On-site verification for installation and permeability of H-jointed SPSPs with H-H joints

La vérification sur place pour l'installation et la perméabilité de SPSPs H-joint avec H-H joint

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ABSTRACT
In this research, we conducted field installation and permeability tests for H-jointed SPSPs with H-H joints for their first application in the field; the tests were conducted in December 2006. Through a series of field installation and permeability tests, we verified the various factors considered in the construction field when using SPSP methods. These factors include the field installation and water interception performance of H-jointed SPSPs with H-H joints as well as their performance with regard to construction vibration, construction noise, welding and pullout. In this paper, the field installation and water interception performance of H-jointed SPSPs with H-H joints are reported on the basis of the results obtained from the field installation and permeability tests.

RÉSUMÉ
Dans cette recherche, nous avons effectué une première installation et des essais de perméabilité in-situ pour les joints H avec des joints H-Hen Décembre 2006. A travers cette série d'essais in-situ, nous avons vérifié différents facteurs rentrant en ligne de compte lorsque l'on utilise la méthode SPSP sur le terrain. Ces facteurs incluent l'installation sur le terrain, les performances d'interception de l'eau des SPSP H-jointed avec des joints H-H également les performances vis-à-vis des vibrations, du bruit, du soudage et de l'arrachage. Dans cette article, les performances de l'installation sur site et de l'interception de l'eau des joints H-H sont relatées sur la base des résultats obtenus et des essais de perméabilité.

Keywords: H-H joint; H-jointed steel pipe sheet pile; field installation; field permeability

1 INTRODUCTION

"H-jointed steel pipe sheet piles" and "H-H joints" are respectively steel pipe sheet pile and steel pipe sheet pile joint, developed as one of the techniques of SPSPs in the year 2000. Here, H-jointed steel pipe sheet pile is an integrated building material comprising Steel pipe - H-shaped steel - Steel pipe, which is obtained by previously welding 2 steel pipes (Kimura et al. 2007) and an H-shaped steel form in the factory; the H-H joint has 2 H-shaped steel forms of different dimensions interlocked together (Inazumi et al. 2005).

In this research, field experiments on installation and water interception were carried out in December 2006 on H-jointed steel pipe sheet piles (SPSPs) with an H-H joint (Photo. 1), which happens to be the first instance of using H-H joints on-site. In a series of field experiments on installation and water interception on H-jointed SPSPs with an H-H joint. This paper reports the knowledge gained by focusing on performance of on-site installation and water cut-off exhibited by H-jointed SPSPs with an H-H joint.

2 H-JOINTED STEEL PIPE SHEET PILES (SPSPS) AND H-H JOINTS

2.1 *Development process*

Figure 1 shows the development process of H-jointed SPSPs and H-H joints as against that of conventional SPSPs. An H-jointed SPSP (Fig. 1(b)) is a steel pipe sheet pile obtained by welding steel pipes with 2 H-shaped steel forms. Further, through the centrifugal membrane test, it is clear that the steel pipe sheet piled foundation which uses H-jointed SPSPs, exhibits 1.3 times the horizontal resistance strength as the conventional SPSP foundation (Kimura et al. 2007). There are H-H joints on both ends of H-jointed SPSPs (Fig. 1(c)), obtained by interlocking 2 pre-fabricated H-shaped steel forms of different sizes. The H-H joint is expected to show high rigidity, economy and water cut-off property due to the usage of pre-fabricated H-shaped steel forms. Further, by the effective use of the wide rectangular gap (hollow portion) in interlocked H-H joints, a design fulfilling the purpose of the application is possible. For example, regarding rigidity of the joints, it is possible to weld steel rods of different diameters along the depth of the inner surface of the H-type steel and mortar can be filled in, or, rigidity can be improved by using bolts. The water cut-off effect can be improved by filling an adhesive and deformable material before installing the water-swelling material (Inazumi et al. 2005 and 2006).

2.2 *Installation performance of H-jointed SPSPs*

It is possible to simultaneously install H-jointed SPSPs as an integrated H-jointed steel pipe sheet pile, as Steel pipe - H-shaped steel - Steel pipe. However, there is a concern over increase in the size of the hammer resulting from increase in the

Photo 1. Stages of improvement of SPSP joints

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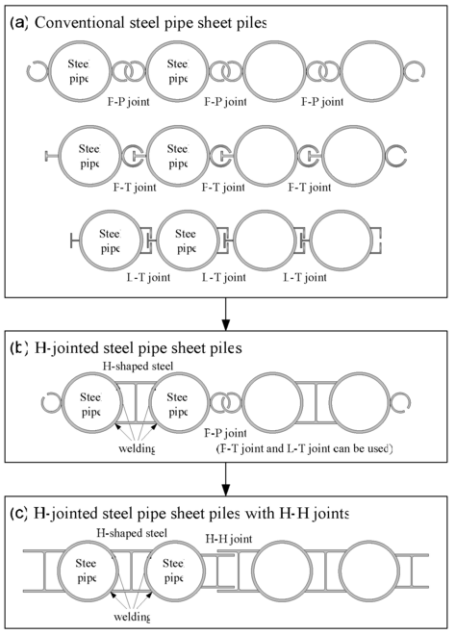

Figure 1. Development process of H-jointed SPSPs and H-H joints

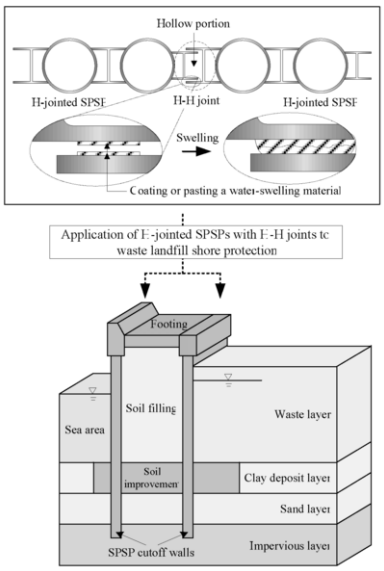

Figure 2. General application of H-jointed SPSP with H-H joints to waste landfill shore protection

resistance of the surrounding surface and bottom ground, leading to difficulty in installation. Accordingly, regarding on-site installation of H-jointed SPSPs (Fig. 1(b)), the following knowledge was gained from the experiments on on-site installation and the bridge pier foundation, after checking the performance at the time of on-site application.

1) In the installation experiments, by the vibration impact method of using a vibro hammer (capacity 150 kW), the H-jointed SPSP was made to penetrate through the sandy soil layer with N value of 10-20 to the supporting layer (N > 50), reaching to a depth of 12 m. The present execution performance test for H-jointed SPSPs was the first on-site test and, in spite of not having any experience-based know-how regarding installation work, a vertical installation accuracy of within 1/240 was possible (Kimura et al. 2007).
2) In case of the application as bridge pier foundation, a vibro hammer of capacity 180 kW was used and the H-jointed steel pipe sheet pile was made to penetrate through the sandy soil layer with N value of more than 20 to the supporting layer (N > 50), reaching a depth of 45 m. Also, it was possible to assure a vertical installation accuracy of 1/200-1/2130 on completion of the installation (Kimura and Inazumi 2007).

2.3 *Water cut-off treatment and performance*

H-jointed SPSPs with an H-H joint are considered to be effective in structures such as waste landfill shore protection or earth retaining walls, where high grade water cut-off has to be assured (Fig. 2). In general, while using H-jointed SPSPs for water cut-off applications, it is necessary to treat the water permeable joints for water cut-off treatment, and the method of filling mortar etc. in the installed interlocking joints is adopted for this purpose.

Regarding H-jointed SPSPs with an H-H joint, in the interlocking H-H joints, there is a plane gap of 6-11 mm between the contact surfaces of the H-shaped steel form, and the gap is considered to be subjected to water cut-off treatment. Accordingly, water cut-off treatment of H-H joints is conducted by closing the plane surface gap of the H-H joint by coating or pasting a sheet of water-swelling material on the contact surface of the flange of the H-H joints before the installation (Fig. 2). Until now, on the basis of large scale laboratory permeability tests, the performance of water cut-off of H-jointed SPSPs with an H-H joint has been determined quantitatively and the properties have been summarized below.

1) Under landfill management water level (2 m, i.e. difference between water levels inside and outside the landfill), the H-jointed SPSPs with an H-H joint can exhibit a high water cut-off property of order 2 of magnitude less than the water cut-off standard ($k_e \leq 1\times10^{-6}$ cm/s) calculated by using the hydraulic conductivity as waste landfill shore protection (Inazumi et al. 2005 and 2006).
2) Strength of the coating of the water-swelling material used for water cut-off treatment of the H-jointed SPSPs with an H-H joint shows a tendency to stabilize in time. Further, it is clear from the recent pressure tests of water-swelling material and the strength tests of the swelling membrane carried out over 4 years (Inazumi et al. 2005 and 2006).
3) The hollow portion of the H-H joint (Fig. 2) is larger than in other types of joints, making it possible to install a borehole camera or some other observation tool, and hence, checking of working condition and long term evaluation of water cut-off effect is possible.
4) Usage of H-jointed SPSPs with an H-H joint for waste landfills site shore protection is effective because of their excellent bending rigidity (Kimura et al. 2007); interlocking and sealing of the joints (Inazumi et al. 2005 and 2006).

3 FIELD EXPERIMENTS ON INSTALLATION AND WATER INTERCEPTION

3.1 *Outline of the test*

Figure 3 shows the shape and standard for the H-jointed SPSPs with an H-H joint used in the field experiments on installation and water interception. In the on-site tests, 3 units of H-jointed SPSPs with an H-H joint were installed in series to form interlocking H-H joints of different sizes at 2 places.

Figure 4 shows soil quality column and N value of the installation ground, obtained from the previous boring examination. By considering the soil quality conditions etc., the H-jointed SPSPs with an H-H joint constructed from the lower and upper posts was inserted to a depth of 14 m into the sandy clay layer. Specifically, after installing the lower post of H-jointed SPSPs with an H-H joint, the top of the lower post and bottom of the upper post were connected by joint welding at the site, and the upper post was then installed. The method of vibration impact from a vibro hammer was adopted for

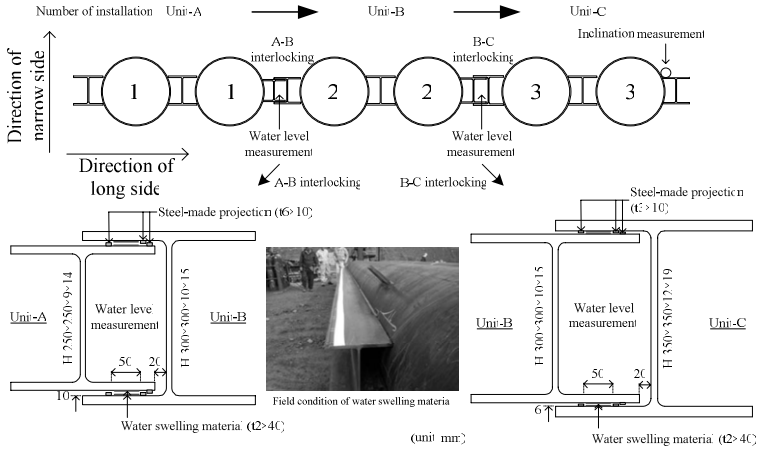

Figure 3. Installation order of H-jointed SPSPs with H-H joint and position of coating water swelling materials

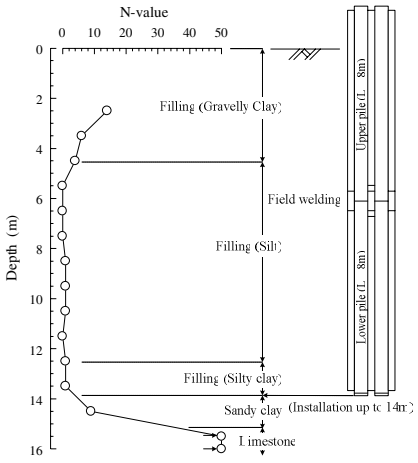

Figure 4. Soil properties of the installation ground

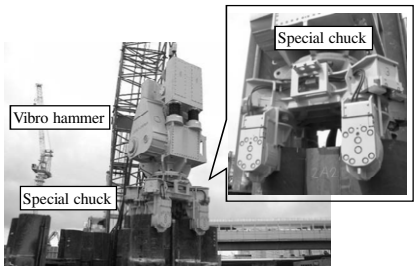

Photo 2. Special purpose working chuck

installation of H-jointed SPSPs with an H-H joint. A vibro hammer with a capacity of 180 kW, that is, one rank higher than that required for the installation of the conventional SPSP according to the required penetration strength was used, and a special purpose working chuck (Photo. 2) was constructed at the tip for the H-jointed SPSP. A 150 t class crawler crane was used as the heavy hoisting machinery.

After the installation of H-jointed SPSPs with an H-H joint (total 3 units) by using the vibro hammer, removal of soil and cleaning of the internal cavity of the interlocking H-H joints (Fig. 3) at 2 places as well as grouting water cut-off treatment of the inner ends of the joints were carried out and this was followed by grouting of the ends of the joints. Then the change in the water level in the two H-H joints and in the observation well separately established at a distance of 30 m from the installation-site was measured. As the test site was close to the harbor, the variation of tide level was also measured at the same time. Here, the variation of water level was measured for 8 hours after a lapse of 24 hours after carrying out the end grouting water cut-off treatment.

3.2 *On-site installation accuracy*

For verifying the on-site performance of the H-jointed SPSPs with an H-H joint, the accuracy of vertical installation is considered to be the most important. An SPSP that can be installed with high accuracy assures a sound interlocking and it increases the reliability of interlocking treatment after the installation (cleaning the earth and sand from the joint and water cut-off treatment). Further, by inhibiting collision between the joint sections, vibration and noise around the installation can also be reduced. Accordingly, the accuracy of vertical installation of the H-jointed SPSPs with an H-H joint was measured by introducing a slot-in type tilt measuring instrument into the protection tube fitted to the Unit-C shown in Fig. 3, during the field experiments on installation and water interception.

Figure 5 shows average relative change in position in H-jointed SPSPs with an H-H joint during the installation. Now, the change in position of the tip of the installed H-jointed SPSPs with an H-H joint is taken as a standard for the relative change in position. According to this, at an installation depth of 14 m, the H-jointed SPSPs with an H-H joint showed a relative change in position of about 1.1 cm along the length and 0.5 cm along the width. One of the reasons for the difference in change in position along the length and width may be that the gap of both flanges of H-H joints along the width (steel protuberance) is 0.6 to 1 cm whereas the gap up to the flange and the web along the length is 2 cm and, the installation is done with comparatively less restriction along the length (Fig. 3). However, when the accuracy of vertical installation is checked, the H-jointed SPSPs with an H-H joint were found to have an accuracy of 1/2620 along the width and 1/1110 along the length. Usually the installation accuracy of SPSP is stipulated to be 1/100 the H-jointed SPSPs with an H-H joint shows a very high accuracy as compared to the stipulated value. Now, the on-site installation of H-jointed SPSPs with an H-H joint was the first trial and no experiential know-how existed for the working persons. Even under those sorts of conditions, for the H-jointed SPSPs with an H-H joint, the rotation of parts during the installation can be suppressed and installation with a high vertical accuracy is possible. One of the reasons for this may be the large cross sections differing in size along the length and width, and high rigidity against the ground resistance that makes vertical installation of the H-jointed SPSPs with an H-H joint in upright manner.

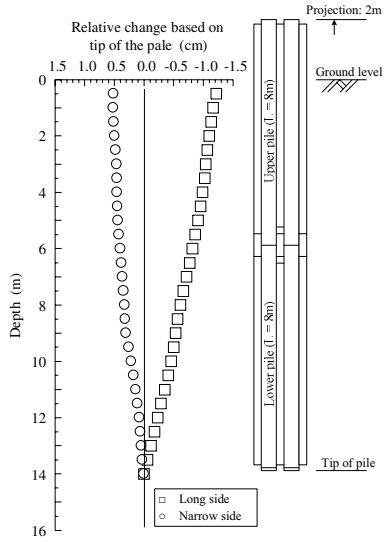

Figure 5 . Average relative change in position in H-jointed SPSPs with an H-H joint during the installation

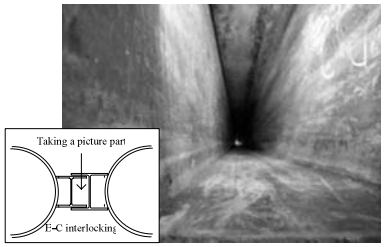

Photo 3. Inside H-H joint after removing soil and cleaning the joints

3.3 *Removing soil and cleaning the joints*

Removing soil and cleaning the 2 places of interlocked H-H joints was done by agitating the soil and sand from the joint portion by using water jet (55 kW high pressure pump) and this was followed by sucking out the agitated soil and sand by means of a vacuum dumper. As a result, it was possible to insert a flexible hose of large size (ϕ100 mm) into the interlocking portion by creating a large rectangular gap in the interlocking H-H joint. Moreover, it was confirmed that the operation of cleaning of the soil and sand could be possible in appropriate time for reducing the friction between the soil and sand in the joint and steel material of the joint. Photograph 3 shows the state of the H-H joint after removing soil and cleaning the joints.

In the water cut-off grouting of the H-H joints end, a grout containing a quick-hardening agent was poured in up to a height of 2 m from the lower end of the joint, after confirming that soil could surely be removed up to the bottom of the joints by inspection of drilling length of the H-H joint interlock. Here also, a certain filling operation was possible by means of inspection of drilling length and visual observation, because there could be a large gap in the H-H joint.

3.4 *On-site water cut-off performance*

Water cut-off performance of H-H joint sections of the H-jointed SPSPs with an H-H joint can be increased by bonding a water-swelling material within the H-H joints. However, the water-swelling material is bonded before the installation of the SPSP and there is a fear of losing it after the installation. Moreover, in this field experiments on installation and water interception, the interval between installation of each unit of

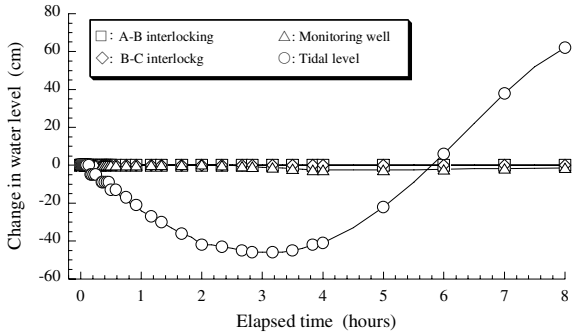

Figure 6. Inner cavity of 2 interlocking H-H joints

H-jointed SPSPs with an H-H joint was about 24 hours. Consequently, in case of the H-jointed SPSPs with an H-H joint installed earlier, the swelling of the water-swelling material had already occurred and thus in this situation, interlocking of the later installed H-jointed SPSPs with an H-H joint had to be done.

On the basis of the above, Fig. 6 shows the inner cavity of 2 interlocking H-H joints, change in the water level measured in the observation well and also tide level variation. This shows that in the 8 hours of observation in the field experiment on water interception, large variations in the water level in the 2 H-H joints and in the water level of the observation well were not observed, although there was a change in the tide level. From this, it may be concluded that H-jointed SPSPs with an H-H joint has sufficient on-site water cut-off properties.

4 CONCLUSIONS

The conclusions obtained are as follows.

1) No rotation or twisting of parts of H-jointed SPSPs with highly rigid H-H joints occurred unless some additional operation was performed at the time of installation. This made it possible to install the H-jointed SPSPs with an H-H joint with high accuracy.
2) On-site interlocking performance of H-jointed SPSPs with an H-H joint was confirmed from the fact that it has enabled the reliable cleaning of soil and sand from inside of the joints and there is no collision at the joints.
3) H-jointed SPSPs with an H-H joint is expected to show a hydraulic conductivity of the order of 1×10^{-8} cm/s even at the site. However, this is based on the results of measurements carried out within 8 hours after a lapse of 24 hours after the completion of installing the H-jointed SPSPs with an H-H joint followed by the seepage analysis.

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