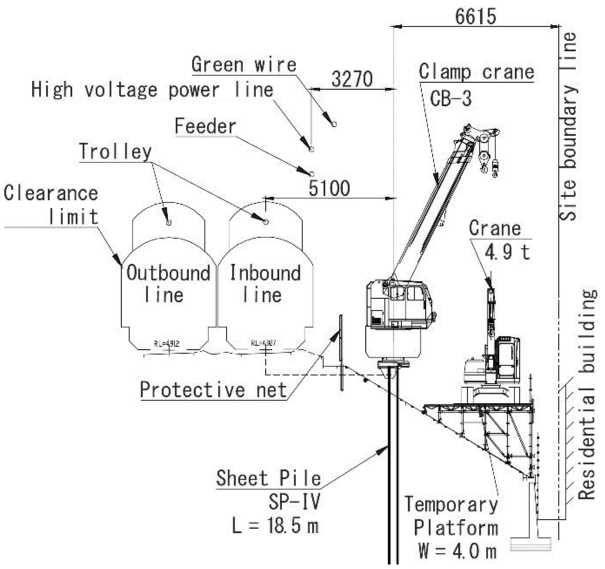

Fig. 2 Cross-sectional view of Koshin site

2.2. Ground condition

Fig. 3 shows the profiles of soil layers and SPT *N*-values at the site. The railway embankment was constructed on a fine sand layer having thickness of two or three meters. A soft sandy silt layer having *N*-values of almost zero underlay it. Some results showed high *N*-values from the surface to the bottom of embankment due to buried debris such as concrete blocks, bricks and so on.

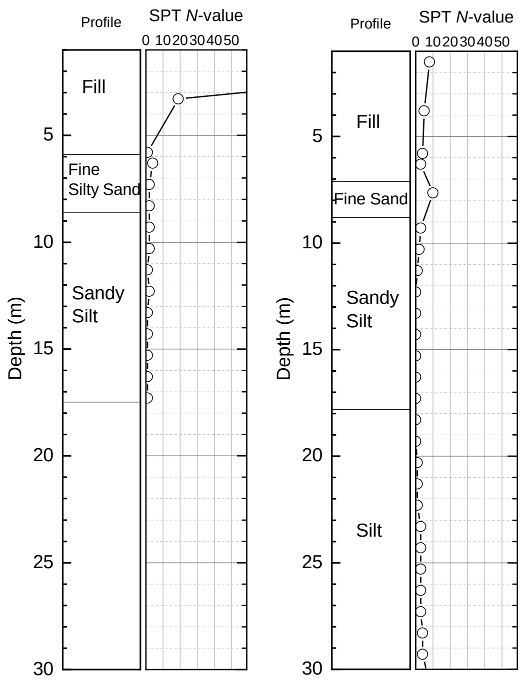

Fig. 3 Soil profiles and results of SPT

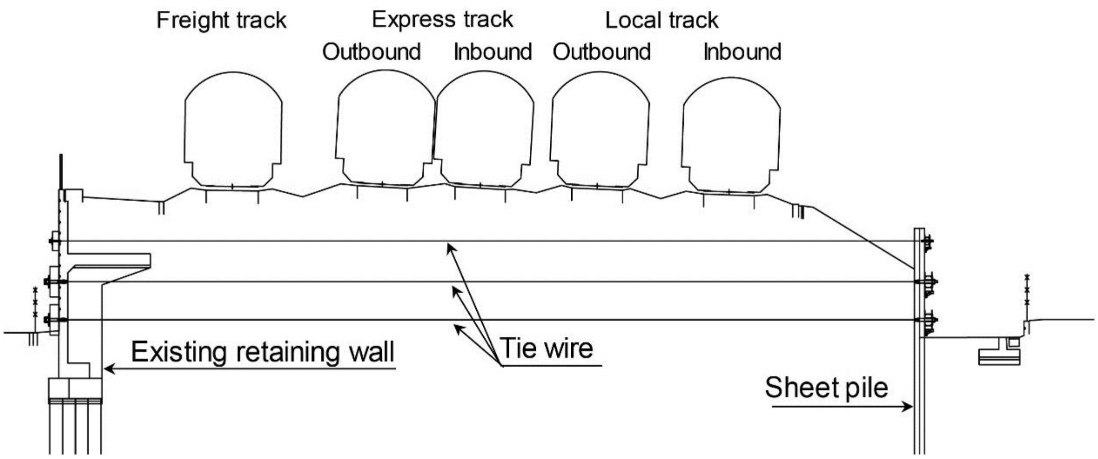

Fig. 4 Cross-sectional view of the reinforcement structures of Hirai site

2.3. Structural type

Fig. 4 shows a cross-section of the reinforcement for the embankment of Hirai site. A sheet pile wall and the existing retaining wall were connected with tie wires tensioned in three tiers. Ground anchors were also used where retaining wall did not exist. This was the same as in Koshin site.

The method using sheet piles was expected to reduce risk of liquefaction by dividing the fine sand layer under the embankment.

Table 1. Specifications of sheet pile

Site name		Pile type	Pile Length (m)	Number of division	Number of pile
Koshin		SP-IV	17.0	4	47
			16.0		151
			18.5		403
				Total	***601***
Hirai	Tokyo side	SP-V_L	21.0	3	61
			25.0		206
				Total	***267***
	Chiba side	SP-V_L	26.5	3	282
			23.0		82
			16.0		106
			17.5		75
				Total	***545***

2.4. Piling method

Table 1 shows the specifications of sheet piles used in Koshin and Hirai site. The type IV sheet piles were used in Koshin site and the type V_L sheet piles were used for Hirai site. The standard press-in method was adopted as a piling method in the initial design for both Koshin and Hirai sites. But, since it was worried that the embankment contained some debris, augering equipment was prepared in addition. The versatile piler machine was required consequently.

In Koshin site, SCU-ECO400S, a versatile piler machine was used for installation of type IV sheet piles. It was able to convert from standard press-in to augering by simply removing the attachment.

On the other hand, a similar versatile piler, SCU-ECO600S, was discussed in Hirai site, where the designed sheet pile was type V_L. It was compatible for simple press-in and augering providing two respective chucking apparatus. But it was difficult to carry the additional chuck apparatus together with the piler machine and to replace them on pile installation site. The working platform in Hirai site was not prepared for the entire construction area. Therefore, the Crush piler, SCU-600 was used for pile installation in Hirai site. The crush piler usually synchronize and install sheet pile together with auger. The installation speed is slower than that of a standard press-in machine.

By the manufacturer's efforts, the piler was enhanced and it became possible to install sheet piles without synchronization of augering. A short casing was used as an attachment to chuck together with sheet piles. It was easy to change operation mode of the piler from augering to press-in. This helped much to reduce the construction period.

As shown in **Fig. 3**, the silt layer below the embankment was very soft and augering was not necessary. Moreover, it was concerned that the resistance against extraction during press-in performance of subsequent pile became insufficient and result in forward inclination of the sheet pile. In order to overcome this problem, additional jack was provided at the front end of the piler machine. The jack was mobilized when the piler extract the sheet pile during pile installation if necessary. As mentioned above, augering was necessary only for hard contents of embankment in case that standard press-in was difficult. Total 62 of 601 sheet piling required pre-augering in Koshin site. On the other hand, most of all piles, 793 of 812 sheet piling required pre-augering in Hirai site.

3. Press-in piling

3.1. Layout of Koshin site

Fig. 5 shows the layout of Koshin site. Sheet piles were constructed over 240 m along the railway. The distance between the center of the nearest rail track and the planned sheet pile center was 4.5 m. A working platform had been constructed having length of 180 m and width of 4 m. The border of the platform was located at 1.5 m from the neighbor’s housing structures.

The construction work was separated into three parts, (a) pile installation, (b) horizontal welding, (c) reception of delivered pile materials.

Fig. 6 shows the flow of a series of construction work. Due to the surrounding condition, the maximum length of carried in materials was limited to less than 6.5 m. The pile sets were delivered after being cut into four and piled up by each set. They were loaded and conveyed by a pile runner to the welding yard. The cut parts were jointed and each upper and lower part of one sheet pile set was assembled. In order to secure linearity of welded pile, a

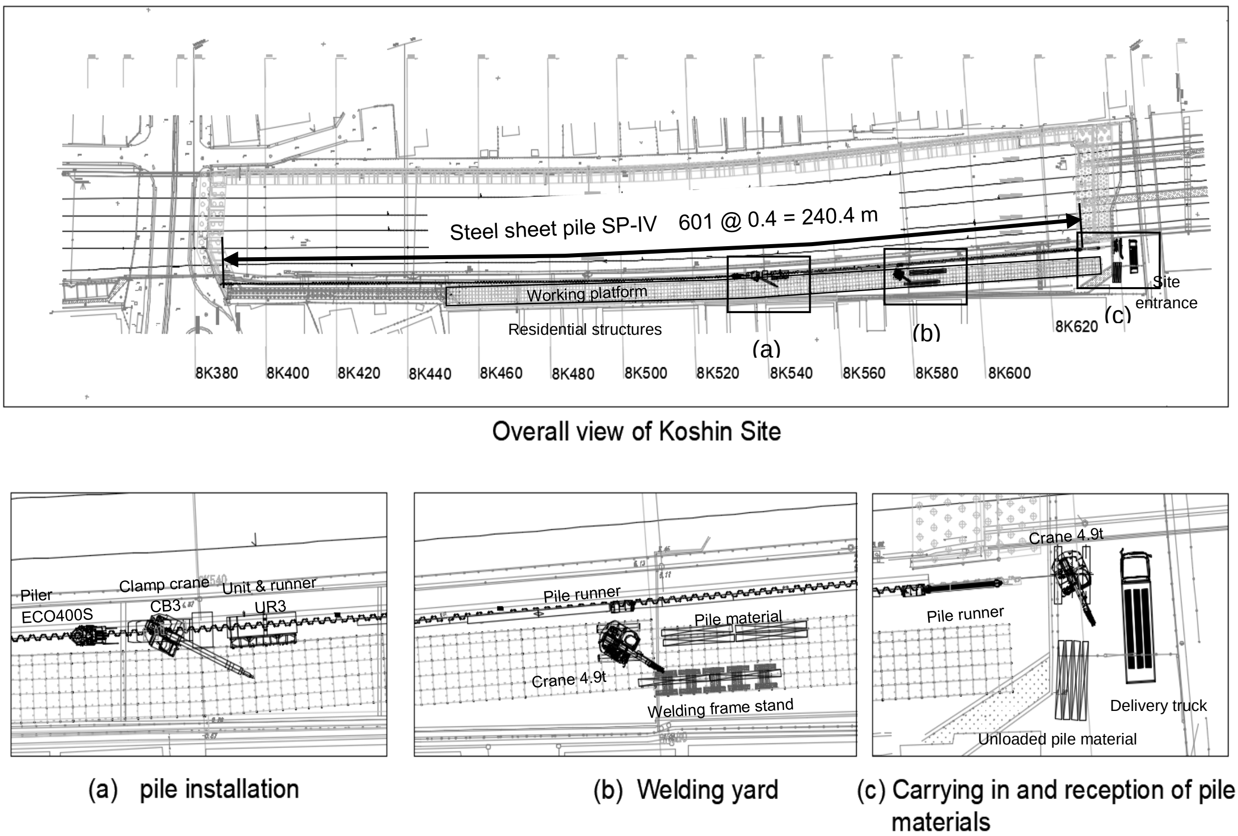

Fig. 5 Layout of sheet pile construction in Koshin site

series of frame stands equipped with leveling jacks were used for the welding procedure.

Jointed upper and lower piles were loaded again to the pile runner and conveyed to the pile installation site. The piles were supplied by a clamp crane to the press-in machine.

3.2. Layout of Hirai site

Fig. 7 shows the layout of Hirai site. The site was on both across the road. The upper figure illustrates the Tokyo side, and the lower illustrates the Chiba side.

Temporary working spaces for machinery introduction and for pile material reception were constructed on each site in advance of main piling works.

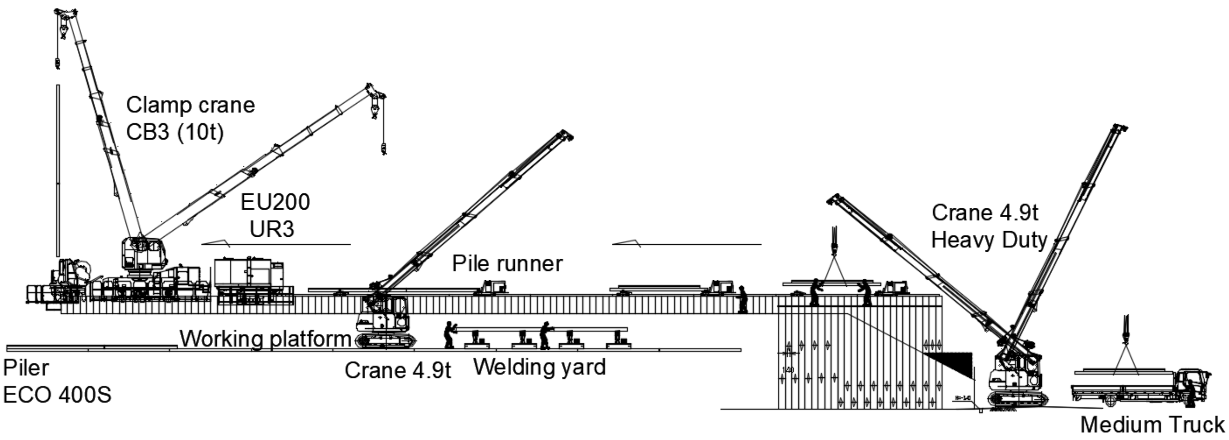

Fig. 6 Working flow of piling procedure in Koshin site

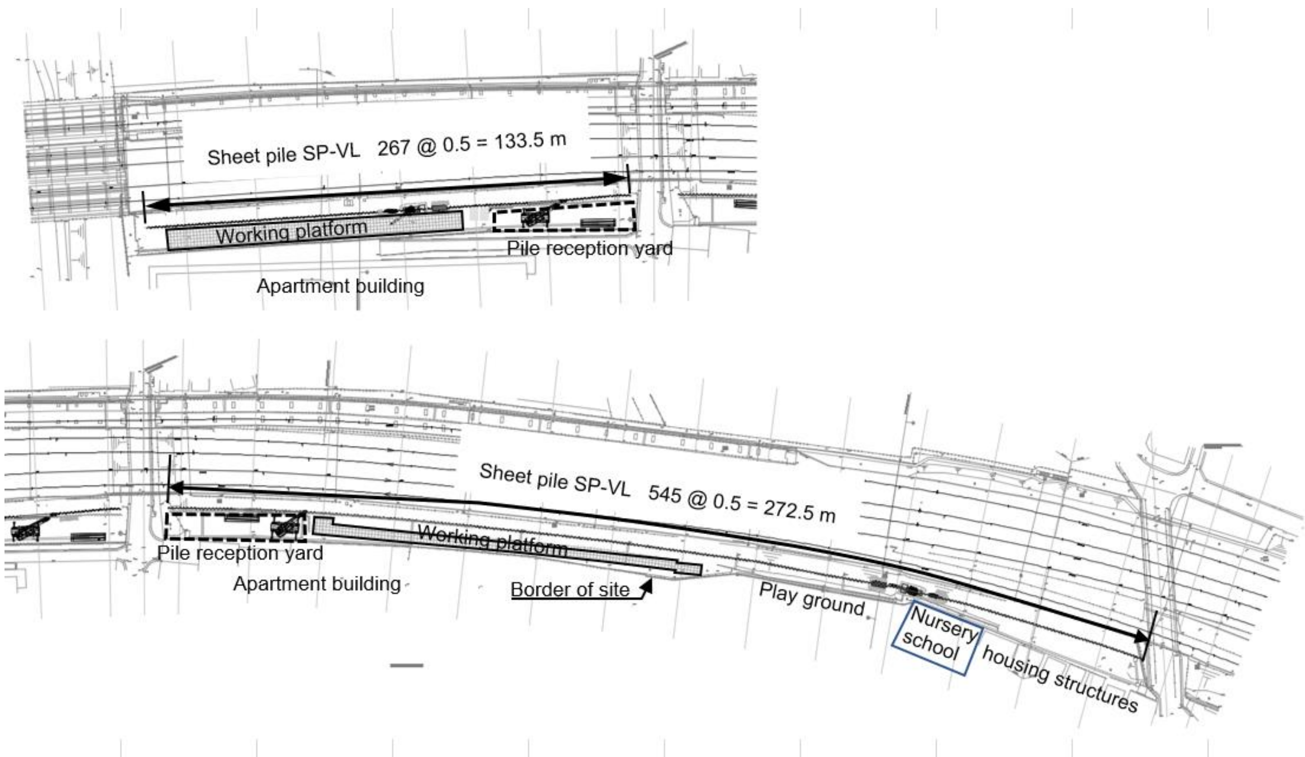

Fig. 7 Layout of Hirai site

Fig. 8 shows temporary working space for Chiba side site. A rectangular space having width of 7 m and length of 40 m were constructed by means of an L-shaped sheet pile wall using type IV sheet piles having length of 7 m, with the embedded depth after excavation was 3.5 m. The first pile installation was carried out by the standard press-in. The piles were obstructed at 30 cm below the surface by debris. The piling method was changed to hard ground piling using a crush piler, ECO400S. **Photo 1** shows the piling work for the temporary sheet pile wall. The sub crane was protruded and set on the road.

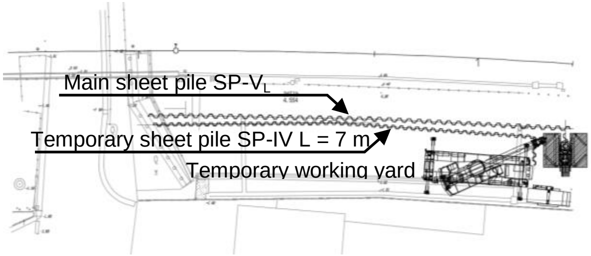

Fig. 8 Temporary working yard for Chiba side site

Photo 1. Construction of temporary working yard

3.3. Productivity

In Koshin site, total 601 sheet piles were required for the construction in the period of seven months. The average number of pile installation was four piles per day.

In Hirai site, two pilers were used for each of the Tokyo side and the Chiba side. Total 812 sheet piles were completed in about 400 days; two piles per day.

3.4. Encountered difficulties

In order to reduce the construction period, two approaches were performed.

The first one was the horizontal welding performed in Koshin site. The welding time for one joint exceeded one hour. Preparing upper and lower piles, jointed them separately in the welding yard, thus reduced the number of joint works during press-in procedure.

Another approach was to carry pre-boring only in shallow depth, i.e. depth of embankment. As shown in **Fig. 9**, auger was re-installed into bored hole beside a completed pile and stood alone while the press-in

Photo 2. Near the end point of construction (Koshin site)

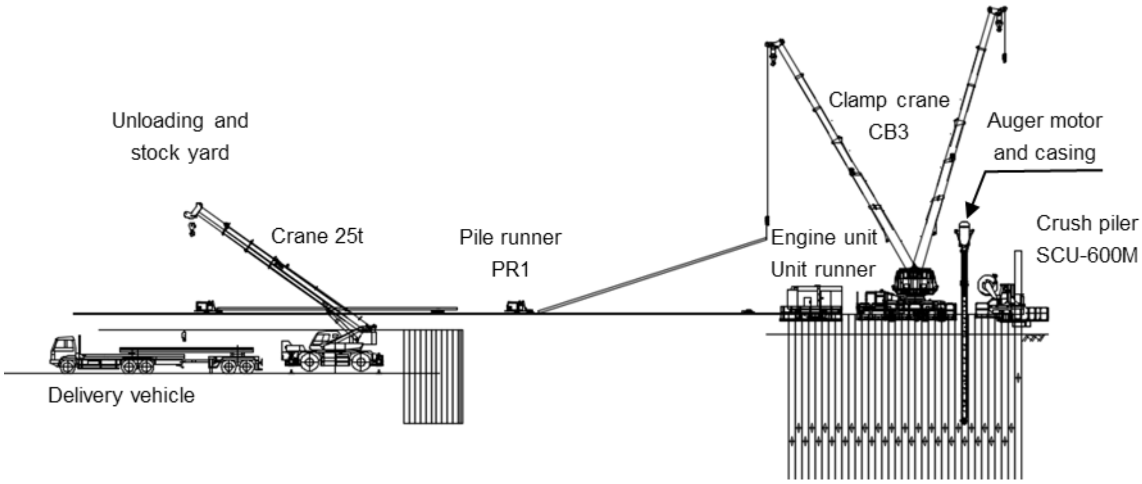

Fig. 9 Working flow of piling procedure in Hirai site

procedure was being performed. It is seen in **Photo 2** that the auger was stood between the piler and the clamp crane. This measure enabled to carry auger assembly together with the piler machine without a working space nearby. Moreover, it could avoid the danger of falling down long tall auger to a narrow space by the clamp crane.

For a permanent structure, welding joint was managed strictly in terms of its quality. Welders skill was tested at some initial welding stages under supervising by the official. The test of welding for one weld joint consisted of penetration test (PT) for the first pass, PT and ultrasonic test (UT) for the last pass and again PT for stiffening plate. These tests were conducted every 30 piles. In addition, the welding supervision engineer was obliged to stay resident in the site.

The embankment contained various unpredictable objects. In this site, the piling was obstructed quite often. **Photo 4** shows the exposed concrete structure after excavation for the temporary yard. The augering was partly interfered by the edge of the concrete and sheet piles were installed with slight inclination. In the main construction of the Tokyo side of Hirai site, a hard granite fragment was removed from augering hole. Surface of the fragment was carved by the auger head as shown in **Photo 5**. Besides this, we encountered embedded reinforced concrete and frequently the reinforcement twisted around the auger head.

The narrowest part was at the nursery school in **Fig. 7.** In the preparation stage of Hirai site, the structure had not been built yet and the ground was used as an open-air car parking lot. The general contractor decided to rent this space during the construction period. Unfortunately, the building was constructed, and the distance between the wall of building and the sheet pile center was 2.5 m. It was a minimum radius for a clamp crane to lift sheet piles vertically and turn to the piler for pile installation. Using an assist rope to prevent swaying of sheet piles, it barely succeeded in making rotation of a clamp crane. (**Photo 6**)

In order to secure safety of the train operation, displacement of the railway was monitored on a steady basis. The maximum displacement of 7 mm occurred once when boring near the back of the abutment. The limit value of displacement for safe train service was 17 mm and the predetermined value for suspension of construction was 12 mm. The railway maintenance was conducted and sheet pile installation at that point was postponed for one month taking extra precaution. One month later, pile installation was conducted again, and any further displacement was not observed.

Photo 3. Ultrasonic test ongoing

Photo 4. Concrete structure at the bottom of embankment exposed after excavation for temporary yard

Photo 5. Fragment of granite shows trace of auger head

4. Concluding remarks

Sheet pile walls were used for reinforcement of railway embankment in Hirai, Tokyo. The site was surrounded by residential buildings and had no sufficient work space for sheet piling.

With adopting the GRB system operation, sheet piling was conducted adjacent to the train in service. The security for railway service was kept steady over construction period.

By reduction of weld jointing during the press-in procedure, the cycle time was shortened.

Pre-augering and the standard press-in procedure efficiently shortened the construction period.

It took two years to complete three sheet pile walls consisting of total 1400 sheet piles.

5. Acknowledgements

Thanks to Giken staff for cooperation to enhance the control system and to manufacture the optional jack system, series of the construction works have completed in a shorter period.

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Photo 6. Clamp crane slewing at the minimum radius

Photo 7. View of construction site from the platform of Hirai station