Report

A new steel sheet-pile method for countermeasures against the settlement of embankment on soft ground -Development of PFS Method-

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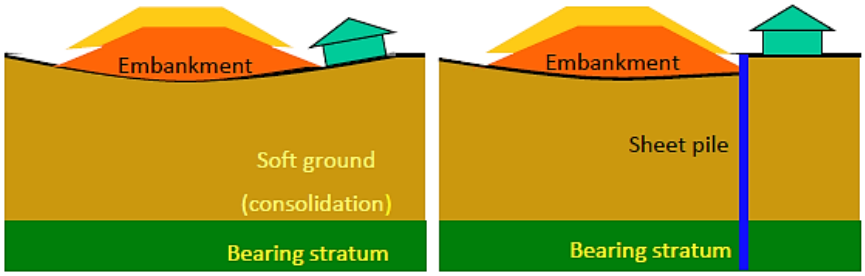
1. Introduction

When the embankment is constructed on soft ground, the ground subsidence for not only the ground under the embankment but also the ones around embankment are serious problems and some countermeasures have to be considered. A steel sheet-pile method is one of the countermeasures for this problem as shown in **Figure 1**. However, this type of structure has a cost problem when the area and depth of soft ground are wider and deeper, so that a new sheet-pile method has been expected.



(a) Without countermeasures (b) With sheet-pile countermeasures

Figure 1 Sheet-pile countermeasures

In 1975, a collaborative research started between Kyushu University and the Ministry of Construction (Ministry of Land, Infrastructure, Transportation and Tourism at present) in Japan. Under this collaboration, a series of in-situ full scale tests were conducted in Kyushu area. Based on those activities, a research committee for developing a new sheet-pile method was established in 2003 (the chair is Prof. Hidetoshi Ochiai, Professor Emeritus of Kyushu University, Japan). In 2005, a new sheet-pile method called PFS method (Partial Floating Sheet-pile) was proposed under the activities of this committee. In this method, the end bearing sheet-pile and that of floating type were combined to deal with its effectiveness and cost as shown in **Figure 2**. **Figure 3** shows the details of this structure. In this report, this PFS method is briefly introduced.

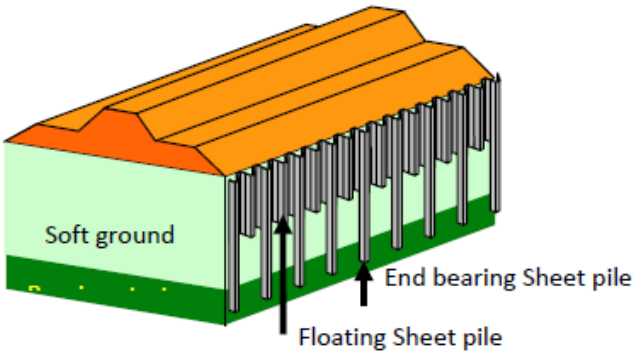


Figure 3 PFS method

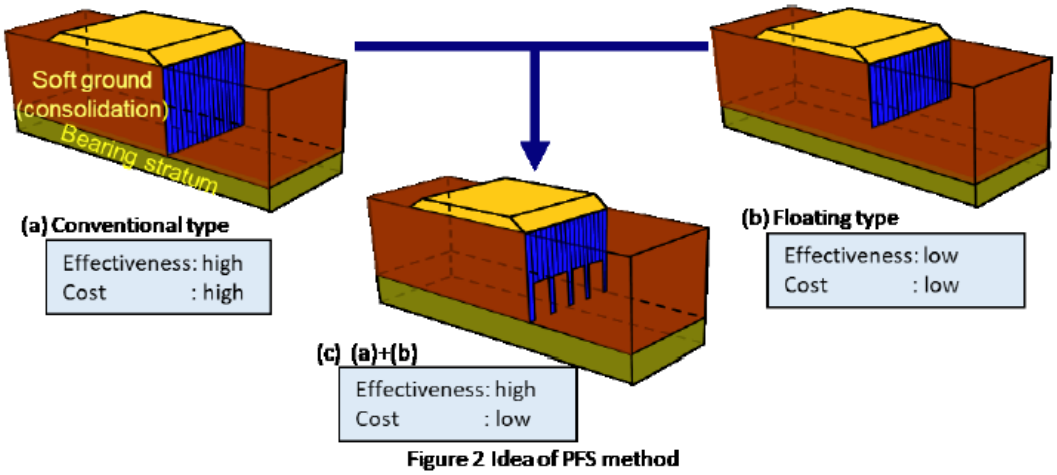


Figure 2 Idea of PFS method

2. Performance of PFS method at the site

As mentioned before, a large number of in-situ full scale tests were conducted in Kumamoto City, Japan. This area is well known as a region of Ariake Clay which is a highly sensitive clay and its depth is up to 40m. **Figure 4** shows the soil profile at the site of in-situ test for PFS method. In this case, one end bearing sheet-pile for five floating sheet piles were constructed. **Figure 5** shows the results of measurement for the settlements at the site and as easily realized, the effectiveness of the PFS method is clearly shown. **Photograph 1** shows the view of the site after PFS construction. Since a large volume of sheet-pile materials were reduced, the cost of the PFS method is obvious and the construction time is also highly reduced because of the less volume of the sheet-piles.

Photograph 1 After the PFS construction

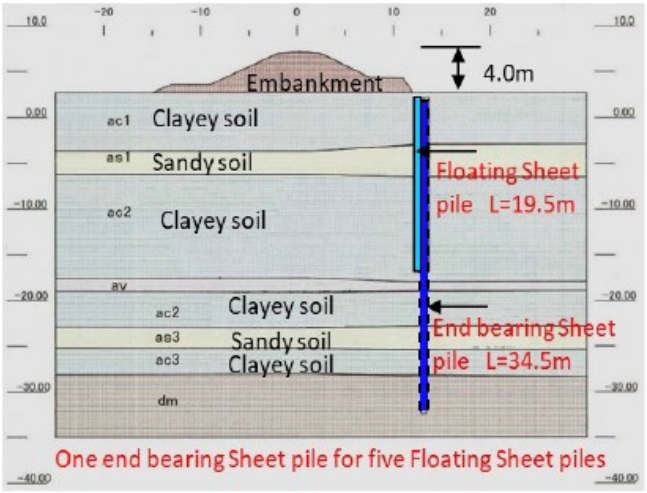


Figure 4 Ground condition at the site

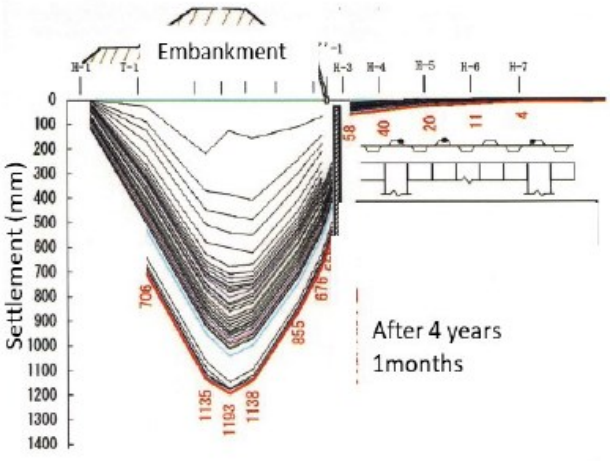


Figure 5 Results of measurements

3. Numerical Modeling

A series of numerical modeling was conducted. Here, because of the shape of PFS method, three dimensional FE analysis was conducted as a consolidation problem. **Figure 6** shows the 3D mesh for this analysis and the results such as total settlement and pore water pressure change in ac.1 layer as shown in **Figure 4** were compared with the measurement results as shown in **Figure 7**.

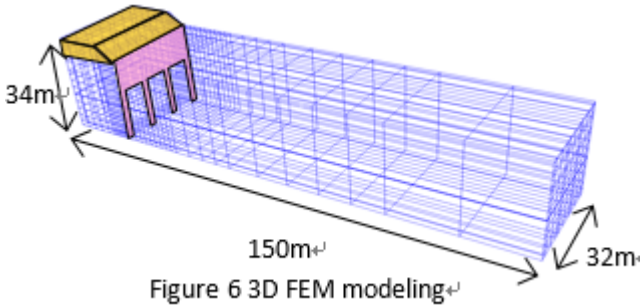
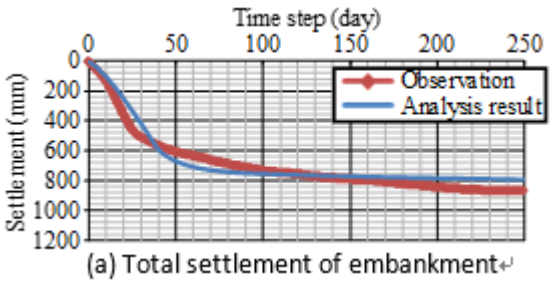


Figure 6 3D FEM modeling



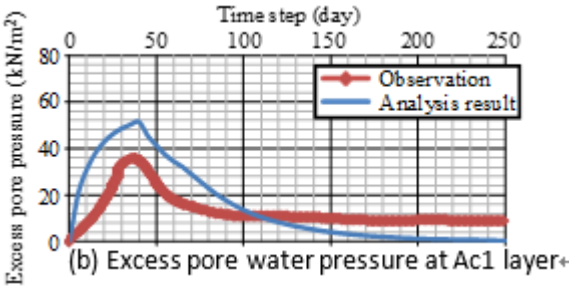


Figure 7 Simplified design model

4. Design Procedure

Under the activities of the research committee of the new sheet-pile, a simple design method was proposed in 2007 and this idea is shown in **Figure 8** which is the combination of spring with beam elements. The basic idea is the consideration of only vertical displacement.

5. Closing Remarks

A summary of the development of PFS method was briefly introduced. The quantification of this method was also done by in-situ test and numerical modeling, and to design this method, a simple model was proposed.
However, as shown in **Photograph 2**, sheet-pile method has been used for more and more for the permanent structures, so that the upgrading of the method is indispensable such as the behavior under earthquake. The potential of liquefaction is also the one for checking at the site. Under those circumstances, IPA has recently started a technical committee for the steel sheet-pie (TC-3) and within three years (2017-2019), a total of 20 members around the world joined this committee to discuss what we have to do for upgrading the PFS method.

Finally, I would like to give my acknowledge to all the researchers and engineers who joined the development of PFS method such as the research committee members in 2003 including the members from the Ministry of Land, Infrastructure, Transportation and Tourism, and the members of Japanese Association for Steel Pipe Piles.

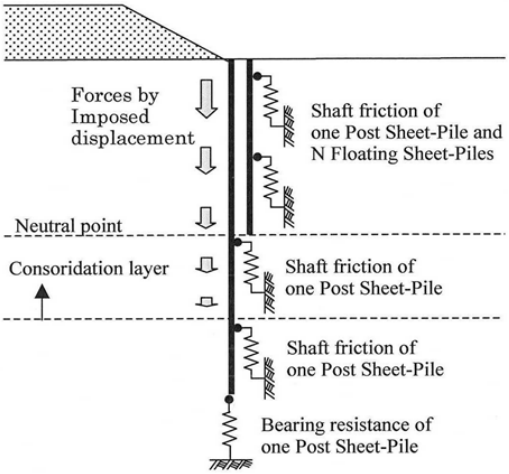
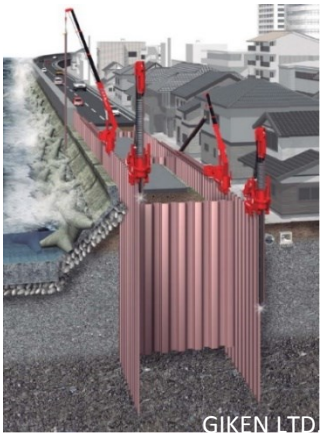


Figure 8 Simplified design model



Photograph 2 Recent sheet-pile method

◆ A brief CV of Prof. Jun Otani

Prof. Jun Otani is a full Professor of Geotechnical Engineering at Kumamoto University, Japan and he is the immediate past Vice President of the Japan Geotechnical Society. He is also the Director of IPA and chair of TC-3 (sheet-pile). He got his master at Nagoya University, Japan and moved to U.S.A. for Ph.D. study. He got his Ph.D. at the University of Houston, TX in 1990. His research was pile foundations as his Ph.D. study and later, he has done many research activities on soil reinforcement. In fact, he was the organizing committee chair of the 15th Asian Regional Conference on Soil Mechanics and Geotechnical Engineering under ISSMGE in 2015. Recently, he deeply involves the research on the application of X-ray CT in geotechnical engineering. He established the international society called IntACT and plays a role of the Vice President.