

DESCRIPTION

TITLE

ROTARY PENETRATION STEEL PIPE PILE AND METHOD FOR
5 CONSTRUCTING ROTARY PENETRATION STEEL PIPE PILE

TECHNICAL FIELD

10 **[0001]** The present disclosure relates to a steel pipe pile that is constructed by rotating it into the ground, and in particular, the present disclosure relates to a rotary penetration steel pipe pile configured to be placed so that a pile end is arranged in an intermediate layer without reaching a supporting layer, and to a method for constructing the rotary penetration steel pipe pile.

BACKGROUND

15 **[0002]** In a case in which the supporting layer exists deep underground (e.g., at a depth of 30 m or more) and the intermediate layer (e.g., 10 m to 20 m underground with an N value of 5 to 30) exists, so-called friction piles, which are designed to support load using frictional resistance from the ground acting on outer circumferential surfaces of pile bodies, are often used so as to reduce
20 pile material costs and construction costs.

[0003] Such friction piles are often inferior to concrete piles in terms of economic efficiency, because the bearing capacity per pile is so small that the material strength cannot be fully exerted when they are formed by steel pipes or tubes.

25 To address this, some steel pipes or tubes are provided, on an outer circumferential surface thereof, with a large number of wings, so that the bearing capacity (apparent frictional force) is increased and the material strength of the steel material can be fully exerted. Typical examples of the existing technology are described in Patent Literature (PLT) 1 and Patent
30 Literature (PTL) 2.

[0004] A steel pipe pile described in PTL 1 includes a large number of spiral vanes each formed in a spiral shape in at least one round on an outer circumferential surface of the pile, wherein the spiral vanes are intermittently arranged on the outer peripheral surface of the pile.

35 A steel pipe pile described in PTL 2 includes a spiral vane that is wound in one round and that is intermittently disposed.

CITATION LIST

Patent Literatures

[0005] PTL 1: JP 2012-136823 A

5 PTL 2: JP 2003-074057 A

SUMMARY

(Technical Problem)

[0006] In the steel pipe pile of PTL 1, each spiral vane has an increased bearing
10 capacity because it is formed in the spiral shape in at least one round. However, material costs and installation costs of the wings inevitably increase.

On the other hand, the spiral vane of the steel pipe pile of PTL 2 is wound in one round, and costs can be reduced than in PTL 1. However, slippage is likely to occur. For this reason, a steel pipe pile that has been put to practical
15 use in a manner similar to that of PTL 1 includes vanes with a diameter (wing diameter) of approximately twice that of a diameter of the steel pipe or tube, making it a costly pile even though they are intermittent.

[0007] It would be helpful to provide a rotary penetration steel pipe pile configured to be placed so that the pile end is arranged in the intermediate
20 layer without reaching the supporting layer and that can provide a sufficient bearing capacity while reducing costs, and a method for constructing the rotary penetration steel pipe pile.

(Solution to Problem)

[0008] (1) A rotary penetration steel pipe pile according to the present
25 disclosure is a rotary penetration steel pipe pile configured to be placed so that a pile end is arranged in an intermediate layer without reaching a supporting layer, the rotary penetration steel pipe pile including:

a substantially spiral-shaped lowermost wing that is wound in one round and that is disposed in vicinity of the pile end; and an upper wing that is
30 wound in one round and that is disposed above the lowermost wing in a plurality of tiers at regular intervals ranging from 1.25 times to 7.5 times a wing diameter, wherein

an outer diameter of the lowermost wing is larger than an outer diameter of the upper wing and is set to be 1.5 times to 3 times a pile diameter,
35 and

the outer diameter of the upper wing is smaller than the outer diameter

of the lowermost wing and is less than or equal to 1.6 times the pile diameter, and a pitch of the upper wing is set to be equal to a pitch of the lowermost wing.

[0009] (2) A method for constructing a rotary penetration steel pipe pile according to the present disclosure is a method for constructing the rotary penetration steel pipe pile according to (1) above, the method including

rotating and penetrating the rotary penetration steel pipe pile, while adjusting downward pushing force applied to the pile from a pile driver so that the degree of penetration per rotation is equal to the pitch of the lowermost wing.

(Advantageous Effects)

[0010] Since including the lowermost wing with a diameter larger than that of the upper wing at the pile end, the rotary penetration steel pipe pile according to the present disclosure can provide a large vertical bearing capacity even though it is a pile to be set in the intermediate layer.

Furthermore, the multi-tiered upper wing having a wing diameter less than or equal to 1.6 times the pile diameter is arranged above the lowermost wing, by considering the diameter and the intervals at which it is attached. This can provide a large frictional resistance, while reducing attachment costs.

Moreover, the pitch of the lowermost wing is equal to the pitch of the upper wing. This can prevent softening of the ground around the upper wing and provide a reliable frictional resistance.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] In the accompanying drawings:

FIG. 1 illustrates a rotary penetration steel pipe pile according to an embodiment of the present disclosure;

FIG. 2 illustrates effects of the rotary penetration steel pipe pile of FIG. 1; and

FIG. 3 is a graph illustrating results of experiments performed to determine the relationship between wing interval and wing diameter of an upper wing in a rotary penetration steel pipe pile according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0012] A rotary penetration steel pipe pile 1 according to the present

embodiment is configured to be placed so that a pile end is arranged in an intermediate layer without reaching a supporting layer, and it includes a substantially spiral-shaped lowermost wing 3 that is wound in one round and that is disposed in the vicinity of the pile end, and an upper wing 5 that is disposed above the lowermost wing 3 in a plurality of tiers.

The features will be described in detail below.

[0013] <Use Application>

As mentioned above, the rotary penetration steel pipe pile 1 according to the present embodiment is a so-called friction pile, which is configured to be placed so that the pile end is arranged in the intermediate layer without reaching the supporting layer.

Such a friction pile is constructed in the ground where the depth of the supporting layer is deep (e.g., 30 m or more in depth) and the intermediate layer (e.g., 10 m to 20 m underground with an N value of approximately 5 to 30) exists.

Additionally, end-bearing piles, which have a pile end configured to be placed into the supporting layer so as to be supported by the supporting layer, are typically set in a stratum with an N value of approximately 30 or more, and their use application is different from that of the rotary penetration steel pipe pile 1 according to the present disclosure.

[0014] <Lowermost Wing>

The lowermost wing 3 is a substantially spiral-shaped wing that is wound in one round and that is disposed in the vicinity of the pile end.

An outer diameter of the lowermost wing 3 is larger than an outer diameter of the upper wing and set to be 1.5 times to 3 times a pile diameter.

The vicinity of the pile end includes an end surface of a steel pipe or tube 7, which is a pile main body, or an outer circumference of the steel pipe or tube 7 in the vicinity of the end.

The substantially spiral-shaped wing refers to a wing that has a spiral shape or a pseudo-spiral shape and that has the same screwing effect as a spiral-shaped wing. For example, it includes a wing composed of two half-split annular flat plates connected in series so as to form a single nearly spiral shape.

[0015] The reason why the outer diameter of the lowermost wing 3 is set to be 1.5 times to 3 times the pile diameter is as follows.

Based on construction track records of rotary penetration piles achieved by the present inventors, it is known that when the outer diameter is

less than 1.5 times the pile diameter, so-called slippage (a spinning phenomenon in which the degree of penetration per rotation becomes extremely small) is likely to occur. On the other hand, when the outer diameter exceeds approximately 3 times, torque during rotational penetration becomes too large, thus exceeding an allowable torsional torque of the pile body and the rotational capacity of the pile driver. Besides, when the outer diameter exceeds 3 times, it is necessary to increase the thickness of the wing so as to accommodate the increased torque, and this can cause stress concentration and welding difficulties.

10 **[0016]** <Upper Wing 5>

The upper wing 5 is a substantially spiral-shaped wing that is wound in one round and that is disposed above the lowermost wing 3 in the plurality of tiers.

15 The wing intervals between the plurality of tiers in the upper wing 5 are set to be regular intervals ranging from 1.25 times to 7.5 times a wing diameter.

The outer diameter of the upper wing 5 is smaller than the outer diameter of the lowermost wing 3 and is less than or equal to 1.6 times the pile diameter, and its pitch is set to be equal to a pitch of the lowermost wing 3.

20 **[0017]** The upper wing 5 is a wing that is wound in one round and that is disposed in the plurality of tiers, and it therefore is an intermittent wing. The reason for this is due to considerations on the attachment cost.

25 That is, although continuous attachment would increase penetration performance and in-service bearing capacity during construction, the attachment cost will be several times more, so more emphasis is placed on the attachment cost.

[0018] The reason for setting the wing intervals between the plurality of tiers in the upper wing 5 to be regular intervals ranging from 1.25 times to 7.5 times the wing diameter will be explained based on FIG. 2.

30 The vertical bearing capacity according to the present disclosure is a composite of two kinds of bearing capacity, that is, upward ground reaction (which is referred to here as "end bearing capacity" for convenience) that acts on a lower surface of the lowermost wing 3, and bearing capacity (referred to here as "friction resistance" for convenience) that is yielded by the multi-tiered upper wing 5.

35 **[0019]** Because the magnitude of the end bearing capacity is roughly

proportional to a value obtained by multiplying the strength (hardness) of the ground by the area of the lowermost wing 3, the larger the wing area, the better for the present disclosure, which is applied to the ground that is not very hard. For this reason, the outer diameter of the lowermost wing 3 is at least 1.5 times
 5 the pile diameter.

Furthermore, the frictional resistance is a smaller one of the following two values: the sum of bearing resistance of the individual tiers of the upper wing 5 illustrated in FIG. 2; and shear resistance of the ground on a cylindrical body (indicated by dotted lines) wherein the circumference coincides with the
 10 outer diameter of the upper wing 5.

[0020] Which one of the sum of the bearing resistance and the shear resistance is larger varies slightly depending on the soil type and the hardness of the ground. Nevertheless, the present inventors have conducted studies and found that when a value obtained by dividing each wing interval of the upper wing 5
 15 by the wing diameter of the upper wing 5 (wing interval/wing diameter) is less than 1.25, the shear resistance on a side surface of the cylindrical body becomes considerably smaller than the sum of the bearing resistance of the upper wing 5.

The wing interval / wing diameter is therefore preferably 1.25 or more.
 20 On the other hand, when the wing interval/wing diameter exceeds 7.5, the sum of the bearing resistance becomes considerably smaller than the shear resistance on the side surface of the cylinder, because the number of attached wings in the intermediate layer, wherein the layer thickness is limited, decreases.

25 In view of the above, by setting the wing interval/wing diameter to be 1.25 to 7.5, a good balance can be achieved, and a large frictional resistance can be provided.

Additionally, it is demonstrated in a later-described Example that the wing interval/wing diameter is preferably 1.25 or more.

30 **[0021]** The reason for setting the outer diameter of the upper wing 5 to be less than or equal to 1.6 times the diameter of the steel pipe or tube is as follows.

Because the cross-sectional area of the upper wing 5 increases in proportion to the square of its diameter, the material cost also increases in proportion to the square.

35 On the other hand, the bearing force yielded by the upper wing 5 is not proportional to the square of the diameter. This makes it uneconomical to

increase the diameter of the upper wing 5 situated in the plurality of tiers. With all of these considered, the outer diameter of the upper wing 5 is preferably less than or equal to 1.6 times the diameter of the steel pipe or tube.

5 **[0022]** The reason for setting the pitch of the upper wing 5 (the distance in a direction perpendicular to the spiral that the upper wing 5 travels in one rotation) to be equal to the pitch of the lowermost wing 3 (the distance in a direction perpendicular to the spiral that the lowermost wing 3 travels in one rotation) is as follows.

During rotational penetration, the rotary penetration steel pipe pile 1
10 penetrates with the degree of penetration per rotation that is a value close to the pitch of the lowermost wing 3, which has a larger outer diameter. At this time, when the pitch of the upper wing 5 differs from that of the lowermost wing 3, it is necessary to further increase torque required to rotate the rotary penetration steel pipe pile 1. Besides, the ground around the upper wing 5 is
15 disturbed more, and the bearing capacity around the upper wing 5 decreases. In other words, when the pitch of the upper wing 5 is equal to that of the lowermost wing 3, the torque required to rotate the rotary penetration steel pipe pile 1 is smaller, and the ground around the upper wing 5 is less disturbed, so that the bearing capacity around the upper wing 5 decreases.

20 **[0023]** According to the rotary penetration steel pipe pile 1 of the present embodiment that is configured as above, the following effects can be achieved.

The lowermost wing 3 with a large diameter is arranged at the pile end. This can provide a large vertical bearing capacity, even though the pile is configured to be set in the intermediate layer.

25 Furthermore, the multi-tiered upper wing 5 having a wing diameter less than or equal to 1.6 times the pile diameter is arranged above the lowermost wing 3, by considering the diameter and the intervals at which it is attached. This can provide a large frictional resistance, while reducing attachment costs.

Moreover, the pitch of the lowermost wing 3 is equal to the pitch of the
30 upper wing 5. This can prevent softening of the ground around the upper wing 5 and provide a reliable frictional resistance.

[0024] Additionally, in a method for constructing a rotary penetration steel pipe pile according to the present embodiment, it is preferable to perform the rotational penetration, while adjusting downward pushing force applied to the
35 pile from a pile driver so that the degree of penetration per rotation is equal to the pitch of the lowermost wing 3. The reasons for this are as follows.

[0025] The rotary penetration steel pipe pile 1 is prone to slippage at an upper end of the hard ground and in areas where the soil varies. Because the rotary penetration steel pipe pile 1 according to the present embodiment includes the lowermost wing 3 with a large diameter at its end, the occurrence of slippage is reduced, but nevertheless, the occurrence of slippage is inevitable under some construction conditions.

Furthermore, because the rotary penetration steel pipe pile 1 according to the present embodiment includes the multi-tiered upper wing 5, when slippage occurs, the ground around the wing is kneaded and softened, resulting in a significant decrease in frictional resistance and spoiling the significance of the attached upper wing 5.

In this respect, when the degree of penetration per rotation of the rotary penetration steel pipe pile 1 is equal to the pitch of the lowermost wing 3, the disturbance of the ground is minimized because the lowermost wing 3 enters to cut the ground.

Accordingly, it is recommended to control penetration, by adjusting the downward pushing force transmitted to the rotary penetration steel pipe pile 1 from the pile driver so that the degree of penetration per rotation matches the pitch of the wing.

EXAMPLE 1

[0026] To find an optimum range of the diameter and the intervals at which the upper wing 5 is attached, soil layer experiments were conducted using a reduced model with the same proportions as a real one. The diameter of a steel pipe or tube of a test model pile used as the reduced model was 76.3 mm, the thickness of the steel pipe or tube was 2.8 mm, and the N value of the soil layer = 20, and test results were compared under the conditions presented in Table 1.

[0027] [Table 1]

Table 1

	Number of wings	Wing interval/wing diameter
Comparative Example 1	5	0.62
Comparative Example 2	4	0.83
Example 1	3	1.25
Example 2	2	2.51

[0028] The test results are presented in FIG. 3.

The horizontal axis of FIG. 3 represents values obtained by dividing wing intervals of upper wings 5 by wing diameters of the upper wings 5 (wing interval/wing diameter), and the vertical axis represents coefficients of shaft friction of wing portions (kN/m^2).

Generally, a coefficient of shaft friction of 2 (kN/m^2) is used for steel pipe piles without wings, regardless of the diameters of the steel pipes or tubes, and because a comparison is made with them, equivalent coefficients of shaft friction for those with multi-tiered wings were calculated for comparison. Specifically, a load was applied to the reduced model to measure the bearing capacity, and this bearing capacity was divided by the surface area of a cylinder whose diameter coincided with a wing diameter and whose length coincided with a pile length, and the obtained value was plotted in the figure as a coefficient of shaft friction.

[0029] As presented in FIG. 3, the coefficient of shaft friction is less than 2 (kN/m^2) in each of Comparative Examples 1 and 2, but the coefficient of shaft friction in each of Examples 1 and 2, in which h/w is within the range of the present disclosure, is more than 2 (kN/m^2), and these values are much larger than those in Comparative Examples 1 and 2.

This indicates that when the wing interval/wing diameter is 1.25 or more, which is the range of the present disclosure, the coefficient of shaft friction can be increased, or in other words, the bearing capacity can be increased.

[0030] Additionally, a full-scale experiment was conducted to confirm that the above model experiment data were valid for a full-scale version. For the full-scale experiment, the pile diameter was 318.5 mm, the wing diameter was 1.5 times the pile diameter = 477.75 mm, and the wing interval h was 1200 mm. A result of the full-scale experiment is indicated by $\times$ plotted in FIG. 3, and a coefficient of shaft friction of 4.762 kN/m^2 , which was almost equal to the model experiment data, was obtained. This demonstrates that the above model experiments were valid for full-scale versions.

REFERENCE SIGNS LIST

- | | | |
|---------------|---|------------------------------------|
| [0031] | 1 | Rotary penetration steel pipe pile |
| | 3 | Lowest wing |
| | 5 | Upper wing |

7 Steel pipe or tube

CLAIMS

[Claim 1] A rotary penetration steel pipe pile configured to be placed so that a pile end is arranged in an intermediate layer without reaching a supporting layer, the rotary penetration steel pipe pile comprising:

5 a substantially spiral-shaped lowermost wing that is wound in one round and that is disposed in vicinity of the pile end; and an upper wing that is wound in one round and that is disposed above the lowermost wing in a plurality of tiers at regular intervals ranging from 1.25 times to 7.5 times a wing diameter of the upper wing, wherein

10 an outer diameter of the lowermost wing is larger than an outer diameter of the upper wing and is set to be 1.5 times to 3 times a pile diameter, and

15 the outer diameter of the upper wing is smaller than the outer diameter of the lowermost wing and is less than or equal to 1.6 times the pile diameter, and a pitch of the upper wing is set to be equal to a pitch of the lowermost wing.

[Claim 2] A method of constructing the rotary penetration steel pipe pile according to claim 1, the method comprising

20 rotating and penetrating the rotary penetration steel pipe pile, while adjusting downward pushing force applied to the pile from a pile driver so that a degree of penetration per rotation is equal to the pitch of the lowermost wing.