Example of Construction of Sheet Pile Walls Using the Cyclic Auger Method for Anti-Seismic Reinforcement of Railway Embankment

Kazuyuki MATSUZAWA
Manager, Engineering Works Division, Sato Juki Corporation, Tokyo, Japan
Email: k.matsuzawa@satojuki.com
Kenichi SHIRASAKI
President, Sato Juki Corporation, Seiro-machi, Niigata, Japan
Seiji KONYA
Senior Executive Director, Tokyo office, Sato Juki Corporation, Tokyo, Japan
Yoshiteru SUZUKI
Manager, Piler Division, Kajikawa Construction, Tokyo, Japan

ABSTRACT

A construction of an anti-seismic reinforcement of a railway embankment was undertaken in Yokohama city. The site was located in a densely populated area. The access road for large vehicles was restricted only on one side of the embankment, i.e. crane work for carrying in equipment and sheet pile materials to the far side working place was conducted over the railway. Sheet pile walls, having length of 60 m were constructed along the railway at the top of the slopes of the both sides of the embankment. In order to conduct deep augering safely in narrow and small work space, the cyclic auger method was adopted. In this method, a middle auger and a lower auger were exchanged alternatingly with advance of piling. Especially in the inbound side, it was difficult to carry in a piler and other equipment across the rail way. A 200-ton crane was installed right in front of a local shopping street, until a clamp crane was installed. This paper introduces the method using a Cyclic auger and reports the difficulty and the resolution in the site.

Key words: *Cyclic Auger, GRB System, Narrow Space, Weld Joint, Railway embankment*

1. Outline of the project

1.1. Place

JR Yokohama Line is a train line from Yokohama to Hachioji through Shin-Yokohama, which is a Shinkansen station. The site is located 4 km northeast from Yokohama Station. At this location, JR Yokohama Line overpasses JR Tokaido Main Line and Yokosuka Line. The embankment was just behind the abutment of the overpassing bridge of the both lines. The location of the site is shown in **Fig. 1**.

1.2. Background and objectives of the project

In preparation for an expected earthquake beneath the metropolitan area, installation of steel sheet piles was required for reinforcement of the railway embankments (JR East, 2016). Even carrying in equipment was difficult because the directly access way to the site was not available. In addition, work space for piling was also very narrow. The purpose of this project was to perform sheet piling adjacent to the railway in service, overcoming these difficulties (IPA, 2017).

The site was surrounded by residential structures, local stores and restaurants. In the outbound side, the border of the site was adjacent to the back of these structures. In the inbound side, the border was the retaining wall of the embankment which stood along an alley. It was near Koyasu station in Keikyu Line with many pedestrians passing by.

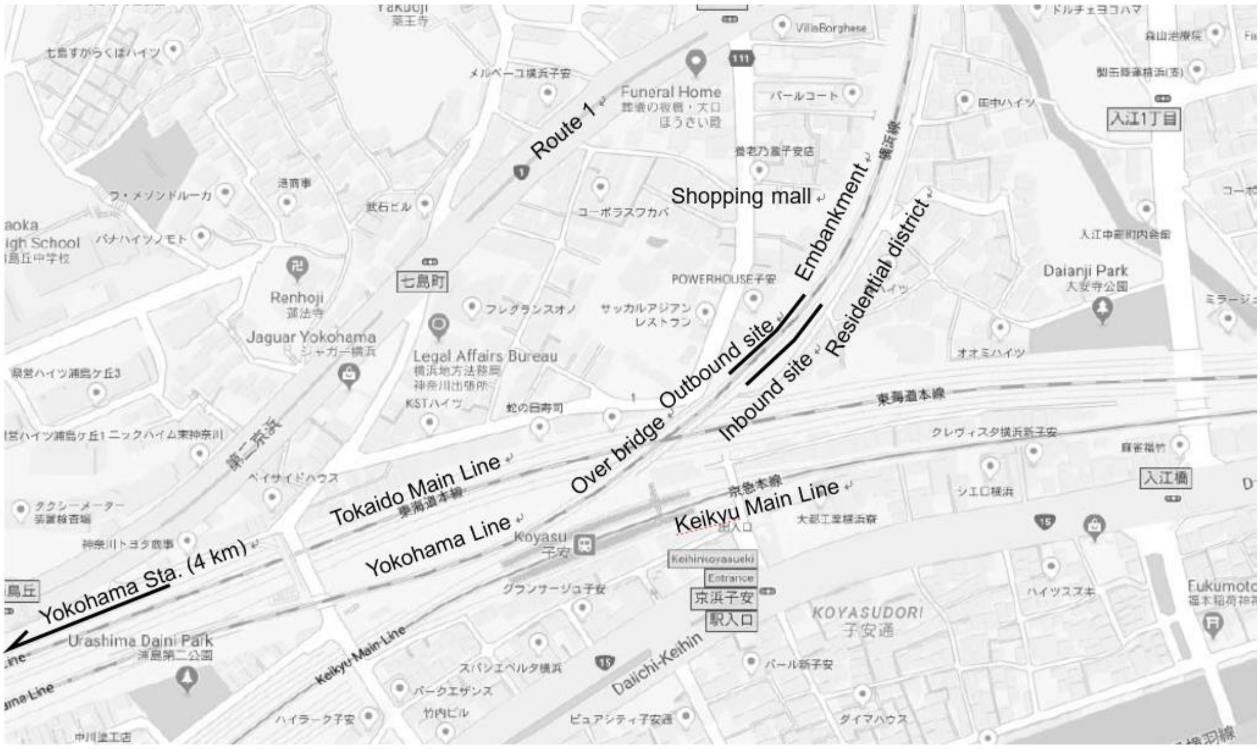


Fig. 1 Location of Construction Sites

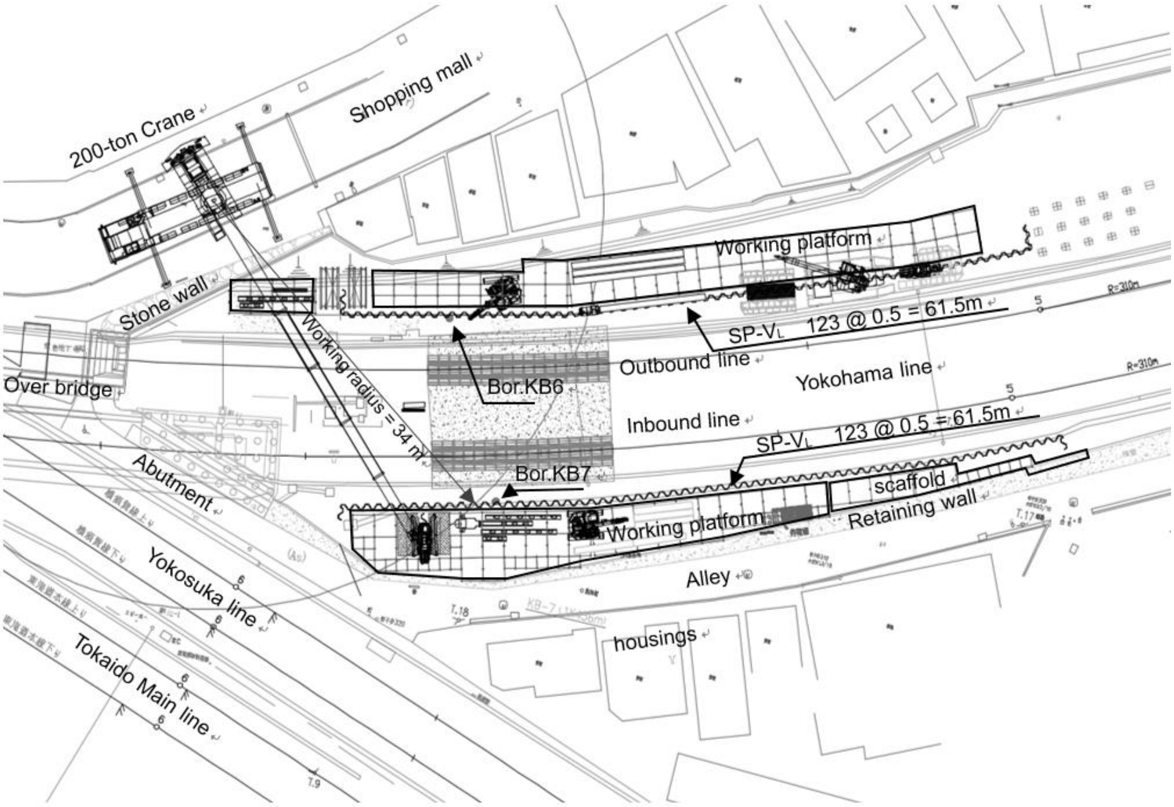


Fig. 2 Top view of the construction site

Since the site was on the embankment, vehicles could not enter the site directly. All equipment and materials were carried in by a crane which was placed on the road, right in front of the entrance of the mall.

2. Structural type and piling method

2.1. Site condition

The first of high-priority issues was how to bring in piler equipment to the inbound site. **Fig. 2** shows the top view of the construction site. A crane could be installed only on the road adjacent to the site. (see **Photo 1**)

Required working radius to set the piler at the initial setting place was 34 m. Lifting capacity of a 200-ton crane was 13.6 ton for the working radius of 34 m, while the weight of the piler machine, SCU-600M, was 15.4 ton including the reaction base. The chuck frame, having weight of 4 ton, was decided to be removed from the piler before bringing in. The total weight decreased to 12 ton including the piler, reaction base and crane hook (0.6 ton).

All the work using the 200-ton crane was performed nighttime after 9:00 p.m., when the traffic of the street was closed. And the crane work over the railway was limited only for 4 hours after feeding was stopped at 1:30 a.m. Having considered emergency, it was only 3 hours that could actually be used.

After introduction of the GRB system, the sheet piling could be performed in daytime.

2.2. Ground condition

Fig. 3 shows the soil profiles and SPT *N*-values from the boring on each side. The location of the boring, KB6 and KB7, was illustrated in **Fig. 2**. The designed sheet pile level is indicated together.

The embankment consists of clayey soils with *N*-values less than ten. Underlying sand layer shows *N*-values approximate 30. But at the depth of 10 m, it exceeded 50. From the test results, it was decided to use a crush piler to perform sheet piling.

2.3. Structural type

Fig. 4 shows a cross-section of the reinforcement structures for the embankment. Sheet pile walls constructed on both sides of the embankment were tensioned by tie wires. The sand layer underlying the embankment was supposed to be grouted for improvement

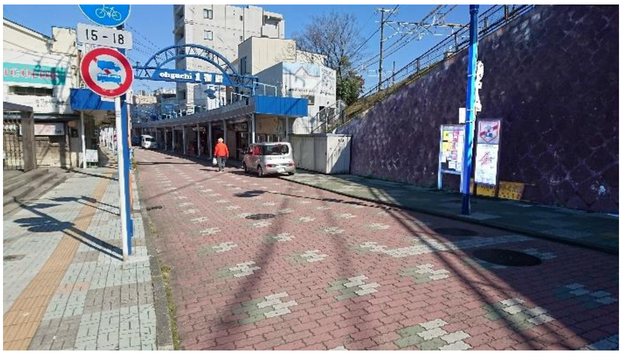
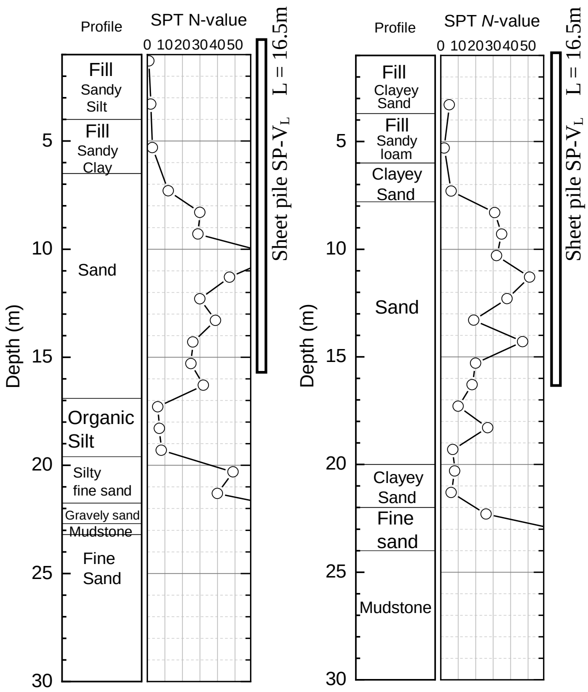


Photo 1. The road adjacent to outbound side site

Photo 2. The inbound side slope before construction started



(a) Outbound side, KB6 (b) Inbound side, KB7

Fig. 3 Soil profiles and SPT *N*-values

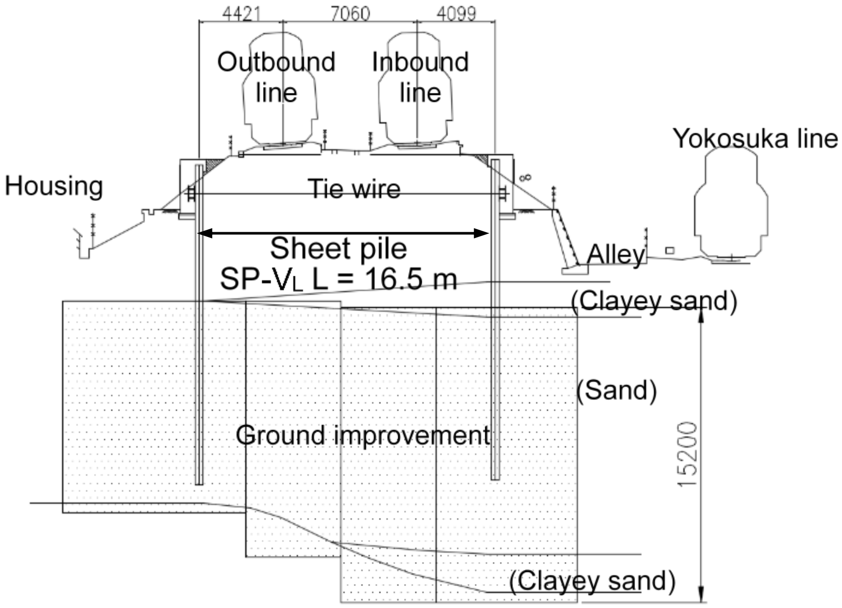


Fig. 4 Cross-section of the structure

over the depth of 15 m. The sheet pile walls were planned to be covered with faced walls at the final stage of the construction.

The combined measure, simultaneously using the ground improvement which restrains the liquefaction of the sandy layer under the railway embankment and sheet pile walls which tie up the embankment and restrain the deformation of the embankment, was adopted as an anti-seismic reinforcement for the railway embankment.

As shown in **Fig. 2**, 123 Sheet piles, type V_L, having length of 16.5 m, were installed for each side of the embankment.

2.4. Piling method

A crush piler was used to perform sheet piling together with the GRB system to carry out piling in narrow

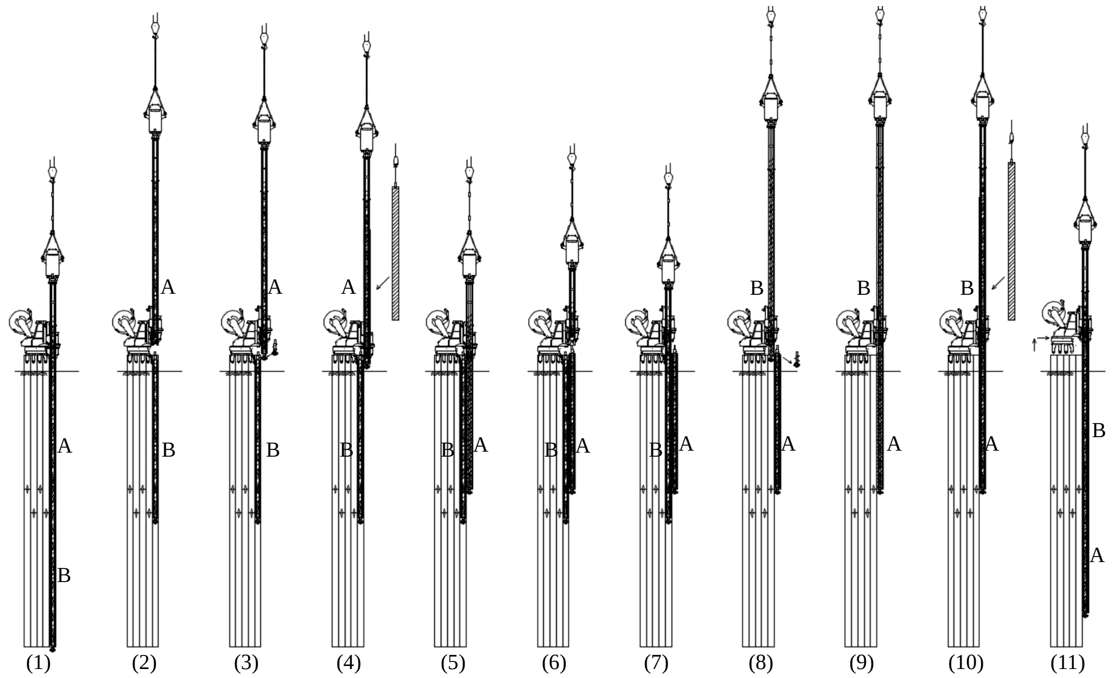


Fig. 5 The procedure of Cyclic auger press-in

space. For the initial stage until a clamp crane was installed, a 200-ton crane was used to support the auger and for other crane works.

3. Press-in piling

In a narrow work space, safe falling down of the auger casing was difficult. In order to reduce this risk, the cyclic auger method was adopted. The casings specified for this method were prepared beforehand.

3.1. Cyclic auger procedure

Fig. 5 illustrates the steps of procedure. The procedure is as follows;

(1) Completion of press-in.
(2) Extract the middle auger (A) and detach after the lower auger (B) was suspended to the pile top by chain and hook.
(3) Attaching a casing bracket and an auger head at the bottom of (A).
(4) Set a lower sheet pile together with (A).
(5) Completion of simultaneous press-in of (A)
(6) Detach the upper auger from (A).
(7) Joint the upper auger to (B).
(8) Extract the auger (B) and detach the auger head and bracket at the bottom of (B).
(9) Joint (B) to (A).
(10) Joint the upper sheet pile by welding to the lower pile.
(11) Continue simultaneous press-in.

3.2. Initial press in situation for inbound site

It was required to reduce the time using the 200-ton crane in order to open the street for traffic and to reduce costs of the crane. In the inbound site, crane work was limited only for 4 hours in one night. In case of considering emergency, it was practically 3 hours. Therefore, early introduction of a clamp crane was expected.

Fig. 6 shows the layout of equipment in the inbound site. Temporary initial piles and temporary piles for crane installation were pressed in by the piler with the 200-ton crane. For the temporary piles, lower part of permanent sheet pile was used because the welding time was too long for limited operation time in the night time. Sixteen sheet piles were required to install a clamp crane and to secure back space for the piler to move forward. After these piles pressed in, a clamp crane was installed as shown in **Fig. 6**. After further sixteen of permanent piles were completed, the temporary piles for the crane were extracted and replaced by permanent piles. Two machines exchanged the place mutually and further permanent piling shifted to daytime work. Carrying in materials had to be done in the night shift.

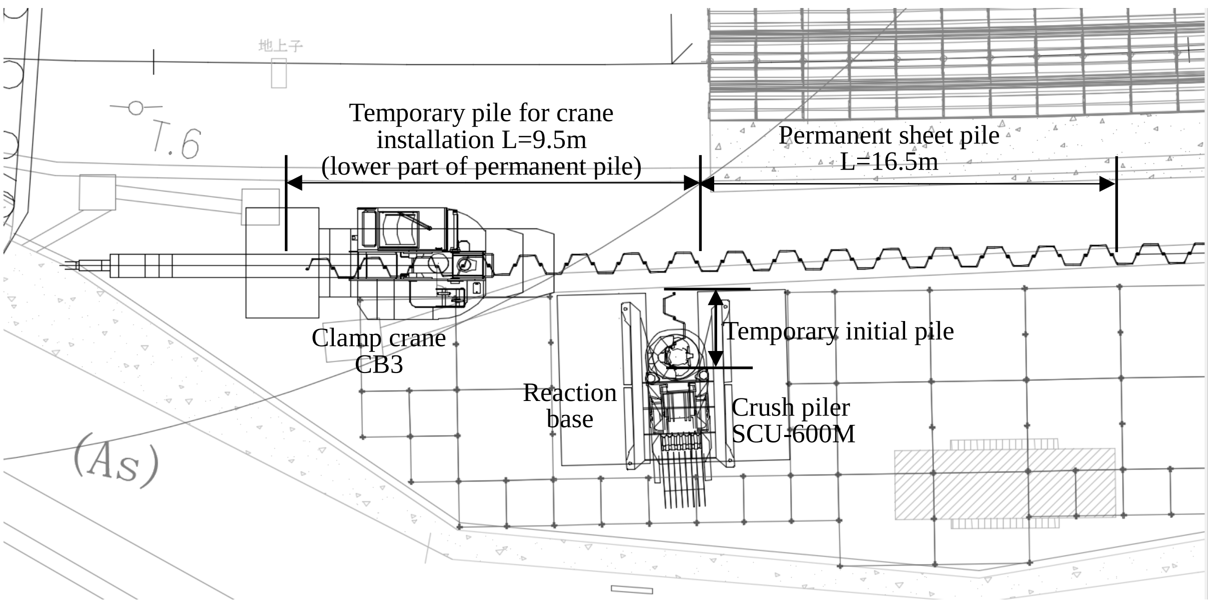


Fig. 6 Layout of inbound site at introduction of clamp crane

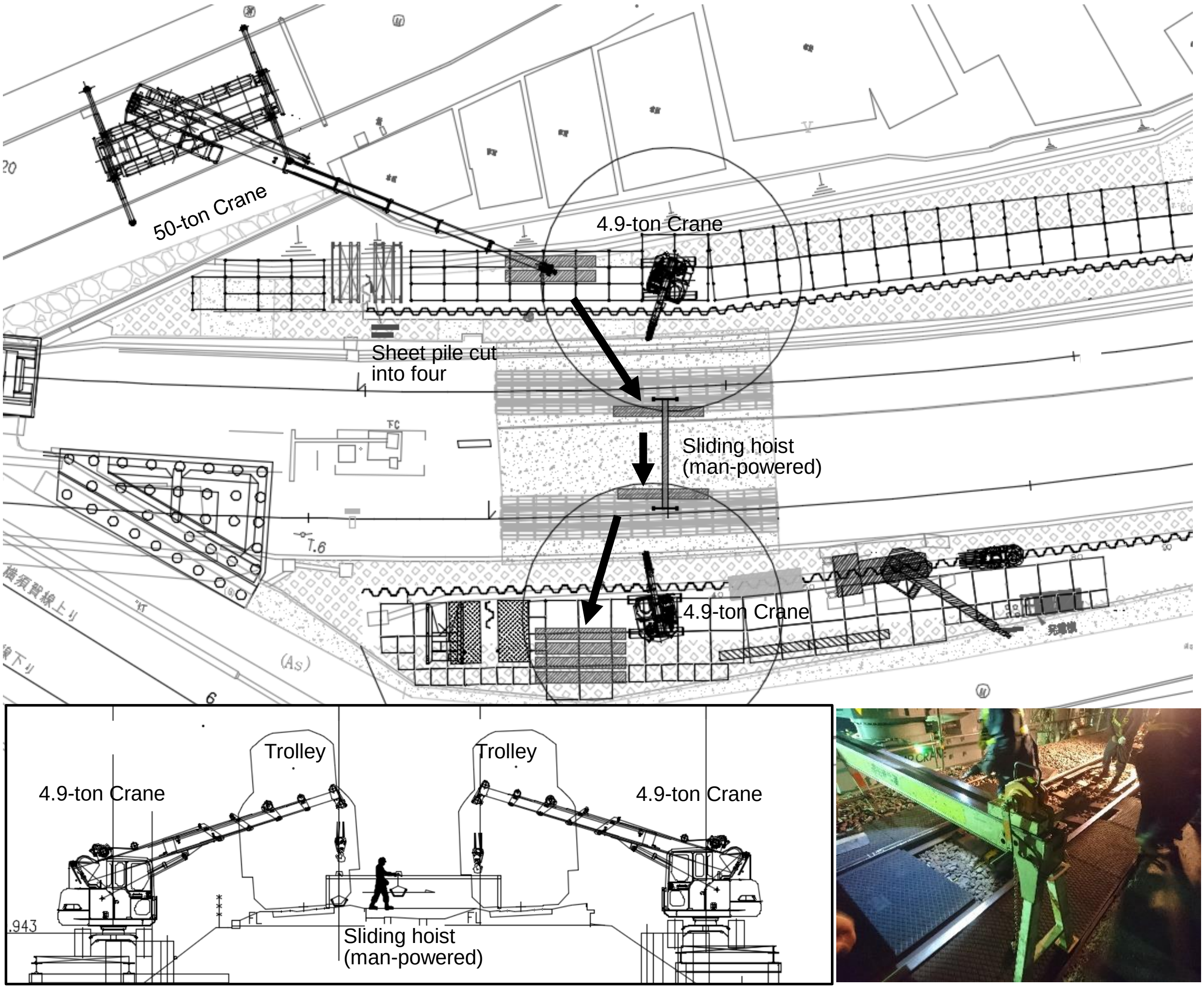


Fig. 7 Conveying of sheet pile material to inbound site

3.3. Carrying in pile materials to inbound site

After the GRB system was introduced, another issue was how to bring in sheet pile materials to the inbound site. A 50-ton crane could temporarily carry in materials into the platform in the outbound site. The sheet piles had been conveyed from the outbound site to the inbound site across the rail road, under the trolley and feeding cable.

A delivery vehicle for sheet piles carried 18 sets of sheet piles at once. A set of sheet piles was divided into four. That was because long materials could not be turned around in the narrow working platform of the inbound site. The length of divided pile was less than 6.5 m. They were temporarily stored in the outbound site.

Two 4.9-ton cranes were installed at each platform. And a sliding hoist beam, named “Yamakoshi-ki”, was set up. This equipment provides reduction gears and it can lift the maximum weight of 1.0 ton by man-power. The hoist slides easily on the portable beam.

Fig. 7 is the illustration of carrying in sheet pile materials. Divided materials were conveyed one by one. The crane in the outbound site move a sheet pile near the outbound rail track. The beam was set above the sheet pile at the end of the beam. The sheet pile was lifted and glided toward the inbound track, then put down. The beam was removed and the crane in the inbound site bring the sheet pile in. It took 3 nights for conveying 18 sets of sheet piles.

3.4. Productivity

For the outbound site, initial piling was performed with a 200-ton crane. Sheet piling progressed one pile a day, while the pile had to be welded. The work at the outbound site was not restricted by the train service while the closure of the traffic permitted from 9:00 p.m. to 5:00 a.m. With using the GRB system, the piling work progressed at the constant pace of 2 piles a day.

For the inbound site, temporary piles were conducted 2 piles per night because it was not necessary to joint them by welding. But 16 piles had to be extracted and replaced by permanent piles. The piling work with GRB system progressed 2 piles per day, while the upper pile and the lower pile had to be prepared before the pile installation. This will be mentioned in next part.

3.5. Encountered difficulties

The narrowness was the issue, especially in the inbound site. Sheet pile materials had to be divided into four, at the length of less than 6.5 m. This caused increase of number of welding works. In order to reduce time for press-in procedure, the upper two members and lower two members were welded respectively before press-in work. Because of the narrowness of working space, it was also difficult to store materials and welded members in the platform. On the platform was always fulfilled with sheet piles.

On the second half of pile installation in the inbound site, the working space was barely available. There was only a small scaffold beside the planned sheet pile line. Moreover, beneath the scaffold was an alley which is not closed during the construction. The crane could not slew behind to lift the sheet pile. The width of working space was only 1 m from the sheet pile center. As shown in **Photo 3**, the pile was supplied by pile runner underneath the clamp crane and lifted carefully between the piler and the border fence.

Photo 3. Pile conveyed underneath the clamp crane

4. Concluding remarks

Sheet pile installation were used for a reinforcement work of a railway embankment in Yokohama city. The site was surrounded by residential buildings and had no sufficient work space for sheet piling.

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

The cyclic auger method reduced the risk of crane work because it was not necessary to frequently fall down the long tall auger.

Photo 4. Two crush pilers with system conducting sheet piling on the both side of the embankment

The construction under difficult conditions was successfully completed by a pair of crush pilers (**Photo 4**).

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