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Interview Report

Overview and Practical Applications of Retaining System by Double-layered Sheet Piles

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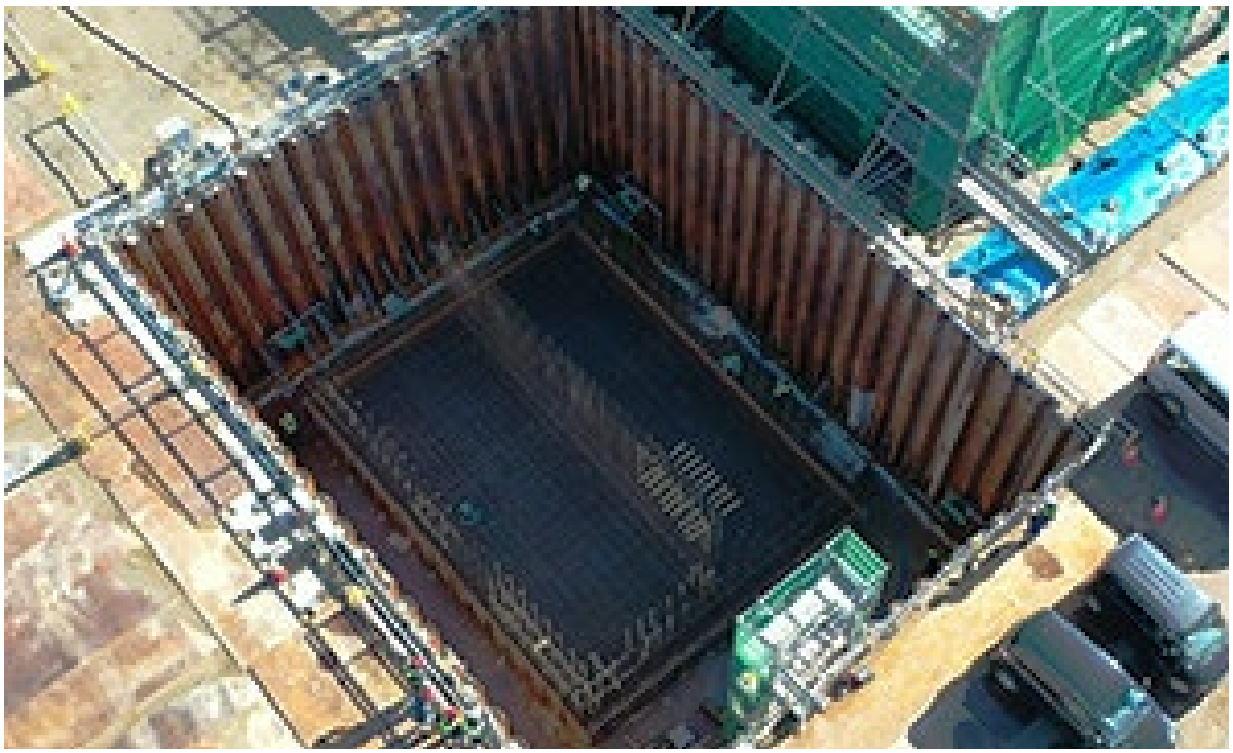


Foreword

Sheet piles have been used in many countries since their first production in Europe in the early 20th century. They are commonly employed for basic foundation structures, such as retaining walls and cofferdams for both temporary and permanent use in the construction of a wide variety of infrastructures. In the case of retaining walls, sheet pile walls are normally propped or anchored when the required retained height is generally greater than 3-4m, in order to restrict lateral deflection of the wall. Alternatively, piles with higher modulus than sheet piles are utilized to achieve a freestanding cantilever retaining wall.

In this report, the IPA introduces the "**Retaining System by Double-layered Sheet Piles**", which enables sheet piles to achieve high modulus walls with a reasonably thin wall thickness, and rationalize bulk excavation works and further construction works. The IPA interviewed the innovator of the method to understand the core idea of the method and its actual practical applications.

Name of the method: Retaining System by Double-layered Sheet Piles
Interviewee: Mr. Naoshi Inoue, KAJIMA CORPORATION

Q1: Could you please tell us about the advantages of the "Retaining System by Double-layered Sheet Piles"?

1) High rigidity: Greater retained height can be achieved compared with normal sheet pile walls.
2) Fewer temporary props required: Bulk excavation works and following construction works can be more easily facilitated.
3) No need for tieback or ground anchors: Less space is required behind the wall.
4) High availability: Sheet piles are widely available and accessible in most areas.
5) Uncomplicated constructability: By utilizing sheet piles, installation works can be carried out trouble-free in limited space.
6) Extractable: Risks of obstacles in future developments are reduced. SDG and decarbonization goals can be more easily met.

Due to the above advantages, the effectiveness of construction works related to retaining structures and substructures can be facilitated with reasonably low costs.

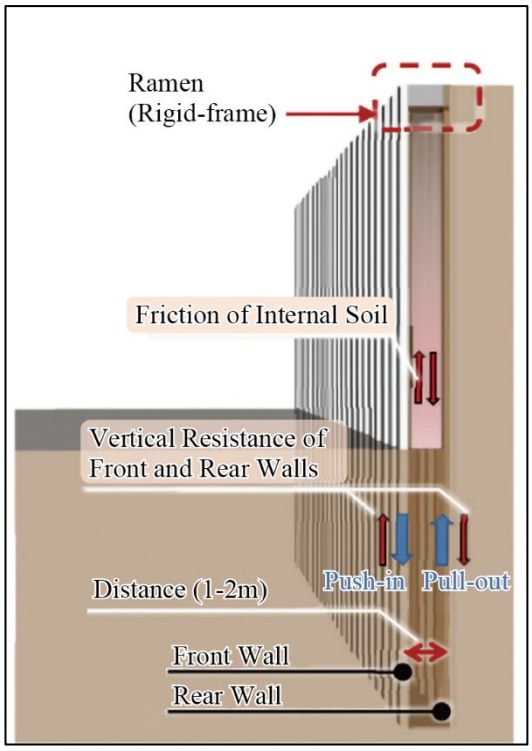


Fig. 1. Overview of Retaining System by Double-layered Sheet Piles

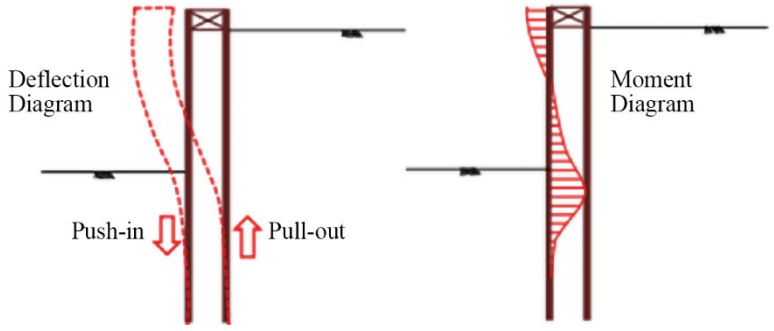


Fig. 2. Behavior of Retaining System by Double-layered Sheet Piles

Q2: What inspired you to develop the method? Please tell us about the background of the development?

In general, temporary support systems, such as props, ground anchors and tieback anchors, are employed when the retained height of a sheet pile wall is 3-4m or greater. Although the temporary support system is effective to maintain lateral deflection of the retaining wall within a certain limit, it may obstruct the following construction works of substructures or require a longer construction time or more construction space behind the wall. As an alternative, high modulus walls, represented by a soil mixing wall (SMW) or other cast in-situ walls are utilized to minimize or eliminate the necessity of temporary support systems. However, these high-modulus retaining walls require large piling equipment and a larger working space, which also accompanies a lot of enabling works. Even if the cast in-situ walls are only for temporary use, most of the time they are left in place, which might be obstacles in future developments.

In order to satisfy such working conditions, the "Retaining System by Double-layered Sheet Piles" was developed to provide economical high-modulus retaining structures with minimum temporary support systems and less working space at relatively low costs.

Q3: As of Feb. 2023, how many projects have the "Retaining System by Double-layered Sheet Piles" been utilized in?

There have been 5 actual projects since the first application in 2020.

Q4: How can we inquire about the method?

Inquiries about the method can be made at the URL below. Kajima Corporation assesses incoming inquiries on a case-by-case project basis.

INQUIRY (KAJIMA CORPORATION)：https://www.kajima.co.jp/english/contact/index.html

Q5: What kind of geotechnical analysis software is required for the utilization of the method?

General FEM software, which has an elasto-plastic analysis function for retaining wall design, can be used.

Q6: What determines the distance between the two walls?

When the double-layered sheet pile walls are designed, the distance between the walls is determined by taking into account 1) the land available behind the front surface of the retaining wall, 2) the required rigidity of the ramen and 3) the constructability of the walls. The greater the distance, both the rigidity of the ramen and its constructability tend to decline. Therefore, a maximum distance of 2m is recommended to satisfactorily meet the above criteria.

Q7: There are two types of rigid connections to fix two sheet pile walls i.e. Steel Frames and RC. How can we decide on the most suitable connection method in relation to the working conditions?

In terms of a structural point of view, both types can equally be utilized as long as the required rigidity of the ramen is achieved. In the past, the type of rigid connection was selected mainly considering working conditions and environmental aspects. For instance, if the hot work (cutting and welding operations) is restricted, steel connections are not normally used. On the other hand, an RC connection is normally avoided when stringent noise & vibration limits are in place.

Fig. 3. RC Connection

Fig. 4. Steel Connection

Q8: Are there any additional items related to project management when constructing the double-layered sheet pile walls compared with normal sheet pile wall?

In order to provide uniform space between the front and rear wall, installation tolerances need to be controlled more stringently compared with a normal sheet pile wall.

Q9: Can curved walls be installed?

Yes, curved walls can be constructed. The minimum radius of the wall is governed by the maximum angle of deviation in the interlocks of sheet piles.

Q10: If a circular double-layered sheet pile wall is constructed and the space between the two walls is filled with concrete, can we expect "arching effect"?

Arching effect can be expected, and as a result, lateral deflection of the wall can be minimized.

Q11: How much water tightness can we expect with the double-layered sheet pile wall?

It is thought that the water tightness is simply doubled in the case of the double-layered sheet pile wall.

Q12: If the retaining wall requires bearing capacity, can we also expect skin friction on the insides of the double-layered wall?

With the double-layered sheet pile wall, skin friction can be expected on entire surfaces of the embedded sheet piles.

Q13: What is the achievable bending stiffness of the wall compared with a normal sheet pile wall?

4-8 times greater bending stiffness can be expected compared with a normal sheet pile wall.

Q14: Could you please tell us about your promotional activities in bringing the method to the market?

We are currently promoting the method by inserting advertisements in construction journals and introducing the method at academic seminars.

Q15: Could you please tell us about your future promotional plan, including overseas markets?

We conduct our promotional activities in both the domestic market and overseas markets. At this time, we are prioritizing Southeast Asia and also countries such as India and Bangladesh in the Subcontinent.

Project Case History

1. Purpose of Project
   Construction of a water purification plant
2. Overview and Purpose of Retaining Wall
   "Retaining System by Double-layered Sheet Piles" by utilizing U sheet piles Type Ⅳ
   (Rectangular Cofferdam, Inner Dimension 19.2m x 14.4m, Retained Height 8.2m)
   Installation Method: Press-in Piling Method (assisted with Water Jetting)
   Extraction Method: Press-in Piling Method
   *See Figure 5.
3. Ground Conditions
   *See Figure 5.

In order to construct a water purification plant on the project, the "Retaining System by Double-layered Sheet Piles" was chosen to carry out bulk excavation works without a temporary support system. The site investigation record shows that there is a thick sandy layer underlying the top cohesive layer. With a high groundwater table and an adjacent new structure, the design of the retaining structure was complicated. Under such conditions, the bulk excavation of over 8m was carried out without a temporary support system.

As Figure 5 shows, the cofferdam was designed in a rectangular shape. As for the riged-frame (ramen), the RC connection was selected because of the additional beam effect at the top of the retaining wall. The bulk excavation was carefully carried out down to the formation level (8.2m below the ground level). At the same time, the lateral deflection of the wall was monitored using surveying equipment and inclinometers.

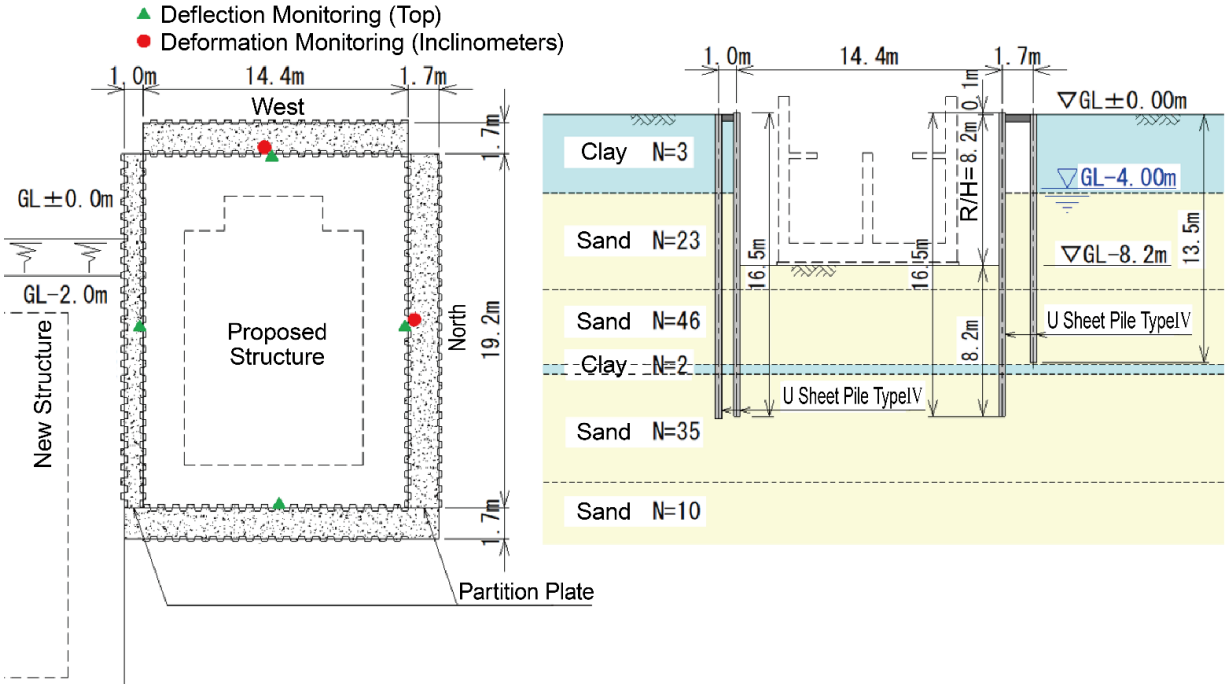
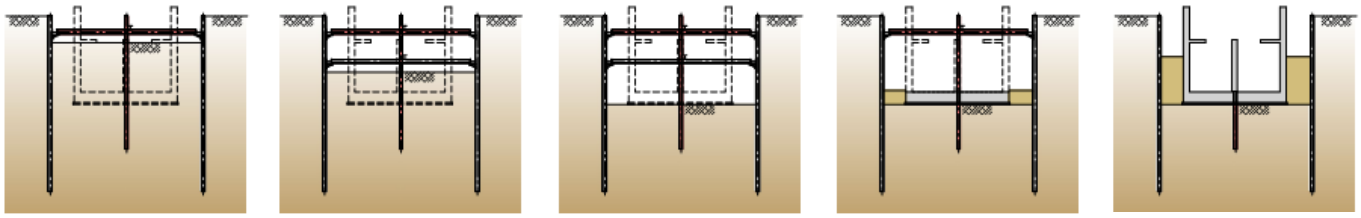


Fig. 5. Plan and Cross Section of the Double-layered Wall

Fig. 6. Excavation and Construction of Substructure

Original Design (Single Sheet Pile Wall with 2 Level Props)



Initial excavation. Install intermediate vertical support. Install 1st level props.

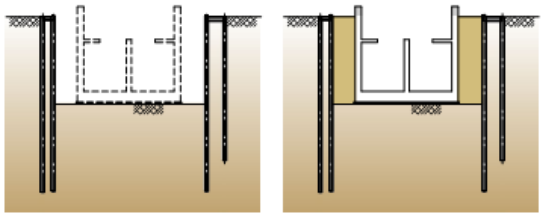
2nd excavation. Install 2nd level props.

Excavation down to formation level.

Base slab construction. Remove 2nd level props.

Side wall construction. Remove 1st level props. Remove intermediate vertical support. Backfilling.

Double-layered Wall



Excavation down to formation level.

Substructure construction. Backfilling.

Advantages of Double-layered Wall

- Reduction of construction sequences.
- Improvement of constructability of substructure.
- Increased construction safety due to a better range of vision and a larger work space.
- Better quality of substructure due to intermediate vertical support being obsolete.

Fig. 7. Comparison in Construction Sequences

As Figure 7 shows, the "Retaining System by Double-layered Sheet Piles" enabled the excavation and construction works for the substructure to be carried out in a spacious environment without obstructive temporary support systems. Thus, the constructability, safety of the substructure construction and the quality of substructure were enhanced.

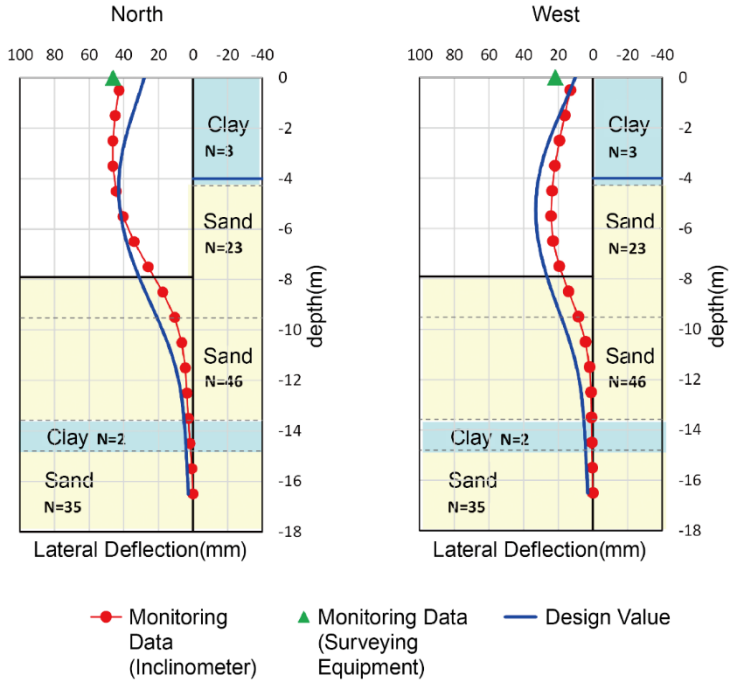


Fig. 8. Deflection Design Values and Monitoring Results

Figure 8 shows deflection monitoring results on monitoring points which are indicated in Figure 5. The wall deflection profiles show that the retaining wall bent in an S-shape profile, which shows that the ramen (riged-frame) at the top of the wall effectively met its functionality. The maximum deflections of the double-layered walls were found to be below the pile top level. In contrast, in the case of a cantilever retaining wall, lateral deflection is normally greater at the top of the wall.

The main purpose of the connection between the front wall and rear wall is basically to fix the walls rigidly to form a ramen (ridged-frame). In addition to this, it is assumed that the RC ridged-frame also acts as an edge beam at the top of the retaining wall. This additional benefit was observed, as shown in Figure 9. There are cracks in the middle of the RC frame and a gap at both ends of the RC frame, which shows that the RC frame was impacted by its bending during excavation. We expect this secondary effect (acting as an edge beam) increases the advantages of the double-layered wall.

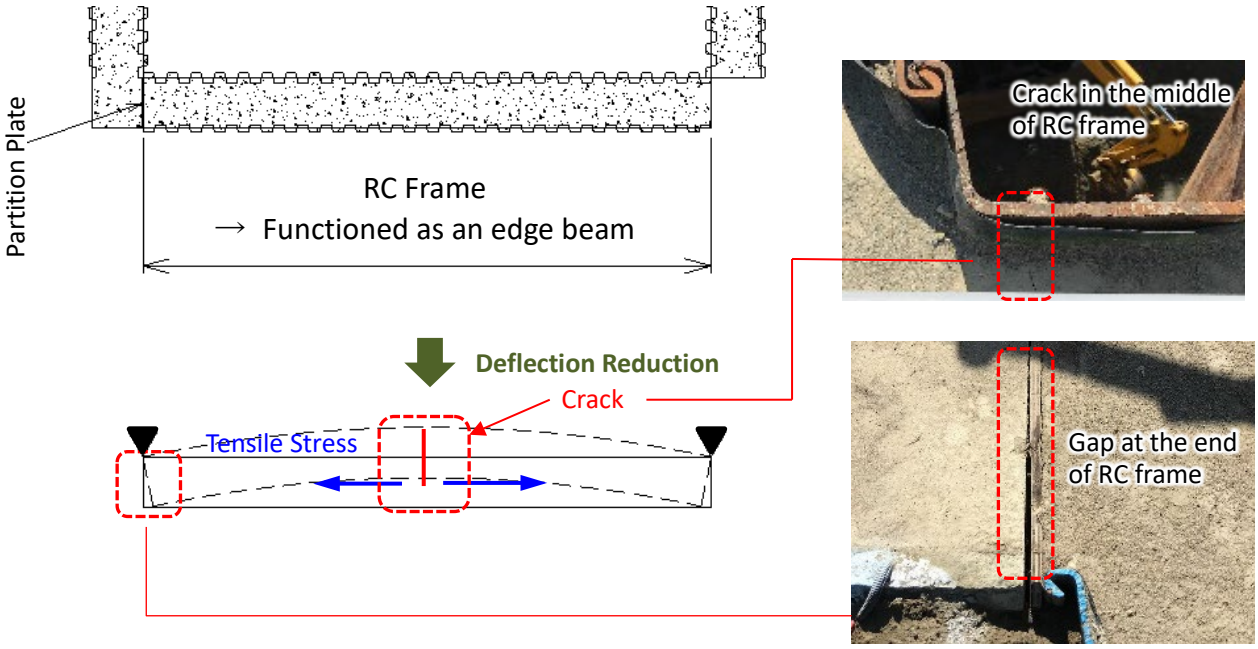


Fig. 9. Edge Beam Effect Observed on the Project

REFERENCE

Inoue, Naoshi., et al., 2022, Development and applications of “Retaining System by Double-layered Sheet Piles” for rationalization/streamlining bulk excavation, *The Construction Technology Research Meeting* (in Japanese).