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Leachate Control Technology Using H-Jointed Steel Pipe Sheet Piles with H-H Joints at Coastal Landfills

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Abstract: H-H joint of "H-jointed SPSP with H-H joint", which is made up of interlocking two H-steel sections of different sizes, is the one of SPSP's joint to improve the hydraulic conductivity. "H-H jointed SPSP with H-H joint" is expected to be applied to a vertical cutoff wall in coastal landfill sites. In H-jointed SPSP with H-H joint, the H-joint is completely imperviousness. H-H joint, however, is pervious at interlocked state because a gap of 8 to 11 mm is left between the interlocking flanges, therefore, a water interception treatment must be conducted to seal the gap. The water shielding treatment of H-H joint is executed by coating the gaps with a water-swelling sheet of paint before its installation. Then, hollow space is generated in H-H joint after treating by water-swelling sheet, and that space can be used effectively. This paper proposes leachate control technologies using H-H joint interior space of SPSP cutoff walls. The possibility of those technologies and hydraulic conductivity of H-jointed SPSP with H-H joints are demonstrated by conducting the hydraulic conductivity test.

Key words: H-H joint, H-jointed steel pipe sheet pile, hydraulic conductivity.

1. Introduction

With the aim of reducing the risk of contaminating groundwater and disposing as much wastes in Japan, waste landfill sites have been transferred from inland to coastal area in recent years. Waste landfill sites in coastal area are constructed as landfills and are required to contain toxic substances in landfills. Generally, in order to contain toxic substances, vertical hydraulic cutoff walls are built at the side of landfills and impervious clay layer at the bottom is used since it's important to prevent toxic substances existing in landfills from flowing out through vertical hydraulic cutoff walls and bottom impervious layer (see Fig. 1), they must be retained the function of containing

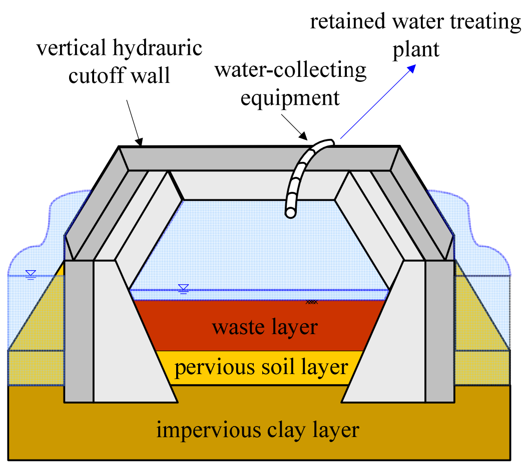

Fig. 1 Vertical hydraulic cutoff walls.

pollutants in landfills at any time. From the viewpoint of construction and economical reasons in vertical hydraulic cutoff walls at the side of landfills, steel pipe sheet piles have been usually used as vertical hydraulic cutoff walls [1].

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Since 1960s when steel pipe sheet piles have been used as vertical cutoff walls, traditional joints, which are P-P joint, P-T joint, and L-T joint, are usually used to connect steel pipes (see Figs. 2(a)-(c)). A water shielding treatment of these joints is done by stuffing a low permeability material which is packed mortar or asphalt in those interior cavity spaces. In addition, the improved P-T joint, which is installed with rubber plate (see Fig. 2(d)), has been proposed to guarantee high water shielding performance. Recently, H-jointed SPSPs with H-H joints (see Fig. 3), whose hydraulic conductivity are higher than above joints, have been developed. In other words, a lot of researches have been done since 1960s and the water shielding performance of SPSPs has been improved step by step.

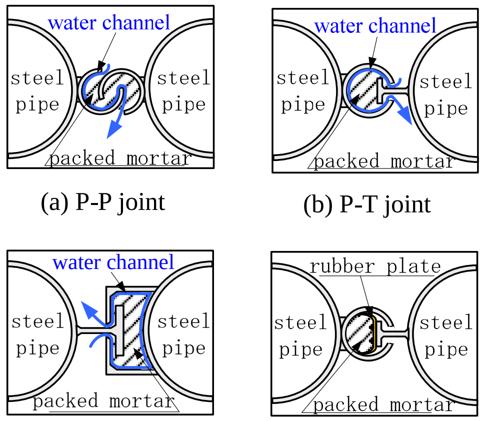
However, reducing the amount of leachate from waste through SPSPs is possible; it's hard to build vertical cutoff walls which have the function of completely preventing water channels from being developed by above treatments from the viewpoint of long term perspective. Thus, it's necessary to consider new water shielding methods in SPSPs to protect environments around landfills from toxic substances.

This paper proposes some leachate control technologies using H-H joint interior space as new methods to prevent leachate from flowing out through vertical hydraulic cutoff walls. It's possible to prevent leachate from flowing out through SPSPs if above technologies are applied to vertical hydraulic cutoff walls.

2. H-Jointed SPSP with H-H Joint

In H-jointed SPSP with H-H joint, the H-jointed SPSP consists of two steel pipe piles connected by a H-steel welded on them [2]. On the other hand, the H-H joint is made up of interlocking two H-steels in different sizes and two H flanges and a interior space are formed in H-H joint [3, 4].

Considering the water shielding treatment, H-joint is completely imperviousness because it's connected by the H-steel between steel pipes each other. H-H joint, however, is pervious because a gap of 8 to 11 mm is left



(a) P-P joint (b) P-T joint

(c) L-T joint (d) improved P-T joint

Fig. 2 Traditional joints of SPSP.

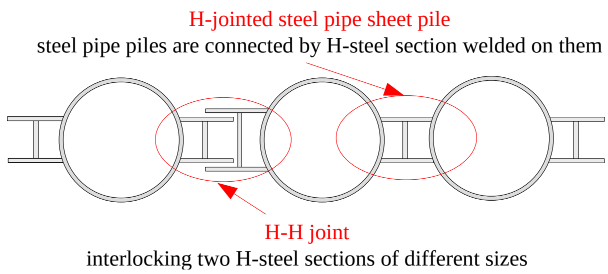


Fig. 3 H-joint SPSP with H-H joint.

between the interlocking flanges. Therefore, a water interception treatment must be conducted to seal the gap. The water shielding treatment of the H-H joint is executed by coating the gaps with water-swelling sheets at both H flanges before its installation (see Fig. 4). Then, the hollow space is generated at the inside of the H-H joint after treating by water-swelling sheets (see Fig. 5). Here, washing sand and clay in internal space of the H-H joint was done in the field test. The test demonstrated that it's possible to exclude sand and clay in the H-H joint interior space.

A variety of hydraulic conductivity test for the H-H joint was carried out using permeability test equipment, and the detailed method of the test is contained in Ref. [3]. For example, the hydraulic conductivity of the H-jointed SPSP with H-H joint, whose sizes of 250×250×9 (in web)×14 (in flange) and 200×200×8 (in web)×12 (in flange) mm, respectively, was evaluated when it is coated with water-swelling sheets of three different thicknesses i.e. 1, 2 and 3 mm. As a result, it is observed that k_e of the H-jointed SPSP with H-H joint

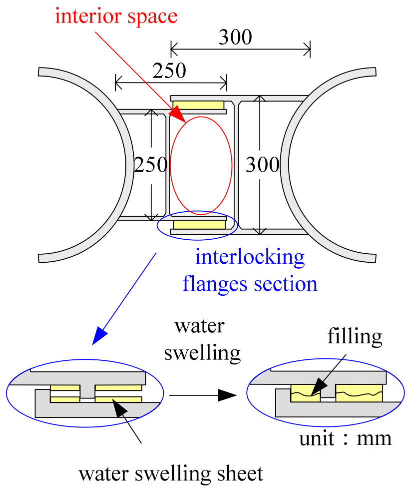
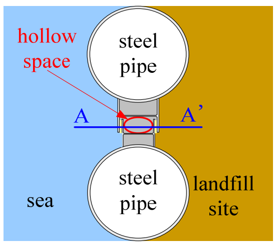
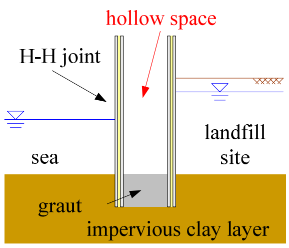


Fig. 4 Water shielding treatment in H-H joint.



(a) top view



(b) A-A' section

Fig. 5 Hollow space generated at H-H joint.

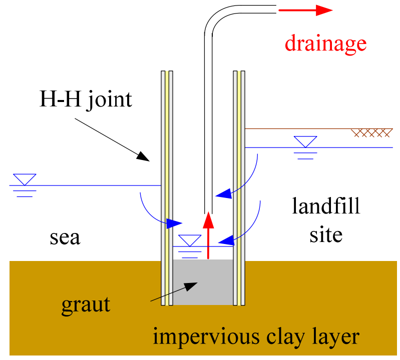
depends on thickness of the applied sealant and the level of water pressure. In addition, the difference of the water quality does not greatly affect the hydraulic conductivity of the H-jointed SPSP with H-H joint.

In the past study, the high water shielding performance of the H-jointed SPSP with H-H joint was demonstrated. However, the hollow space of H-H joint wasn't considered to be used effectively. Hence, this paper proposes some leachate control technologies using that hollow space to archive the water-shielding perfectly.

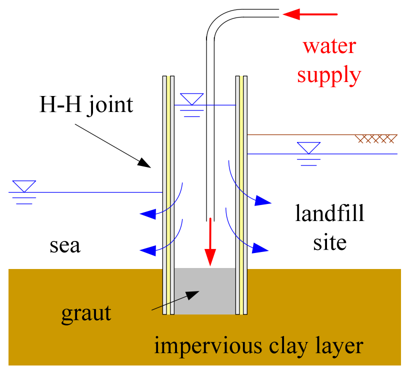
This paper shows some leachate control technologies using the hollow space at the inside of H-H joint.

3. Leachate Control Technology

Leachate control technologies using H-H joint interior space are as follows: (1) filling it with low permeability materials, (2) keeping the water level of the hollow space low (see Fig. 6(a)), (3) maintaining high water level (see Fig. 6(b)).



(a) keeping the water level of the hollow space low



(b) maintaining high water-level

Fig. 6 Leachate control technologies using H-H joint at coastal landfill site.

First technology of filling it with low permeability materials includes stuffing the H-H joint interior space with packed mortar or asphalt to prevent development of bleeding channel. On the other hand, keeping the water level of the hollow space low forms hydraulic gradient where water flows in from the exterior of H-H joint to interior space, then all water that flows in is drained through pumping. In the case of keeping the water level of the hollow space low, furthermore, pollutants in waste are expected to be cleaned up since leachate from a waste landfill site is pumped out. In addition, maintaining the high water level is seepage control technology that water flows out from inside of H-H joint to outside by retaining the high water level.

Considering the maintenances and repairs of the hollow space from a long-term perspective, in filling it with low permeability material, it's difficult to find water channels when they are developed and fixing water shielding treatments is almost impossible because H-H joint interior space is packed full of mortar or asphalt. In the case of keeping the water level of the hollow space low and maintaining the high water level, by contrast, the repairs of the deteriorated water interception treatment are easy because there is nothing but only water that can be excluded handily in H-H joint. In addition, it's possible to monitoring the permeability of both H flanges by measuring the extent of the elevation of water level at H-H joint interior space. Hence, this paper takes into account not only keeping the water level of the hollow space low but also maintaining the high water level among the three technologies and discusses the effectiveness and the possibility of two technologies by a demonstration test which is a hydraulic conductivity test.

4. Demonstration Test

This paper evaluates the effectiveness and the possibility of two technologies with the demonstration test on maintaining the high water level.

Though a testing procedure is followed from the past hydraulic conductivity test, the height of this H-H joint model is 500 mm. A water tank and a H-H joint model are made from transparent acrylic to confirm the movement of water. Additionally, in coastal waste landfill sites, the maximum water level difference between the contained water and the outer sea level must not exceed 2 m [1]; this level must be controlled during heavy rains, water tide variations, and high water waves. Reports, however, indicate that some landfills have been filled to 5 m way beyond the specified limit of 2 m water level difference. It is important therefore to evaluate k_e of a H-jointed SPSP with H-H joint for application as a cutoff material at landfills based on the 5 m (equivalent to 0.05 MPa) water pressure rather than the specified 2 m (equivalent to 0.02 MPa) water level difference.

A layout of apparatus used in the test is shown in Fig. 7 and Fig. 8. In addition, the procedure of the test is as follows:

(1) The water-swelling sheets were used, they were coated the H flanges at the interlocking interfaces by a

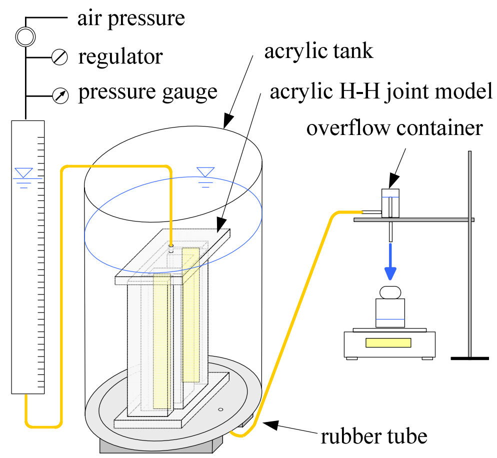


Fig. 7 A layout of testing apparatus.

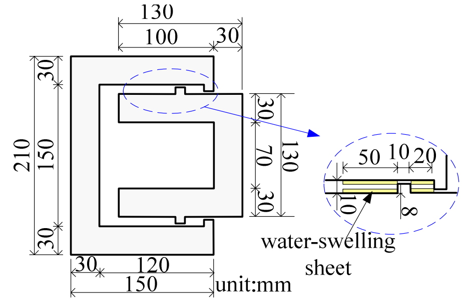


Fig. 8 The detail of the acrylic H-H joint.

high strength adhesive.

(2) Water was poured into the acrylic tank so that the largest surface area of the water-swelling sheets was wetted and balance of water pressure achieved in the H-H joint model.

(3) The acrylic plate cover was bolted over the rubber packing onto the H-H joint model before swelling process of the water-swelling sheet began, this procedure ensures that swelling is only in the horizontal and transverse directions.

(4) The sealed model was kept at an immersed state for 24 hours and temperature maintained 20 °C to allow for the paint sheet to react and swell to its optimum.

(5) A small amount of colorant (uranine) was mixed with water in the H-H model.

(6) The air compressor accessories are fixed in the pressure inlet on the acrylic plate cover and the outflow tube fixed in place to terminate into the overflow container.

(7) The following pressure amounts were applied:

0.02, 0.05 MPa. Each pressure level was maintained for 1 hour.

(8) The amount of the water flow from interior space to outside was measured 1 hour after the start of the test.

In Japan, the specified standard hydraulic conductivity of waterproofing structures in landfills is k=1.0×10^{-6} cm/s; it is based on hydraulic conductivity of a 50 cm thick soil layer. Since the current standard does not expressly specify standards for SPSP as cutoff walls in landfills, the measured hydraulic conductivity of the SPSP are thus converted to equivalent hydraulic conductivity for an homogenous soil layer whose dimensions are equal to those used to develop the Japanese hydraulic conductivity (k_e= 1.0×10^{-6} cm/s) standard.

5. Results and Discussion

Fig. 9 shows the acrylic tank 1 hour after start of the test.

In the case of coating the water-swelling sheets of thickness 2 mm, the change didn't take place in the water in the acrylic water tank. This result was the same as the sheets of thickness 3 mm. On the other hand, in coating the water-swelling sheets of thickness 1 mm, the water in the acrylic water tank has been slightly dyed because internal water of H-H joint model flowed out from inside to outside where the water level is lower than inside. Therefore, in the case of keeping the water level of the hollow space low, the hydraulic gradient that flows from the outside to the inside is formed. Meanwhile, in the case of maintaining the high water level at H-H joint interior space, the water that exists internal flows out outside. Thus, in both technologies, leachate through H-H joint can be prevented to reasonably manage the interior space of H-H joint.

Fig. 10 shows the measured equivalent hydraulic conductivity for H-jointed SPSP with H-H joint sealed with water-swelling sheets of thickness 1, 2, and 3 mm against water pressure.

(a) thickness : 1 mm

(b) thickness : 2 mm

Fig. 9 The acrylic tank 1 hour after start of the test.

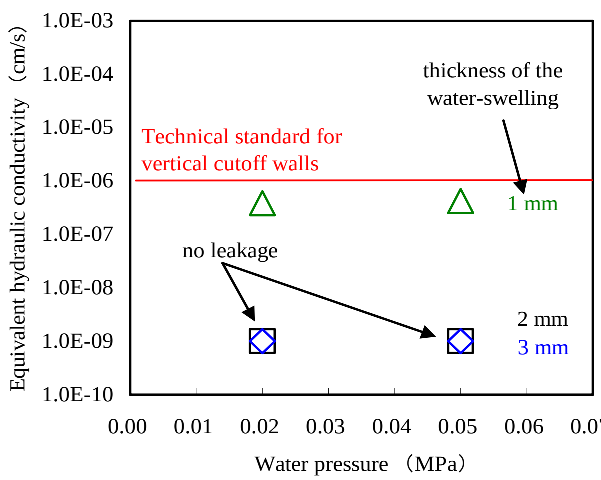


Fig. 10 Measured equivalent hydraulic conductivity for H-jointe.

The water-swelling sheets with thickness of 1 mm and above meet specified the equivalent hydraulic conductivity of k_e 1.0×10^{-6} cm/s (see Fig. 10). In addition, it is confirmed that impermeability of H flanges interlocking section can be controlled by adjusting the thickness of the bonded water-swelling sheet. For example, k_e for the H-jointed SPSP with H-H joint coated with 1 mm paint sheets was very low in the order of 1×10^{-7} cm/s at a water pressure of 0.02 and 0.05 MPa. On the other hand, k_e for the 2 and 3 mm sheets coated joint was too small and could not be measured, since there was no effluent flow collected in the 1 hour test duration, k_e can be said to be below 1.0×10^{-9} cm/s. Hence, it's possible to form the hollow space (the low water level) or the high water level at H-H joint interior space by coating the water-swelling sheets that have the thickness of 1, 2, and 3 mm on the H flanges at the interlocking interfaces. In both keeping the water level of the hollow space low and maintaining high water level, even if the hydraulic gradient is generated due to the decrease in water shielding performance at H flanges, in the case of keeping the water level of the hollow space low, water flows from outside of H-H joint to inside, while it flows from outside to inside when high water level is maintained at H-H joint interior space.

In this study, the water shielding technologies using H-H joint interior space are guaranteed to appropriately manage interior space. In addition, the required permeability to keep hollow space or maintain the high water level at H-H joint interior space is obtained through coating the water-swelling sheets of thickness 1, 2, and 3 mm. Moreover, the volume of the water flowing into inner space of H-H joint or flowing out from interior space of it can be controlled in keeping hollow space (the low water level) or maintaining the high water level respectively.

6. Conclusions

The following conclusions were drawn from this study:

(1) Hollow space (the low water level) or the high water level can be formed to the interior space of H-H joint by coating the water-swelling sheet that has the thickness of 1, 2, and 3 mm on the H flanges at the interlocking interfaces.

(2) In maintaining the high water level at H-H joint interior space, leachate from H-H joint can be prevented from flowing out because the water flows from inside the space to low water level.

(3) It's possible to control permeability of H flanges interlocking section by adjusting the thickness of the coated water-swelling seat.

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