Development and future prospects of waterproofing wall method between tubular piles based on the Gyropress Method

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ABSTRACT

In the case of continuous steel tubular pile wall by rotary cutting press-in, it was considered difficult to provide watertight walls by utilizing steel tubular piles and the rotary press-in method, since it is not feasible to install tubular sheet piles (tubular piles with interlocks) by the rotary press-in method. Therefore, the "Waterproofing Method between piles" using closure pipes (small diameter steel pipes) and mortar jackets were developed to provide watertightness with continuous steel tubular pile wall using the rotary press-in method, called the Gyropress Method™. In the early stages of the development of the waterproofing method between piles, after the installation of tubular piles were completed, a special attachment was attached to the main body of the GYRO PILER™ for rotating and press-in small diameter pipes between tubular piles. Then, in order to improve the efficiency of a waterproof method for allowing high water tightness walls installed by the Gyropress Method, we developed a compact press-in machine specialized for small-diameter pipe press-in, the press-in machine for small diameter pipes. The development of a special press-in machine for small-diameter pipes has eliminated the need to install and remove special attachments to and from the main body of the GYRO PILER, and also the machine made it possible to install tubular piles in tandem with small-diameter pipes, thereby shortening the process and construction period. This paper introduces the Waterproofing Method between piles using a small press-in machine for closure pipe installation and grouting method with mortar jackets based on a construction case study and future prospects.

Key words: *Gyropress Method, Waterproofing Method between piles, Press-in machine for small diameter pipes*

1. Introduction

Since the Gyropress Method was adopted in the Biratori Bridge disaster rehabilitation project in 2004 to reinforce the bridge piers, the efficiency of the construction method has been improved in accordance with site conditions.

In 2016, the waterproofing method was developed[1)] to seal gaps between adjacent tubular piles utilizing closure pipes (pairs of small diameter pipes) and grouting.

At early stage of the machine development, these closure pipes were being installed with an attachment mounted onto the GYRO PILER. After some improvement of the attachment, eventually, an independent press-in piling machine was developed, which was dedicated to install closure pipes. This enabled main tubular pile installation and closure pipe installation to be carried out concurrently, reducing piling processes and construction time and costs simultaneously.

The seawall of the Furubira Fishing Port Beach described in this paper had deteriorated and was severely damaged by waves, requiring immediate countermeasures. In order to overcome the difficult site conditions (hard ground, narrow working space, low-vibration, low-noise and limited impact on the surrounding environment), The Gyropress Method and the waterproofing method were adopted for the project.

2. Outline of the project

2.1. Site Location

The site was a seawall improvement project facing the Furubira fishing port beach in the eastern central part of Hokkaido's Shakotan Peninsula (Fig.1). There is a good seaweed bed in front of the existing seawall, which is used as a sea urchin fishing ground. Furthermore, the surrounding hinterland is adjacent to a fish processing plant and school facilities, which placed many constraints on improvement work.[2)3)4)]

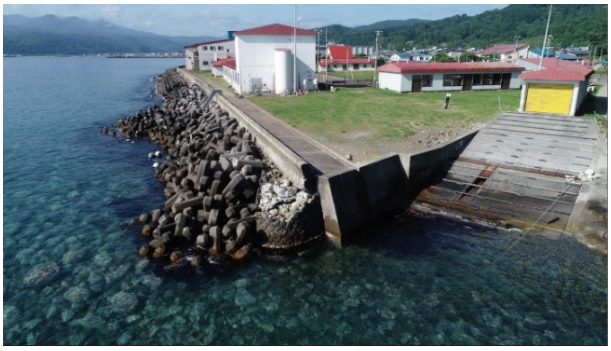

Fig.1 Furubira fishing port beach

2.2. Background and objectives of the project

This coastal seawall was constructed in the 1960's as a coastal protection facility. In recent years, high waves caused by climate change have resulted in wave overtopping due to insufficient top height. In addition, those coastal areas had deteriorated significantly due to aging and damage caused by waves over the past 50 years since the construction of the coastal seawall (Fig.2), and immediate action was required.[2)3)4)] Therefore, as a countermeasure against aging facilities and wave overtopping, a project to improve the coastal seawall was initiated and this work was commissioned.

Fig.2 Collapse of coastal seawall

3. Structural type and piling method

3.1. Site condition

The only laydown area available for the proposed piling works was a vacant parking lot at the end of the proposed new seawall (Fig.3) due to the presence of adjacent buildings to the existing seawall. Therefore, a low-vibration and low-noise construction method was required to minimize the impact on the surrounding environment. In addition, it was necessary to construct a new seawall that extends seaward from the existing seawall. However, encroachment of the new seawall in the sea must be minimized because the front of the existing seawall has a good seaweed bed used as a sea urchin fishing ground. [2)3)4)]

Fig.3 Working space

3.2. Ground condition

The borehole log shows that the ground is hard to extremely hard due to the presence of gravels and cobbles. Therefore, the Gyropress Method was utilized to install tubular piles into these hard soil layers, as the new seawall. (Fig.4).

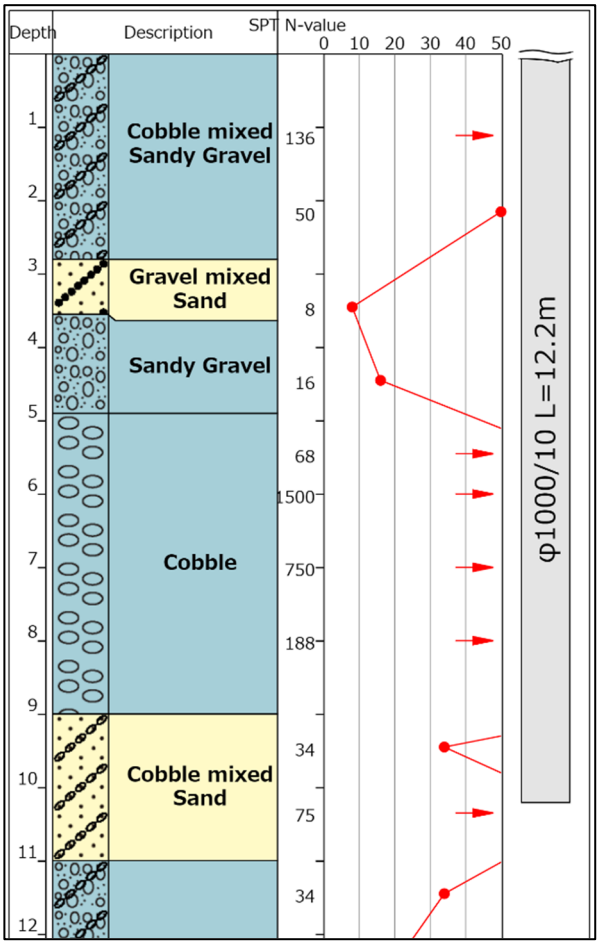

Fig.4 Borehole log

3.3. Structural type

In order to minimize the encroachment of the new seawall in the sea, a cantilevered tubular pile wall was proposed as the foundation of the seawall. After installing tubular piles, RC seawall was constructed over the tubular piles (Fig.5). As the seawall is firmly embedded into the ground, it is extremely resilient. This type of embedded substructure installed by the press-in piling method is called Implant ™ Structure[7].

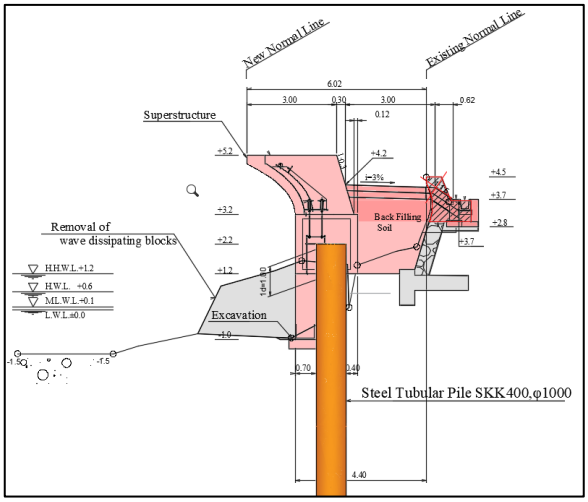

Fig.5 Cross section[4]

3.4. Piling method

(1) Steel tubular pile installation by Gyropress Method

In order to install tubular piles into the hard ground in the restricted site conditions i.e. limited working space and limitation of noise and vibration, the Gyropress Method was utilized.

The Gyropress Method is the rotary cutting press-in method of tubular piles with ring bits by using the GYRO PILER (Fig.6) to install the pile head by itself while using previously installed piles as a reaction force. It is possible to install tubular piles in hard ground and underground obstructions with low vibration and noise.

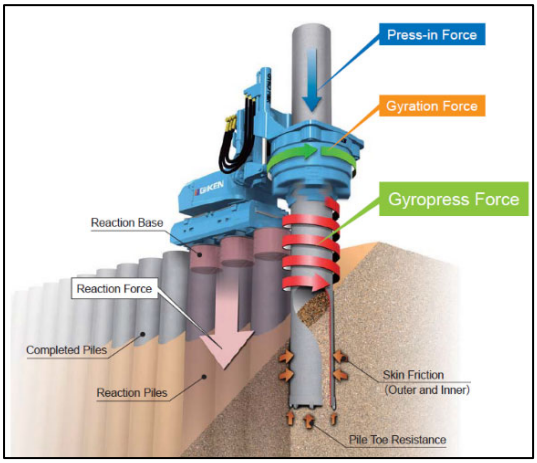

Fig.6 Gyropress Method™ [4]

Fig.7 Installation of tubular piles by the Gyropress Method™

(2) Installation of closure pipes using the specialized press-in piling machine

Conventionally, the small chuck for installation of closure pipes was built-in the pile follower of the GYRO PILER. (Fig.8 and Fig.9). The attachment (pile follower) is attached to the GYRO PILER and a pair of closure pipes are installed at each gap between adjacent tubular piles to form a closed space (Fig.10).

Fig.8 Driving attachment (pile follower) with a built-in small chuck

Fig.9 Chuck for closure pipe installation

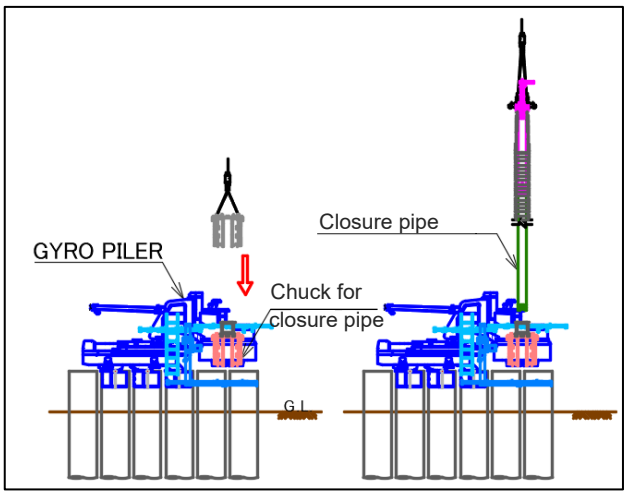

Fig.10 Installation of closure pipes and mortar jacket (Chuck for closure pile installation)

The installation procedure of closure pipes is as follows.

i) Completion of main tubular pile (structural piles) installation.
ii) Attach the small chuck to the GYRO PILER.
iii) Install two closure pipes at each gap between adjacent main tubular piles.
iv) Remove the small chuck.
v) Install the next main tubular pile.
vi) Repeat ii) – v).

However, it is not efficient to install both tubular piles and closure pipes by the same GYRO PILER since it is time consuming to attach and detach these attachments at each time. In addition, the GYRO PILER is over-engineered for small closure pipes.

Fig.11 Press-in machine for closure pipe installation

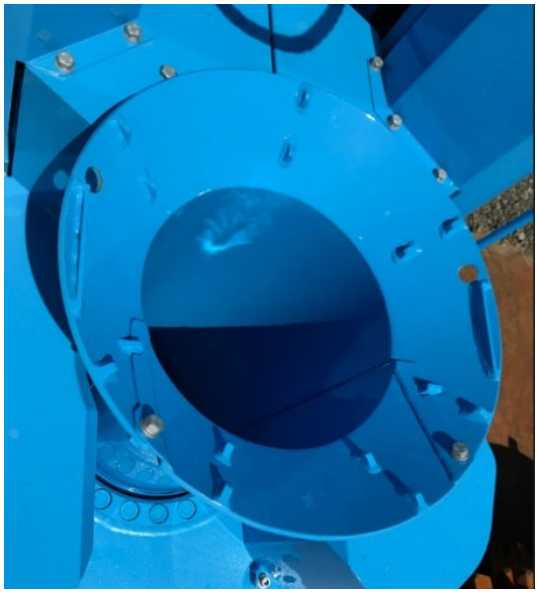

Fig.12 Small diameter chuck
(Specialized press-in machine)

Table 1. Specification of press-in machine

Press-in Machine for Only Small-diameter : SP14		
Press-in Force		500 kN
Extraction Force		600 kN
Stroke		600 mm
Rotational Torque		150 kN・m
Rotational Speed		15 min^{-1}
Applicable Pile Diameter	Reaction Pile	**φ800mm-1500mm**
	Pressed-in Pile	**φ105mm/318.5mm**
Control System		Radio Control
Movement		Self Moving
Mass		6,000 kg (φ800)
		6,100 kg (φ900)
		6,100 kg (φ1000)
		6,200 kg (φ1200)
		6,450 kg (φ1300)
		6,500 kg (φ1400)
		6,550 kg (φ1500)
Power Unit		EU300K4

Advantages of installing tubular piles and closure pipes by two different press-in machines are as follows:

- Installation works of tubular piles and closure pipes can be carried out concurrently, resulting in shorter construction time.
- Closure pipes can be installed a smaller and lighter press-in machine. Thus, mobilization/demobilization costs, size of a service crane and CO_2 emission etc. can be reduced.
- Both the GYRO PILER and the specialized press-in machine can self-move above previously installed piles without crane liftings.
- The specialized press-in machine covers a wide range of applicable pile diameters, making the applicability of the Gyropress Method wider.

Fig.13 Installation of closure pipes in progress

(3). Waterproofing method between piles

The waterproofing method between piles[1)] is a method to provide water tightness performance by filling mortar between piles with small-diameter pipes and special mortar jackets. Thus, with the Gyropress Method, it is feasible to provide water tight walls without having Interlocks attached onto tubular piles. As the applicability of the Gyropress Method to hard ground conditions is much higher than other press-in piling modes, it increases the applicable of cut-off walls which comprise steel tubular piles. On the project, 2no. 318.5mm O.D. closure pipes were installed at each gap between previously installed main tubular piles and closed spaces between the piles were excavated by water hummer. Then, closed spaces between the piles were cleaned by double pipes with air or water and inserted geotextile bag and filled with mortar to provide water tightness. (Fig.14)

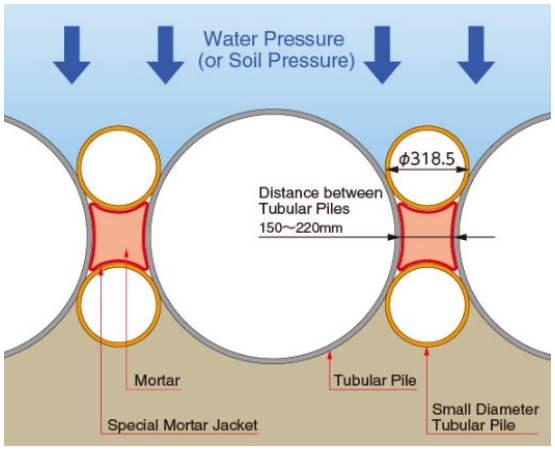

Fig.14 Waterproofing method

The standard installation procedure for a standard pile-to-pile watertight construction method is shown in Fig. 15.

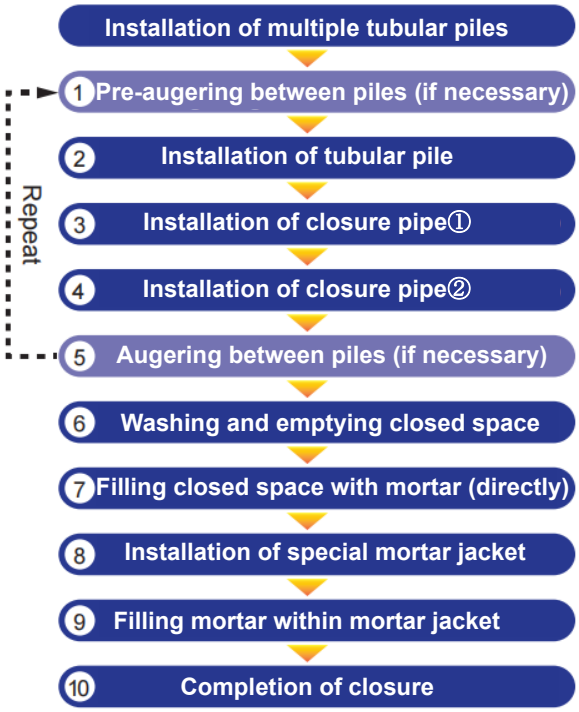

Fig.15 Flowchart of waterproofing method

Fig.16 shows the sequence of the waterproofing method on the project.

Small diameter pipes were installed assisted with the water hammer method. Then, excavation of closed space was performed using a water hammer. After closed the gap between tubular piles, each closed space was washed and cleaned by using 2no. high pressure water jet pipes and compressive air. As a result, the closed space was emptied to the bottom of the closure pipes by removing soil inside the closed space. Mortar jackets are then installed into the closed space and lowered to the specified depth.

Table 2 shows the standard specifications for the special mortar jackets and the mortar.

Table 2. Specification of mortar jacket and mortar

Special Mortar Jacket Specification			Combination of mortar (per 1m³)	
Rupture Strength	Length	4 kN / 5 cm(min.)	Standard	JC Crete N (Standard)
	Width	0.55 kN / 5 cm(min.)	Nominal Strength	21 N/mm²
Elasticity	Length	30%(max.)	W/JC	23%
	Width	50%(min.)	JC Crete	1,660 kg
			Water	384 kg

* The above specifications are standard with the possibility to consider other dimensions.

Therefore, subsequent processes i.e. cleaning the closed space, installing special mortar jackets and filling mortar, can be carried out smoothly.

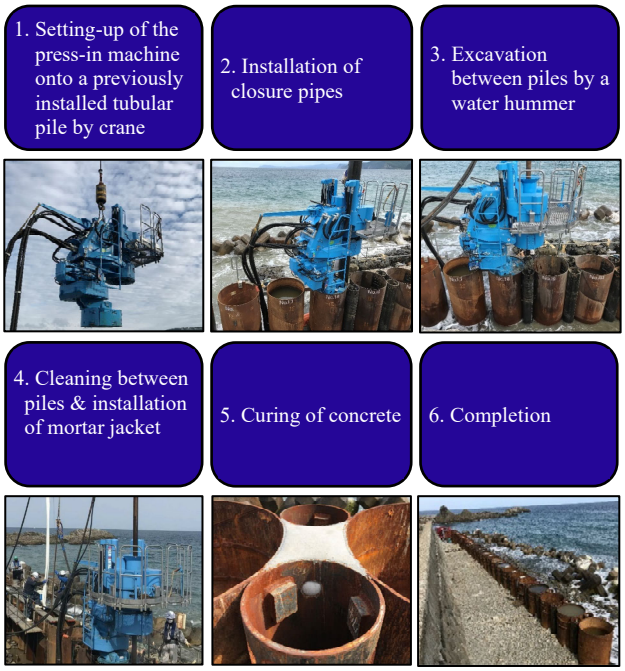

Fig.16 Sequence of waterproofing works

Fig.17 Washing between piles

Fig.18 Mortar filling

3.5. Machine layout plan

Due to the constrained working space, and in consideration of crane lifting capacity and construction efficiency, the pile installation work was started in the middle of the proposed pile line, rather than at either ends of the pile line (Fig.19).

On the other hand, the installation of small diameter pipes began at the ends (Fig.20).

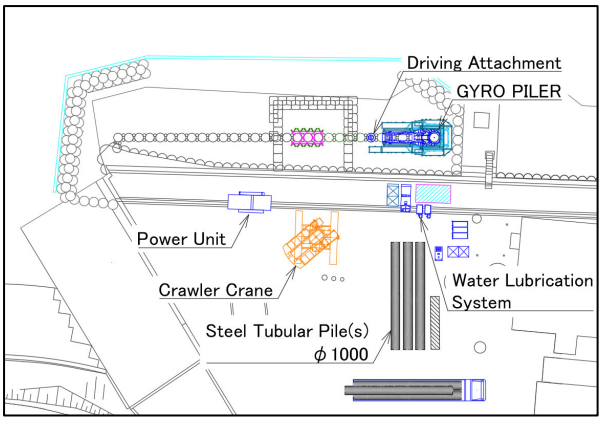

Fig.19 Plan view (Tubular pile)

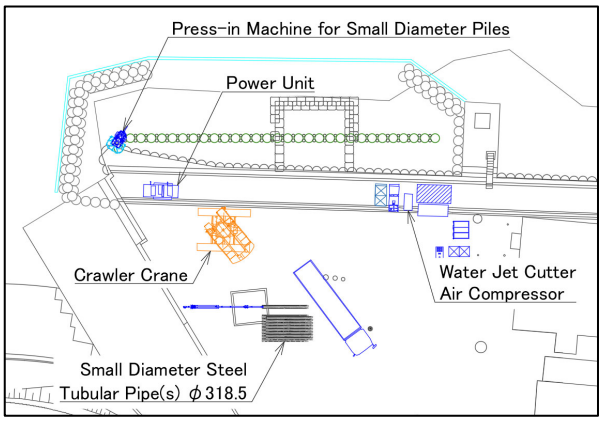

Fig.20 Plan view (Small diameter pies)

3.6. Cross section of the piling

The crane was assembled on land (hinterland) with no impact on the existing seawall, minimizing the frontage to the sea side due to the construction of the work yard. The continuous steel tubular pile wall was constructed with minimal impact on the seaweed beds by Gyropress Method.

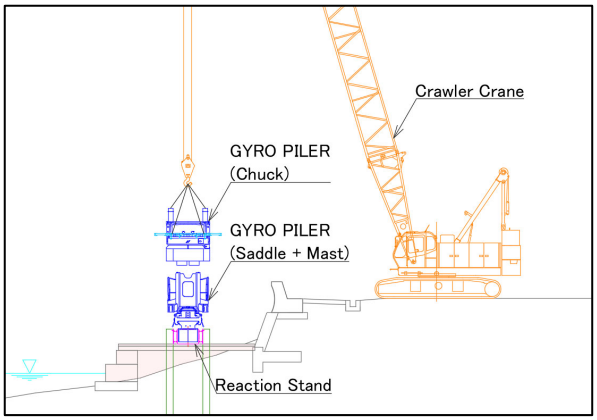

Fig.21 Cross section

3.7. Productivity

The waterproofing work with rotary cutting press-in of tubular piles and small diameter pipes and loading of mortar jackets was completed in approximately two months, from early August to late September 2021. The average productivity of the tubular pile installation was 2 piles per day. As for the water proofing works, the average productivity was 3no. closures (3 gaps between tubular piles) per day, due to the presence of cobbles below the ground surface. The size of cobbles was approximately 300mm in diameter.

As mentioned in 3.4.(2), closure pipes were installed by using the chuck attachment before the specialized press-in machine was developed for installation of the closure pipes. The chuck attachment needs to be attached and detached to/from the GYRO PILER at each time. In contrast, as the specialized press-in machine is dedicated to install closure pipes, it does not require such additional preparation works, resulted in shortening the construction time by approximately 10min per main pile.

Table 3. Specification of steel tubular piles

Type of pile	Specification	Number of piles	Remarks
Tubular pile	Dia.=1000mm, t12mm, L=12.2m	34piles	Main structural pile of seawall
	Dia=318.5mm, t10.3mm, L=5.1m	62piles	Closure pipe

In addition, the piling costs can be reduced by utilizing the specialized press-in machine since it is more economical than the GYRO PILER.

Furthermore, as mentioned in 3.4 (3), with the specialized press-in machine, it is feasible to carry out the installation of tubular piles and closure pipes concurrently. Thus, the construction time can dramatically be shortened compared to the one operation by the GYRO PILER.

4. Concluding remarks

This paper introduces the waterproofing method between piles using closure pipes and mortar and the small-diameter pipe press-in machine through a case study of construction using the Gyropress Method.

As mentioned previously, the development of the specialized press-in machine which is dedicated to install closure pipes aimed for 1) more efficient closure pile installation, 2) reduction of construction time and 3) reduction of construction costs.

Since the first use of the waterproofing method between piles in 2016, there have been approximately 120 actual applications, and the number of applications is increasing.

Based on the experiences gained at the project, the waterproofing method will be improved further to overcome difficult working conditions, such as piling works within a restricted headroom. At the same time, more sophisticated auxiliary equipment and devices will be developed in the future, to achieve higher work efficiencies. These improvements will enhance the completeness of the method as a construction method.

On the other hand, comprehensive monitoring and verification of water tightness of the waterproofing method remain as future challenges. However, one of our case histories shows that the water conductivity of 4.0 x 10-6 (cm/s) was observed on the waterproofing method. With the combination of the efficient and accurate closure pipe installation techniques and highly permeable sealing material (mortar), it will be proved that the waterproofing method performs the similar water tightness to steel sheet pile walls (with interlock filler), secant pile walls and diaphragm walls.

Fig.22 Completion

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