

SPECIFICATION

TITLE OF THE INVENTION

STEEL PIPE PILE

5 Field of the Invention

[0001]

The present invention relates to a steel pipe pile that is used in the fields of civil engineering and construction such as a harbor structure, a bridge foundation, a building foundation or the like.

10 Priority is claimed on Japanese Patent Application No. 2009-095734, filed April 10, 2009, the content of which is incorporated herein by reference.

Description of Related Art

[0002]

15 In the past, in order to increase a friction force of an outside circumferential face of a pile, a friction pile having a tapered outside circumferential face at one end of the pile and a friction pile having a tapered outside circumferential face through the entire pile have been disclosed (see for example, Patent Citation 1 and Patent Citation 2).

Also, in order to compact a ground surface layer, a technique in which a tapered
20 pile having a tapered outside circumferential face is driven into the ground in a lattice geometry and in which liquefaction of the ground is prevented is disclosed (see for example, Patent Citation 3). Also, in order to remove the negative friction force of a circumferential face, a technique in which a tapered pile penetrates into a ground is disclosed (see for example, Patent Citation 4).

25 [0003]

Also, a closed end pile in which a cone having a tapered outside circumferential face and a closed end is provided at an end portion (a tip portion) of the pile is disclosed (see for example, Patent Citation 5).

[0004]

5 As described above, in the conventional tapered pile, an object thereof is to increase a friction force of the pile circumferential face. However, in the conventional tapered pile, the object thereof is not to obtain a bearing capacity of the pile end and to relief plug effect at the end that becomes a resistance at the time of pile construction.

[0005]

10 Also, in order to bury a cast-in-place ferroconcrete pile or pre-cast concrete pile in the ground, a technique that uses a casing having a tapered outside circumferential face and a tapered inside circumferential face at an end portion thereof is disclosed (see for example, Patent Citation 6 and Patent Citation 7).

[0006]

15 In the above-described conventional casing having the tapered outside circumferential face and the tapered inside circumferential face, the object thereof is to increase the friction force of the pile circumferential face so that the bearing capacity of a vertical load of the pile increases and the surplus of soil of excavation decreases. However, the object thereof is not to obtain a bearing capacity of the pile end and to
20 relief plug effect at the end that becomes a resistance at the time of pile construction.

[0007]

A steel pipe pile may be classified as a closed end pile in which a end is closed or an opened end pile in which a end is opened depending on the shape of the end (tip) of the steel pipe pile. A steel pipe pile of the present invention is classified as the opened
25 end pile.

Also, a steel pipe pile may be classified as a friction pile or a end-supported pile. The friction pile is not driven into to the bearing stratum so that a bearing capacity is generated mainly by the friction force of the circumferential face. Also, the end-supported pile is driven into to the bearing stratum so that the bearing capacity of the pile end portion is mainly exerted. The steel pipe pile of the present invention is classified as the end-supported pile.

Patent Citation

[0008]

[Patent Citation 1] Japanese Unexamined Patent Application, First Publication
10 No. 2003-3465

[Patent Citation 2] Japanese Unexamined Patent Application, First Publication
No. 2007-327280

[Patent Citation 3] Japanese Unexamined Patent Application, First Publication
No. 2008-190116

15 [Patent Citation 4] Japanese Unexamined Patent Application, First Publication
No. S57-81526

[Patent Citation 5] Japanese Unexamined Patent Application, First Publication
No. H8-284160

[Patent Citation 6] Japanese Unexamined Patent Application, First Publication
20 No. 2008-297752

[Patent Citation 7] Japanese Unexamined Patent Application, First Publication
No. 2005-248439

SUMMARY OF THE INVENTION

25 Problems to be Solved by the Invention

[0009]

When the steel pipe pile is driven or penetrated into the ground, for example, if the vertical load is applied to the steel pipe pile which is then driven, a penetration force that exceeds ground resistances is required to be applied to the steel pipe pile.

5 Generally, the ground resistances increase according to the increase of a driving depth of the steel pipe pile. When the opened end pile penetrates into the ground, as shown in FIG. 6A, a soil (or a soil including stones or rocks) 11 that is taken within the steel pipe pile is accumulated within the steel pipe pile and the soil is restrained by the steel pipe pile. Thus, it is known that a friction force between an inside circumferential
10 face 12 of the steel pipe pile and the soil 11 that is taken within steel pipe pile increases and a resistance of the inside circumferential face of the pipe among the ground resistances increases.

Until now, increasing the ability of a pile driving machine has been proposed, and also various kinds of driving assistance methods such as ejecting water or
15 compressed air from the pipe that is arranged within the steel pipe pile, or ejecting soil within the pipe by an earth auger and a hammer grab have been proposed, in order to decrease the resistance of the inside circumferential face of the pile.

In the driving assistance method, the driving of the steel pipe pile is assisted, while the cost for manufacturing of the steel pipe pile increases and the period of the pile
20 construction becomes long. Thus, even though the driving assistance measurement is applied to steel pipe pile, it is desirable that the steel pipe pile be provided such that the cost for manufacturing of the steel pipe pile and the cost for the construction of the steel pipe pile can decrease and the entire cost can be suppressed to be low.

[0010]

25 Also, in the past, as a steel pipe pile that is used in a rotary press-in method so as

to increase a bearing capacity of the pile, a tapered pile that includes a tapered outside circumferential face and a tapered inside circumferential face through the entire length of the pile is disclosed. The pile (the friction pile) that uses the friction force of the circumferential face of the pile can be extremely tapered so as to penetrate into soft ground. However, in the pile (the end-supported pile) that penetrates into the bearing stratum and uses the bearing capacity of the pile end portion, the pile end portion is required to penetrate into the bearing stratum by a vibration method or the like. Thus, if the steel pipe pile that drives into the ground is extremely tapered as in the past, the pile driving resistance significantly increases and the ability of the pile-driving machine is required to increase further. Also, when the pile is processed in a taper through the entire length thereof, the processing equipment becomes large and the cost for processing the tapered portion significantly increases such that the steel pipe pile cannot be manufactured economically.

[0011]

Thus, in the past, as a steel pipe pile that is used in the vibration method or the like as shown in FIGS. 7A to 7C, the steel pipe pile (the straight steel pipe pile) is used, wherein the outside diameter thereof is constant through out the entire length thereof and the end portion thereof is opened. However, from the above-described reason, the steel pipe pile of which the end portion is tapered and the end is opened is not used.

[0012]

In the end-opened pile of which the end is opened, the pile end portion is tapered. In other words, when the pile end portion has the tapered outside circumferential face and the tapered inside circumferential face, advantages are considered to be (1) and (2) as explained below. Also, advantages thereof are described using FIG. 6B.

(1) If the end portion of the steel pipe pile 1 is tapered, since the amount of the soil 11 that is taken within the pipe decreases, increase of the density of the soil is suppressed. Thus, the resistance of the inside circumferential face of the pile that is a main cause of the driving resistance of the steel pipe pile 1 and is exerted between the soil 11 that is taken within the pipe and the inside circumferential face 7 of the steel pipe pile can decrease.

(2) If the end portion 4 of the steel pipe pile 1 is tapered, a projected cross-sectional area to the vertical direction of the steel member that is supported at the bearing stratum becomes large. Thus, as shown in FIG. 6B, the reaction force (and the confining pressure) against the soil (or the soil including stones or rocks) 14 around the end portion of the steel pipe pile can be effectively received so that the steel pipe pile can be stabilized. Accordingly, the end bearing capacity of the pile that can be obtained can be large. Here, the soil 15 around the end portion of the steel pipe pile is formed such that the soil (or the soil including stones or rocks) 13 of outside of steel pipe is pressed to an appropriate direction. Also, the reaction force against the soil (or the soil including stones or rocks) 14 around the end portion of the steel pipe pile is shown using arrows in FIG. 6B.

[0013]

The inventors have found that the steel pipe pile having the tapered pile end portion can be used in each of the construction methods such as a vibration method, a pile driving method, a jacked piling method, and a rotary press-in method. Furthermore, the inventors have found that even when the steel pipe pile having the tapered pile end portion is driven into the ground, the ground resistance decreases and the workability is improved, and it is hereby that the present invention was conceived.

Adding to the above-described findings, the inventors have studied the effects of

a ratio (a diameter-reducing ratio) of reducing a diameter of the pile end portion, and a ratio (ratio of length to diameter) between the length of the tapered pile end (the tapered portion) in the longitudinal direction of the pile and the maximum outside diameter of the pile end portion. Thus, the inventors performed a construction test in which the pile is driven and a bearing capacity test in which the vertical load is loaded on the pile that is driven in order to examine the ground resistance that is received by the pile end portion. As a result, the inventors obtained the findings that the ground resistance received by the end portion of the steel pipe pile changes according to two parameters of the above-described ratio that the diameter of the pile end portion is reduced, and the ratio between the length of the tapered pile end portion in the longitudinal direction of the pile and the maximum outside diameter of the pile end portion. The inventors found that the entire ground resistance decreases and the workability is improved using the steel pipe pile having the pile end portion (the tapered portion) that limits the parameters thereof in a predetermined range, compared to using the end-opened pile of the straight steel pipe having a constant outside diameter through the entire length. The inventors found that the bearing capacity is improved since the above-described tapered portion receives the ground resistance at the hard bearing stratum, and it is hereby that the present invention was conceived.

[0014]

It is, therefore, an object of the present invention to provide a steel pipe pile that can be used in various construction methods such as the vibration method, in which an end bearing capacity of a pile can be obtained and a resistance can be decreased at the time of pile construction.

Methods for Solving the Problem

[0015]

The present invention employs methods, as described below, to solve the above-described problems.

(1) A steel pipe pile of the present invention includes a straight portion having a cylindrical shape; and a tapered portion that continues to an end of the straight portion and the outside diameter and the inside diameter thereof decrease away from the end, wherein a ratio of length to diameter $H1/D1$ in which the length $H1$ between a large end and a small end of the tapered portion is divided by the outside diameter $D1$ of the large end is 0.1 to 2.5.

(2) The steel pipe pile according to (1), wherein the diameter-reducing ratio $D2/D1$ in which the outside diameter $D2$ of the small end is divided by the outside diameter $D1$ of the large end may be 0.70 to 0.95.

(3) The steel pipe pile according to (1) or (2), wherein the entire tapered portion may be a penetrated portion that penetrates into a bearing stratum of a ground.

(4) The steel pipe pile according to (1) or (2), wherein a ratio in which a sum length L of the length $H1$ of the tapered portion and a length $H2$ of the straight portion is divided by the length $H1$ of the taper portion may be 0.01 to 0.1.

(5) The steel pipe pile according to (1) or (2), wherein the outside diameter $D1$ of the large end may be 600 mm to 3000 mm.

Effects of the Invention

[0016]

In the steel pipe pile according to (1), the ratio between the length $H1$ of the tapered portion having the tapered outside circumferential face and the tapered inside circumferential face in the longitudinal direction of the pile, and the outside diameter $D1$ of the large end of the tapered portion is in the range of 0.1 to 2.5. Thus, when the steel pipe pile according to (1) is driven into the ground, the workability can be improved

compared to the straight steel pipe pile. Furthermore, when the steel pipe pile according to (1) penetrates into the bearing stratum or the like, the bearing capacity of the pile end can be improved compared to the straight steel pipe pile.

In the steel pipe pile according to (2), the diameter-reducing ratio $D2/D1$ that is a ratio between the outside diameter $D2$ of the end (the small end) of the tapered portion and the outside diameter $D1$ of the large end of the tapered portion is in the range of 0.70 to 0.95. Thus, the steel pipe pile according to (2) can reduce the construction resistance compared to the straight steel pipe pile at the time of the pile construction and can significantly increase the end bearing capacity of the pile.

In the steel pipe pile according to (3), the entire tapered portion is a penetrated portion that penetrates into the bearing stratum so that the end bearing capacity of the pile required as the foundation of the steel pipe pile is improved compared to the straight steel pipe pile having the same pile outside diameter and the same plate thickness t as well.

In the steel pipe pile according to (4), the ratio $H1/L$ between the length of the tapered portion in the longitudinal direction of the pile and the entire length of the steel pipe pile is 0.01 to 0.1, so that in practical use, the construction resistance of the pile can decrease at the time of penetrating into the ground and the end bearing capacity of the pile can increase at the time of penetrating into the bearing stratum compared to the straight steel pipe pile having the same pile outside diameter and the same plate thickness t as well.

In the steel pipe pile according to (5), the outside diameter $D1$ of the large end of the tapered portion is at least 600 mm so that when the tapered portion penetrates into the bearing stratum, the outside circumferential face area of the tapered portion and the projected cross-section area of the steel pipe pile to the vertical direction that is supported

by the bearing stratum can become large and the end bearing capacity of the pile that is obtained can increase.

BRIEF DESCRIPTION OF THE DRAWINGS

5 [0017]

FIG. 1A is a front view illustrating a steel pipe pile having a tapered portion according to an embodiment of the present invention.

FIG. 1B is a vertical cross-sectional view illustrating the steel pipe pile having the tapered portion according to the embodiment of the present invention.

10 FIG. 1C is a cross-sectional view taken along a cross-sectional line a-a shown in FIG. 1B illustrating the steel pipe pile having the tapered portion according to the embodiment of the present invention.

FIG. 1D is a cross-sectional view taken along a cross-sectional line b-b shown in FIG. 1B illustrating the steel pipe pile having the tapered portion according to the
15 embodiment of the present invention.

FIG. 2 is a graph illustrating a relationship between a ratio $H1/D1$ of the taper length $H1$ and the pile outer diameter $D1$ of a straight portion, and a construction resistance ratio with respect to the straight steel pipe pile.

FIG. 3 is a graph illustrating a relationship between a diameter-reducing ratio $D2/D1$ and the construction resistance ratio with respect to the straight steel pipe pile.
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FIG. 4 is a graph illustrating a relationship between the diameter-reducing ratio $D2/D1$ and an end bearing capacity ratio with respect to the straight steel pipe pile.

FIG. 5 is a graph illustrating a relationship between a ratio $H1/D1$ of the taper length $H1$ and the pile outside diameter $D1$ of the straight portion, and the end bearing
25 capacity ratio with respect to the straight steel pipe pile.

FIG. 6A is an explanatory drawing illustrating a ground resistance that is generated when the straight steel pipe pile penetrates the ground.

FIG. 6B is an explanatory drawing illustrating the ground resistance that is generated when the steel pipe pile having the tapered portion penetrates the ground.

5 FIG. 7A is a front view illustrating the straight steel pipe pile as a comparative example.

FIG. 7B is a vertical cross-sectional view illustrating the straight steel pipe pile as the comparative example.

FIG. 7C is a horizontal cross-sectional view illustrating the straight steel pipe
10 pile as the comparative example.

DETAILED DESCRIPTION OF THE INVENTION

[0018]

Preferred embodiments of the present invention are described in detail with
15 reference to the accompanying drawings.

[0019]

FIGS. 1A to 1D illustrate a steel pipe pile 1 having a tapered portion according to one embodiment of the present invention.

[0020]

20 The steel pipe pile 1 having the tapered portion of the present invention is driven through an appropriate construction method such as a vibration method. The steel pipe pile 1 is constituted of a hollow straight portion 8 and a hollow tapered portion 4. The straight portion 8 has a constant pile outside diameter and a cylindrical shape. The tapered portion 4 has a large end (an end portion of the large diameter side) 5 that
25 continues to an end face of the straight portion 8 and a small end (an end portion of the

small diameter side) 6 that is opened. Also, both of the inside diameter and the outside diameter of the tapered portion 4 gradually reduce toward the small end 6 from the large end 5. In other words, a tapered outside circumferential face 2 and a tapered inside circumferential face 3 are provided at the tapered portion (an end portion) 4, wherein the tapered outside circumferential face 2 and the tapered inside circumferential face 3 gradually reduce the diameter toward the end (the small end 6) of the tapered portion 4 in the pile longitudinal direction from a boundary (the large end 5) between the tapered portion 4 and the straight portion 8. The steel pipe pile 1 may be connected to a steel pipe having a diameter larger than the pile outside diameter of the straight portion 8 at a head portion of the steel pipe pile 1 so as to withstand a larger horizontal force and a moment thereof. In the embodiment, an explanation is given for a case in which the pile outside diameter of the straight portion 8 is the same as that of the large end 5 of the tapered portion 4.

[0021]

As shown in FIG. 1B, the cross-sectional shape of the tapered outside circumferential face 2 and the tapered inside circumferential face 3 in the longitudinal direction of the pile may be a linear shape (a planar face) or may be a curved shape (a curved face; not shown). Also, the cross-sectional shape of the tapered outside circumferential face 2 and the tapered inside circumferential face 3 in the longitudinal direction of the pile may be convex (concave toward the inside in the radial direction) toward the outside in the radial direction from the central axis of the pile or may be convex (concave toward the outside in the radial direction) toward the inside in the radial direction from the central axis of the pile. Also, the tapered outside circumferential face 2 and the tapered inside circumferential face 3 may gradually reduce the diameter in a step shape in the longitudinal direction of the pile. However, it is desirable that the

tapered outside circumferential face 2 and the tapered inside circumferential face 3 be the linear shape or the curved shape so that the steel pipe pile 1 can be manufactured with a low cost and the cross-section thereof can be continuously formed in the longitudinal direction of the pile.

5 [0022]

In the embodiments shown in FIGS. 1A to 1D, a ratio ($H1/D1$; a ratio of length to diameter in which the length $H1$ of the tapered portion 4 in the longitudinal direction of the pile is divided by the pile outside diameter $D1$) between the length (the taper length, in other words, the distance between the large end 5 and the small end 6) $H1$ of the tapered outside circumferential face 2 of the tapered portion 4 in the longitudinal direction of the pile and the pile outside diameter (the outside diameter $D1$ of the large end) $D1$ of the straight portion 8 (the steady portion having a constant outside diameter) is 0.1 to 2.5. Similarly, a ratio (the ratio of length to diameter) $H1/D1$ between the length $H1$ of the taper inside circumferential face 3 of the tapered portion 4 in the longitudinal direction of the pile and the pile outside diameter $D1$, is 0.1 to 2.5. It is desirable that a diameter-reducing ratio ($D2/D1$; a diameter-reducing ratio in which the end outside diameter $D2$ of the small end is divided by the pile outside diameter $D1$ of the straight portion) that is a ratio between the outside diameter $D2$ (the end outside diameter) of the end (the small end) 6 of the tapered portion 4 and the pile outside diameter $D1$ of the straight portion 8 be 0.70 to 0.95. The diameter-reducing ratio $D2/D1$ is the diameter-reducing ratio of the end of the steel pipe pile. Also, in the embodiment, following Equation (1) is established among the length $H1$ of the tapered portion 4 in the longitudinal direction of the pile (the axial direction of the pile), the outside diameter $D2$ of the end (the small end) 6 of the tapered portion 4, the pile outside diameter $D1$ of the straight portion 8, and the taper angle θ .

$$\tan\theta=(D1-D2)/2H1 \dots(1)$$

Also, when the range of the ratio of length to diameter $H1/D1$ varies between 0.1 and 2.5 and the range of the diameter-reducing ratio $D2/D1$ varies between 0.70 and 0.95, the range of the taper angle θ corresponds between 0.57° and 56.31° .

5 [0023]

As described above, the ratio (the ratio of length to diameter) $H1/D1$ between the length (the taper length) $H1$ of the tapered outside circumferential face 2 and the tapered inside circumferential face 3 in the longitudinal direction of the pile and the pile outside diameter $D1$ is a range of 0.1 to 2.5. Also, the diameter-reducing ratio $D2/D1$ that is the ratio between the outside diameter $D2$ of the end (the small end) 6 of the tapered portion 4 and the pile outside diameter $D1$ of the straight portion 8 is set to a desirable range, in other words, a range of 0.70 to 0.95. The reason for the determination of the ranges is described with reference to FIGS. 2 to 5.

[0024]

15 FIG. 2 is a graph illustrating a relationship between the ratio (the ratio of length to diameter) $H1/D1$ that is the ratio between the taper length $H1$ of the tapered portion 4 and the pile outside diameter $D1$ of the straight portion 8, and the construction resistance ratio with respect to the straight steel pipe pile. Also, FIG. 3 is a graph illustrating a relationship between the diameter-reducing ratio $D2/D1$ of the tapered portion 4 and the construction resistance ratio with respect to the straight steel pipe pile. In FIG. 2 and FIG. 3, in order to obtain the construction resistance ratio, a driving test (a comparison test) was performed using a test ground (a soil tank) with respect to the steel pipe pile 1 having the tapered portion of the embodiment of the present invention and the straight steel pipe pile 10 shown in FIGS. 7A to 7C that is used for the comparative examples.

25 The construction resistance was obtained until these steel pipe piles reach the bearing

stratum. The construction resistance ratio is the construction resistance ratio of the steel pipe pile 1 having the tapered portion with respect to the construction resistance of the straight steel pipe pile 10. In FIG. 2, the diameter-reducing ratio $D2/D1$ is 0.9 and in FIG. 3, the ratio of length to diameter (the ratio of length to diameter ratio at the tapered portion) $H1/D1$ is 0.8. When the construction resistance is measured using the steel pipe pile 1 having the diameter-reducing ratio $D2/D1$ that is different from FIG. 2, the correlation between the ratio of length to diameter $H1/D1$ and the construction resistance ratio is the same as that illustrated in FIG. 2. Also, when the construction resistance is measured using the steel pipe pile 1 having the ratio of length to diameter $H1/D1$ that is different from FIG. 3, the correlation between the diameter-reducing ratio $D2/D1$ and the construction resistance ratio is the same as that illustrated in FIG. 3. Hereinafter, FIGS. 2 and 3 will be explained subsequently.

[0025]

In FIG. 2, regarding the steel pipe pile 1 having the tapered portion according to the embodiment of the present invention, the ratio (ratio of length to diameter) $H1/D1$ between the length $H1$ of the tapered portion 4 in the longitudinal direction of the pile and the pile outside diameter $D1$ of the straight portion 8 varies along the horizontal axis and the construction resistance ratio that is the ratio between the construction resistance of the steel pipe pile 1 having the tapered portion and the construction resistance of the straight steel pipe pile 10 of the comparative example is illustrated along the vertical axis. As shown in FIG. 2, the construction resistance ratio of the steel pipe pile 1 having the tapered portion draws a convex-downward curve while the length of the taper portion 4 varies. In addition, it is found that when the ratio of length to diameter $H1/D1$ is extremely small, the construction resistance ratio of the steel pipe pile 1 having the tapered portion approaches the construction resistance ratio (in other words, the

construction resistance ratio is 1) of the straight steel pipe pile 10 of the comparative example. Similarly, it is found that when the ratio of length to diameter $H1/D1$ is extremely large, the construction resistance ratio of the steel pipe pile 1 having the tapered portion approaches the construction resistance ratio of the straight steel pipe pile 10 of the comparative example.

[0026]

In the present invention, the construction resistance of the pile is a load (a ground resistance) that is taken in the construction until the pile reaches the bearing stratum when the pile is constructed (penetrated) to the ground (the ground layer). The construction resistance ratio is the construction resistance of the steel pipe pile 1 having the tapered portion when the construction resistance of the straight steel pipe pile 10 of the comparative example is 1.0. In other words, the construction resistance ratio is defined by the ratio between the construction resistance of the steel pipe pile 1 having the tapered portion and the construction resistance of the straight steel pipe pile 10 of the comparative example. The construction resistance ratio has a negative correlation with the construction speed. In other words, when the construction is performed with a predetermined output (the output of the machine), the construction resistance ratio decreases, and therefore the construction speed increases. Thus, the construction period can be shortened and the construction cost can be lowered. If the construction must be completed within a predetermined period (the construction period), since the construction resistance ratio decreases and the output that is required for the construction is lowered, the machine that is used in the construction can change to a machine having a lower performance (output) and the construction cost can be lowered. Accordingly, the construction resistance ratio decreases, and thereby the construction period and the construction machine can be selected flexibly according to the needs of the construction.

When the cost (or energy) for manufacturing the steel pipe pile 1 having the tapered portion is considered, the construction resistance is required to decrease by at least 10%.

[0027]

As shown in FIG. 2, when the ratio of length to diameter $H1/D1$ is 0.1, the construction resistance ratio is 0.9, similarly when the ratio of length to diameter $H1/D1$ is 1, the construction resistance ratio is 0.7, and when the ratio of length to diameter $H1/D1$ is 2.5, the construction resistance ratio is 0.9. Accordingly, when the ratio of length to diameter $H1/D1$ is in the range of 0.1 to 2.5, the construction resistance of the steel pipe pile 1 having the tapered portion is lowered by 10% compared to the construction resistance of the straight steel pipe pile 10 of the comparative example. In addition, when the ratio of length to diameter $H1/D1$ is in the range of 0.4 to 1.7, the construction resistance of the steel pipe pile 1 having the tapered portion is lowered by 20% compared to the construction resistance of the straight steel pipe pile 10 of the comparative example.

Accordingly, the ratio of length to diameter $H1/D1$ is required to be 0.1 to 2.5 to lower the construction resistance by at least 10%. In this case, the length of the taper portion 4 in the longitudinal direction (the axial direction of the pile) is 0.1 to 2.5 times the length of the pile outside diameter $D1$. It is preferable that the ratio of length to diameter $H1/D1$ be 0.4 to 1.7 to decrease the construction resistance by at least 20%. In this case, the length of the taper portion 4 in the longitudinal direction (the axial direction of the pile) is 0.4 to 1.7 times the length of the pile outside diameter $D1$. When the steel pipe pile 1 having the tapered portion that has the above-described range of the ratio of length to diameter $H1/D1$ is driven into the ground, the ground resistance decreases and then the workability enhances.

[0028]

In FIG. 3, regarding the steel pipe pile 1 having the tapered portion according to the embodiment, the diameter-reducing ratio $D2/D1$ that is the ratio between the outside diameter $D2$ of the end (the small end) 6 of the tapered portion 4 and the pile outside diameter $D1$ of the straight portion 8 varies along the horizontal axis and the construction resistance ratio that is the ratio between the construction resistance of the steel pipe pile 1 having the tapered portion and the construction resistance of the straight steel pipe pile 10 of the comparative example illustrates along the vertical axis.

As shown in FIG. 3, in the steel pipe pile 1 having the tapered portion of the embodiment, when the diameter-reducing ratio $D2/D1$ is 0.7, the construction resistance ratio is 0.9 and when the diameter-reducing ratio $D2/D1$ is 0.95, the construction resistance ratio is 0.9. In addition, when the diameter-reducing ratio $D2/D1$ is 0.70 to 0.95, the construction resistance ratio is less than or equal to 0.9. Furthermore, when the diameter-reducing ratio $D2/D1$ is 0.80 to 0.94, the construction resistance ratio is less than or equal to 0.8. In other words, when the diameter-reducing ratio $D2/D1$ is 0.80 to 0.94, the construction resistance of the steel pipe pile 1 having the tapered portion is lowered to about less than or equal to 80% compared to the construction resistance of the straight steel pipe pile 10 of the comparative example. As described above, it is preferable that the diameter-reducing ratio $D2/D1$ be 0.70 to 0.95 to lower the construction resistance by at least 10%. In addition, it is preferable that the diameter-reducing ratio $D2/D1$ be 0.80 to 0.94 to lower the construction resistance by about 20%.

[0029]

Moreover, the machine (rank of the machine) that is used for the construction is selected according to the working space and the output (or press-in force) that is required for general construction. In the Table 1, as an example, the output of the vibratory pile

driver that is used in the general vibration method and the corresponding output of a vibratory pile driver which is required when the construction resistance ratio (the construction load) of the steel pipe pile decreases by 20% and 25% are shown. As shown in Table 1, when the construction resistance ratio of the steel pipe pile decreases by 20%, the output of the vibratory pile driver can decrease reliably by one rank. Furthermore, when the construction resistance ratio decreases by 25%, the output of the vibratory pile driver can decrease reliably by one or more ranks.

[0030]

[Table 1]

Output of vibratory pile driver (kW)	Output required when construction resistance decreases by 20% (kW)	Output of vibratory pile driver when construction resistance decreases by 20% (kW)	Output required when construction resistance decreases by 25% (kW)	Output of vibratory pile driver when construction resistance decreases by 25% (kW)
240	192	200	180	180 (2 rank down)
200	160	180	150	150 (2 rank down)
180	144	150	135	135 (2 rank down)
150	120	135	112.5	120 (2 rank down)
135	108	120	101.25	120

[0031]

Accordingly, it is further preferable that the construction resistance ratio of the steel pipe pile decrease by at least 20%. In other words, a more preferable range of the ratio of length to diameter H_1/D_1 is 0.4 to 1.7. Similarly, a more preferable range of the

diameter-reducing ratio $D2/D1$ is 0.80 to 0.94.

[0032]

Also, in the Table 2, as an example, the press-in force of the machine that is used in the general rotary press-in method and the press-in force of the machine which is required when the construction resistance ratio (the construction load) of the steel pipe pile decreases by 25% are shown. As shown in Table 2, when the construction resistance ratio of the steel pipe pile decreases by 25%, the press-in force of the machine can decrease reliably by one rank.

[0033]

[Table 2]

Press-in force of machine for rotary press-in method		Press-in force required when construction resistance decreases by 25% (kN)	Press-in force when construction resistance decreases by 25% (kN)	
Name of machine	Press-in force (kN)		Name of machine	Press-in force (kN)
RT-260H	1120	840	RT-200H	840
RT-200H	840	630	RT-200AⅢ	690
RT-200AⅢ	690	517.5	RT-150AⅢ	560

[0034]

Accordingly, it is most preferable that the construction resistance ratio of the steel pipe pile decrease by 25% or more. In other words, the most preferable range of the ratio of length to diameter $H1/D1$ is 0.5 to 1.4. Similarly, the most preferable range of the diameter-decreasing ratio $D2/D1$ is 0.85 to 0.93. The general construction machines are shown in Table 1 and Table 2; however the machine that constructs the steel pipe pile 1 is not limited to only the construction machines shown in Table 1 and Table 2.

[0035]

As described above, in the steel pipe pile 1 having the tapered portion according

to the embodiment, the construction resistance (the ground resistance) that the end portion of the steel pipe pile receives is changed largely by two parameters of the diameter-reducing ratio $D2/D1$ and the ratio of length to diameter $H1/D1$. The diameter-reducing ratio $D2/D1$ is the ratio of the decrease of the diameter of the end portion of the pile (the tapered portion) 4 and the ratio of length to diameter $H1/D1$ is the ratio between the length $H1$ of the tapered portion 4 in the longitudinal direction and the pile outside diameter $D1$ of the straight portion 8. If the diameter-reducing ratio $D2/D1$ and the ratio of length to diameter $H1/D1$ are within a predetermined range, the entire construction resistance (the ground resistance) decreases compared to the straight steel pipe pile 10 that is open end pile so that the workability is improved.

[0036]

FIG. 4 is a graph illustrating a relationship between the diameter-reducing ratio $D2/D1$ (the horizontal axis) of the tapered portion 4 and an end bearing capacity ratio (the vertical axis) with respect to the straight steel pipe pile. FIG. 5 is a graph illustrating a relationship between the ratio $H1/D1$ (the horizontal axis) between the taper length $H1$ of the tapered portion 4 and the pile outside diameter $D1$ of the straight portion and the end bearing capacity ratio (the vertical axis) with respect to the straight steel pipe pile. The end bearing capacity ratio is the end bearing capacity of the steel pipe pile 1 having the tapered portion when the end bearing capacity of the straight steel pipe pile 10 of the comparative example is 1.0. In other words, the end bearing capacity ratio is the ratio between the end bearing capacity of the steel pipe pile 1 having the tapered portion and the end bearing capacity of the straight steel pipe pile 10 of the comparative example. In order to secure the end bearing capacity of the steel pipe pile, both the steel pipe pile 1 having the tapered portion and the straight steel pipe pile 10 of comparative example are required to penetrate by the length that is at least 1 times the pile outside diameter $D1$

into the layer that is used as the bearing stratum. The layer that is used as the bearing stratum is the ground, wherein an N-value that is generally obtained by the standard penetration test (for example, the test method that is defined in JIS A1219) is greater than or equal to 30 in the ground including sand, gravel layer, and rock, and is greater than or equal to 10 in the ground of cohesive soil. Here, in FIG. 4, the ratio of length to diameter $H1/D1$ is 1.0 and in FIG. 5, the diameter-reducing ratio $D2/D1$ is 0.9. When the construction resistance is measured using the steel pipe pile 1 having the ratio of length to diameter $H1/D1$ that is different from FIG. 4, the correlation between the diameter-reducing ratio $D2/D1$ and the construction resistance ratio is the same as that illustrated in FIG. 4. Similarly, when the construction resistance is measured using the steel pipe pile 1 having the diameter-reducing ratio $D2/D1$ that is different from FIG. 5, the correlation between the ratio of length to diameter $H1/D1$ and the construction resistance ratio is the same as that illustrated in FIG. 5.

[0037]

Here, the cost for manufacturing the steel pipe pile 1 having the tapered portion is higher than the cost for manufacturing the straight steel pipe pile 10 by about 10%. In other words, the cost for processing the tapered portion 4 is about 10% of the manufacturing cost for the straight steel pipe pile. In addition, if the ratio of the end bearing capacity (the resistance with respect to the vertical load) is improved by 10%, the number of the steel pipe piles that are required to support a predetermined load can decrease by 10%. In this case, the material cost of the steel pipe pile can decrease by 10%. Thus, it is preferable that the end bearing capacity ratio be increased at least by 10% or more. The end bearing capacity ratio is further improved so that the number of the piles that are used can decrease.

[0038]

As shown in FIG. 4, in the steel pipe pile 1 having the tapered portion of the embodiment, the end bearing capacity ratio is greater than or equal to 1.3 at the diameter-reducing ratio $D2/D1$ of 0.70, and the end bearing capacity ratio is greater than or equal to 1.1 at the diameter-reducing ratio $D2/D1$ of 0.95. Accordingly, in the range that the diameter-reducing ratio $D2/D1$ is 0.70 to 0.95, the end bearing capacity ratio increases to 1 or more (specifically, greater than or equal to 10%). Similarly, in the steel pipe pile 1 having the tapered portion, in the range that the diameter-reducing ratio $D2/D1$ is 0.80 to 0.90, the end bearing capacity is greater than or equal to 1.40. Thus, in the range that the diameter-reducing ratio $D2/D1$ is 0.80 to 0.90, the end bearing capacity of the steel pipe pile 1 having the tapered portion is improved by 40% or more compared to the straight steel pipe pile 10 of the comparative example. As described above, it is preferable that the diameter-reducing ratio $D2/D1$ be 0.70 to 0.95, so that the end bearing capacity of the steel pipe pile 1 having the tapered portion increases to more than the end bearing capacity of the straight steel pipe pile 10 by 10% or more. It is further preferable that the range of the diameter-reducing ratio $D2/D1$ be 0.80 to 0.90.

Also, as shown in FIG. 5, when the ratio of length to diameter $H1/D1$ is 0.3, the end bearing capacity ratio is about 1.2, when the ratio of length to diameter $H1/D1$ is 2.5, the end bearing capacity ratio is 1.1 and when the ratio of length to diameter $H1/D1$ is 1.0, the end bearing capacity ratio is 1.4. Accordingly, it is preferable that the ratio of length to diameter $H1/D1$ be 0.3 to 2.5 so that the end bearing capacity of the steel pipe pile 1 having the tapered portion increases to more than the end bearing capacity of the straight steel pipe pile 10 by 10% or more.

[0039]

If the ratio of length to diameter $H1/D1$ decreases and the diameter-reducing ratio $D2/D1$ increases, the processing cost (specifically, plastic deformation) of the

tapered portion 4 can be suppressed. In order to achieve this, it is preferable that the upper limit of the ratio of length to diameter $H1/D1$ be set and the lower limit of the diameter-reducing ratio $D2/D1$ be set.

In the steel pipe pile 1 having the tapered portion, when considering both of the construction resistance ratio and the end bearing capacity ratio, the upper limit of the ratio of length to diameter $H1/D1$ is at least 2.5, preferably 1.7, and most preferably 1.4. In addition, the lower limit of the ratio of length to diameter $H1/D1$ is at least 0.1, preferably 0.3, more preferably 0.4, and most preferably 0.5. Similarly, the lower limit of the diameter-reducing ratio $D2/D1$ is preferably 0.70, more preferably 0.80, and most preferably 0.85. Furthermore, the upper limit of the diameter-reducing ratio $D2/D1$ is preferably 0.95, more preferably 0.94, furthermore preferably 0.93, and most preferably 0.90.

Accordingly, when considering the decrease of the construction resistance ratio and increase of the end bearing capacity ratio as a whole, the most preferable range of the ratio of length to diameter $H1/D1$ is 0.5 to 1.4 and the most preferable range of the diameter-reducing ratio $D2/D1$ is 0.85 to 0.90.

[0040]

Here, the size of the steel pipe pile 1 having the tapered portion that is used in the test for obtaining the graphs shown in FIGS. 2 to 5 is described. When the pile outside diameter $D1$ of the straight portion 8 that is at the base end side of the steel pipe pile 1 is 100 mm, the plate thickness t of the steel pipe pile 1 is 4.2 mm. In addition, when the pile outside diameter $D1$ of the straight portion 8 that is at the base end side of the steel pipe pile 1 is 76 mm, the plate thickness t of the steel pipe pile 1 is 2.8 mm. In FIG. 1A or 1B, the ratio (the ratio of length to diameter) $H1/D1$ between the length $H1$ of the tapered outside circumferential face 2 and the tapered inside circumferential face 3 in

the longitudinal direction of the pile, and the pile outside diameter D1 (the outside diameter of the straight portion 8) is 0.1 to 2.5.

On the other hand, regarding the dimension of the straight steel pipe pile 10 of the comparative example that is used in the test, the pile outside diameter D1 is 100 mm and the plate thickness t of the steel pipe pile is 4.2 mm.

[0041]

In the steel pipe pile 1 having the tapered portion, it is preferable that the entire tapered portion 4 including the tapered inside circumferential face 3 or the tapered outside circumferential face 2 penetrate the bearing stratum. When the steel pipe pile 1 having the tapered portion is driven into the ground, the construction resistance decreases and the construction is further effectively performed compared to that when the straight steel pipe pile 10 is driven into the ground. As described above, the entire tapered portion 4 penetrates the bearing stratum so that the end bearing capacity of the steel pipe pile 1 having the tapered portion is further improved compared to the end bearing capacity of the straight steel pipe pile 10 of which the pile outside diameter D1 and the plate thickness of the steel pipe pile are the same. Thus, the construction period of the pile and the number of the driving of the pile can also decrease, and economical steel pipe pile foundation can be constructed.

[0042]

It is preferable that the steel pipe pile 1 having the tapered portion be manufactured such that a ratio $H1/L$ between the length (the taper length) H1 of the tapered portion 4 in the longitudinal direction of the pile and the entire length (the sum of the length H2 of the straight portion 8 and the taper length H1 of the tapered portion 4) L of the steel pipe pile is in the range of 0.01 to 0.1. If the length H1 of the tapered portion 4 in the longitudinal direction of the pile is longer than one tenth (0.1) of the

entire length L of the steel pipe pile, since the processing range of the tapered portion 4 per one pile becomes long, the processing cost of the pile increases and becomes uneconomical. In addition, if the length $H1$ of the tapered portion 4 in the longitudinal direction of the pile is shorter than one hundredth (0.01) of the entire length L of the steel pipe pile, since the absolute value of the frictional resistance that is received by the circumferential face of the pile from the ground becomes large, the above-described decreasing effect of the construction resistance becomes low. Thus, in the steel pipe pile 1 having the tapered portion, it is preferable that the ratio of the length $H1$ of the tapered portion 4 to the pile longitudinal direction with respect to the entire length L of the steel pipe pile be 0.01 to 0.1. Additionally, it is preferable that the shape of the tapered portion 4 be determined such that the ratio $H1/D1$ (the ratio of length to diameter) between the length $H1$ of the tapered portion 4 in the longitudinal direction of the pile and the pile outside diameter $D1$ of the straight portion 8 is in the range of 0.1 to 2.5, and the ratio (the diameter-reducing ratio) $D2/D1$ between the outside diameter $D2$ of the tapered portion 4 and the pile outside diameter $D1$ of the straight portion 8 is in the range of 0.70 to 0.95.

[0043]

In addition, in the steel pipe pile 1 having the tapered portion, the pile outside diameter $D1$ of the straight portion (the linear shape portion) 8 may be at least 600 mm. When the tapered portion 4 penetrates the bearing stratum, the larger the pile diameter, the larger the area of the outside circumferential face of the tapered portion 4, and the area that is supported by the bearing stratum and the reaction force (and the confining pressure) against the bearing stratum becomes large. Thus, it is preferable that the pile outside diameter $D1$ of the steel pipe pile 1 having the tapered portion be 600 mm or more. Furthermore, when the using purpose of the pile and the economic efficiency are

considered, the pile outside diameter $D1$ may be 3000 mm or less. Furthermore, it is preferable that the plate thickness t of the straight portion 8 of the steel pipe pile 1 having the tapered portion be 6 mm to 30 mm such that the strength of the steel pipe pile is secured, and the material cost and the construction cost decrease. Similarly, when

5 workability or economic efficiency at the time of manufacturing is considered, the plate thickness t' of the tapered portion 4 and the plate thickness t of the straight portion 8 may be substantially equal. In this case, the tapered outside circumferential face 2 connects to the pile outside circumferential face 9 of the straight portion 8 having the constant pile outside diameter $D1$ without a step. Similarly, the tapered inside circumferential face 3

10 connects to the pile inside circumferential face 7 of the straight portion 8 without a step. Since the tapered portion 4 receives the load more than the straight portion 8 at the time of construction and after construction, the plate thickness t' of the tapered portion 4 may be larger than the plate thickness t of the straight portion. Specifically, it is preferable that the plate thickness t' of the tapered portion 4 be 6 mm to 40 mm. In this case, the

15 tapered outside circumferential face 2 and the pile outside circumferential face 9 of the straight portion 8 do not necessarily continue at the same level. Similarly, the tapered inside circumferential face 3 and the pile inside circumferential face 7 of the straight portion 8 do not necessarily continue at the same level.

[0044]

20 When the above-described steel pipe pile 1 having the tapered portion is constructed, the construction is capable of being performed by an appropriate known construction method. The steel pipe pile 1 may be driven into the ground by, for example, the vibration method, the pile driving method, the jacked piling method, the rotary press-in method or any other appropriate pile construction method.

25 [0045]

As the manufacturing method of the steel pipe pile having the tapered portion at the above-described end portion, methods may be used as described below. In other words, the steel pipe pile may be manufactured by a cold bending or a cold press forming in order to form the end portion of one steel pipe. In addition, the large end face of the short pipe having the tapered shape is welded to the end face of the straight steel pipe and the steel pipe pile having the tapered portion may be manufactured. Here, fan shaped steel strip is processed to the tapered shape through the cold bending and both end portions of the processed steel strip are joined by welding so that the short pipe having the tapered shape can be manufactured. In this case, the fan shaped steel strip is processed such that the outside diameter of the large end portion of the short pipe of the tapered shape is substantially the same as the outside diameter of the straight steel pipe. In addition, the plastic forming of the end portion of the steel pipe is performed and then the steel pipe pile having the tapered portion may be manufactured.

Industrial Applicability

[0046]

The steel pipe pile is capable of being provided, in which the end bearing capacity can be obtained, the resistance can decrease at the time of the pile construction and the plug effect of the pile end that becomes the resistance at the time of the pile construction can be relieved.

Brief Description of the Reference Symbols

[0047]

- 1 STEEL PIPE PILE (STEEL PIPE PILE HAVING TAPERED PORTION)
- 2 TAPERED OUTSIDE CIRCUMFERENTIAL FACE
- 3 TAPERED INSIDE CIRCUMFERENTIAL FACE
- 4 TAPERED PORTION (END PORTION, TIP END PORTION)

- 5 LARGE END (END PORTION OF LARGE DIAMETER SIDE)
- 6 SMALL END (END, TIP END, END PORTION OF SMALL DIAMETER
SIDE)
- 7 PILE INSIDE CIRCUMFERENTIAL FACE
- 5 8 STRAIGHT PORTION (STEADY PORTION OF WHICH THE OUTSIDE
DIAMETER IS CONSTANT)
- 9 PILE OUTSIDE CIRCUMFERENTIAL FACE
- 10 STRAIGHT STEEL PIPE PILE
- 11 SOIL (OR SOIL INCLUDING STONE OR ROCK) THAT IS TAKEN
10 WITHIN STEEL PIPE PILE
- 12 PILE INSIDE CIRCUMFERENTIAL FACE
- 13 SOIL (OR SOIL INCLUDING STONE OR ROCK) OF OUTSIDE OF
STEEL PIPE
- 15 SOIL (OR SOIL INCLUDING STONE OR ROCK) SURROUNDING
15 END PORTION OF STEEL PIPE PILE

What is claimed is:

1. A steel pipe pile comprising:

a straight portion having a cylindrical shape; and

5 a tapered portion that continues to an end of the straight portion and an outside diameter and an inside diameter thereof decrease away from the end,

wherein a ratio of length to diameter $H1/D1$ in which a length $H1$ between a large end and a small end of the tapered portion is divided by an outside diameter $D1$ of the large end is 0.1 to 2. 5.

10

2. The steel pipe pile according to claim 1, wherein a diameter-reducing ratio $D2/D1$ in which the outside diameter $D2$ of the small end is divided by the outside diameter $D1$ of the large end is 0.70 to 0.95.

15 3. The steel pipe pile according to claim 1 or 2, wherein the entire tapered portion is a penetrated portion that penetrates into a bearing stratum of a ground.

4. The steel pipe pile according to claim 1 or 2, wherein a ratio in which a sum length L of the length $H1$ of the tapered portion and a length $H2$ of the straight portion is divided
20 by the length $H1$ of the tapered portion is 0.01 to 0.1.

5. The steel pipe pile according to claim 1 or 2, wherein the outside diameter $D1$ of the large end is 600 mm to 3000 mm.