

## DESCRIPTION

### TITLE

#### SCREWED STEEL PILE

### FIELD

#### [0001]

The present invention relates to a screwed steel pile.

### BACKGROUND

#### [0002]

Known since the past has been a method of construction imparting a rotational force to a screwed steel pile comprised of a steel pipe at a lower end of which a helical blade is attached to make it penetrate the ground (for example, see PTL 1).

#### [CITATIONS LIST]

#### [PATENT LITERATURE]

#### [0003]

[PTL 1] Japanese Unexamined Patent Publication No. 2001-193063

### SUMMARY

#### [TECHNICAL PROBLEM]

#### [0004]

A screwed steel pile is made to penetrate the ground by the action of the rotational force of an installation machine. Specifically, by making the screwed steel pile rotate from above the ground, the soil is excavated by the front end of the helical blade, the soil excavated by the top surface of the blade is pushed upward along with rotation of the blade, and the pile is made to penetrate the ground by the thrust generated by the reaction force of the ground.

#### [0005]

When the screwed steel pile is made to penetrate the ground, due to the resistance to penetration, a rotational moment in the opposite direction to the rotational direction acts on the steel pipe forming the steel pipe pile. If this rotational moment increases, sometimes the steel pipe breaks. In particular, if the screwed steel pile penetrates the bedrock in the ground or other hard ground, the penetration resistance will increase and a large rotational moment will act on the steel pipe. In this case, the likelihood of the steel pipe breaking will become higher.

#### [0006]

The inventors engaged in repeated experiments to demonstrate this. As a result, it was confirmed that a crack began from the starting end of the steel pipe in the rotational direction along the joint with the blade at the lower end of the steel pipe, the crack spread by the crack advancing in the rotational direction, and finally the steel pipe broke along the crack and the steel pipe and blade separated.

**[0007]**

On the other hand, in the screwed steel pile described in the above PTL 1, the installation ability when making lower end of the pile reach the bearing stratum (meaning a stratum of gravel, sand, cohesive soil, or other ground with for example an N value of 50 or more. Note that the “N value” is the N value of a standard penetration test.) and securing of the bearing capacity are mentioned as technical issues. Means for solving these technical issues are mentioned, but no measures at all are devised against the penetration resistance causing the steel pipe to break.

**[0008]**

Therefore, the present invention has as its object the provision of a screwed steel pile able to suppress breakage due to resistance at the time of penetration without obstructing smooth penetration into the ground and realization of the bearing capacity.

**[SOLUTION TO PROBLEM]**

**[0009]**

The gist of the present disclosure is as follows:

**[0010]**

(1) A bladed steel pipe pile provided with a blade at its tip and screwed into the ground by the blade excavating the soil while rotating,

in the screwed steel pile, the blade provided with an open part of 0.1 time or more and 0.9 time or less of an area of a circle having a steel pipe pile outside diameter as its diameter being welded concentrically to a tip of steel pipe pile having an asymmetrical end shape when viewed from a side surface and the blade made to bulge to an inside and outside of the steel pipe pile.

**[0011]**

(2) The screwed steel pile according to the above (1), wherein a wall thickness of the steel pipe pile is made thicker in at least a predetermined range of greater than or equal to a distance corresponding to the steel pipe pile outside diameter from the tip of steel pipe pile in an axial direction of the steel pipe pile compared to outside of the predetermined range.

**[0012]**

(3) The screwed steel pile according to the above (2), wherein a ratio of the wall thickness outside of the predetermined range to the wall thickness of the predetermined range is 0.5 or more and a ratio of the wall thickness of the predetermined range to the steel pipe pile outside

diameter is 0.02 or more.

**[0013]**

(4) The screwed steel pile according to any one of the above (1) to (3), wherein the blade is a helical blade and is welded to the tip of steel pipe pile which is cut to a spiral.

**[0014]**

(5) The screwed steel pile according to any one of the above (1) to (4), wherein the tip of steel pipe pile is cut to a spiral, a step part of a starting end and terminal end of the tip of steel pipe pile cut to a spiral is made a shape comprised of an arc, any curve, or a combination of an arc or any curve and a straight line, and, when laying out flat the spiral shape tip of steel pipe pile and viewing a right angle triangle having a circumferential length of an outer circumference of the steel pipe pile as a bottom side, having a pitch of the spiral as a height, and having the spiral shaped tip of steel pipe pile made a slanted side, an area of a triangle having the height of the right angle triangle as a bottom side and having the terminal end as the vertex is 0.25 time or less of an area of the right angle triangle.

**[0015]**

(6) The screwed steel pile according to any one of the above (1) to (5), wherein the tip of steel pipe pile is cut to a spiral, a step part of a starting end and terminal end of the tip of steel pipe pile cut to a spiral is formed into an arc shape, and a radius R of the arc is defined by the following formula (1):

$$R=k \times P \dots (1)$$

where, in formula (1), P is the spiral pitch and “k” is a predetermined coefficient ( $0.8 \leq k \leq 1.5$ ).

**[0016]**

(7) The screwed steel pile according to any one of the above (1) to (6), wherein at a starting end in the rotational direction in a screw piling,

a bead welding together the blade and the tip of steel pipe pile is formed so as to continue from an outer circumference of the steel pipe pile to an inner circumference.

**[0017]**

(8) The screwed steel pile according to any one of the above (1) to (7), wherein, at a starting end in the rotational direction in a screw piling,

a cross-sectional shape along the rotational direction of a bead welding together the blade and the tip of steel pipe pile forms a slanted surface forming an acute angle with respect to a surface of the blade.

**[0018]**

(9) The screwed steel pile according to any one of the above (1) to (8), wherein in an upright state with the tip of steel pipe pile facing down, the blade is arranged so that an outside edge is lower than an inside edge or an inside edge and outside edge are positioned at equal heights.

## [ADVANTAGEOUS EFFECTS OF INVENTION]

### [0019]

According to the present invention, it is possible to suppress breakage due to resistance at  
5 the time of penetration without obstructing smooth penetration into the ground and realization of  
the bearing capacity.

## BRIEF DESCRIPTION OF DRAWINGS

### [0020]

10 FIG. 1 is a view showing a steel pipe pile according to an embodiment.

FIG. 2 is a view showing a steel pipe pile according to an embodiment.

FIG. 3 is a view showing a steel pipe pile according to an embodiment.

FIG. 4 is a view showing a steel pipe pile according to an embodiment.

FIG. 5 is a view showing a steel pipe pile according to an embodiment.

15 FIG. 6A is a graph showing results of analysis of a distribution of stress acting on a steel  
pipe pile at the time of penetration.

FIG. 6B is a graph showing results of analysis of a distribution of stress acting on a steel  
pipe pile at the time of penetration.

FIG. 6C is a graph showing results of analysis of a distribution of stress acting on a steel  
20 pipe pile at the time of penetration.

FIG. 6D is a graph showing results of analysis of a distribution of stress acting on a steel  
pipe pile at the time of penetration.

FIG. 7 is a view showing a steel pipe pile according to a comparative example of the  
present embodiment.

25 FIG. 8 is a developed view of a steel pipe pile in the vicinity of a step part.

FIG. 9 is a view showing enlarged a region A1 in a plan view shown in FIG. 5.

FIG. 10 is a view showing enlarged a vicinity of a starting end shown in FIG. 3.

FIG. 11 is a view showing a state when viewing a vicinity of a starting end from an arrow  
A3 direction of FIG. 9.

30 FIG. 12 is a vertical cross-sectional view showing enlarged a vicinity of a helical blade of  
FIG. 2.

FIG. 13 is a schematic view for explaining a shape of a step part.

FIG. 14 is a schematic view for explaining a shape of a step part.

FIG. 15 is a side view showing an example of a tip of steel pipe pile having an asymmetric  
35 end shape.

FIG. 16 is a cross-sectional view showing in detail a vicinity of a boundary of a steel pipe

pile where a thickness changes from a thick wall to a thin wall.

FIG. 17 is a cross-sectional view showing in detail a vicinity of a boundary of a steel pipe pile where a thickness changes from a thick wall to a thin wall.

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## DESCRIPTION OF EMBODIMENTS

### [0021]

First, referring to FIG. 1 to FIG. 5, the configuration of a screwed steel pile 10 according to one embodiment of the present invention will be explained. FIG. 1 to FIG. 5 are views showing the steel pipe pile 10 according to one embodiment. Specifically, FIG. 1 is a front view of the steel pipe pile 10, FIG. 2 is a vertical cross-sectional view of the steel pipe pile 10, FIG. 3 is a top perspective view of the steel pipe pile 10, FIG. 4 is a bottom perspective view of the steel pipe pile 10, and FIG. 5 is a plan view of the steel pipe pile 10. Note that, in FIG. 1 to FIG. 5, illustration of the later explained bead 30 is omitted.

### [0022]

15 This steel pipe pile 10 has an open lower end. This lower end is provided with a helical blade 12 with an inside edge 20 and an outside edge 21 bulging to the inside and outside of the steel pipe pile 10 by predetermined dimensions. Further, the tip of steel pipe pile 13 is cut to a spiral. A step part 16 of a starting end 15 and a terminal end 14 is formed into an arc shape.

### [0023]

20 An outside diameter ( $D_2$ ) of the helical blade 12 is made an outside diameter of about 1.2 to 3 times the steel pipe pile outside diameter ( $D$ ), while an inside diameter ( $D_3$ ) of the helical blade 12 is made an inside diameter of about 0.2 to 0.3 time the steel pipe pile inside diameter ( $D_1$ ). The helical blade 12 is configured using a ring shaped steel plate (donut shaped steel plate). That is, this ring shaped steel plate is cut in the radial direction at one location, one end is made a circumferential direction starting end 18, the other is made a circumferential direction terminal end 17, the steel plate is welded concentrically to the tip of steel pipe pile 13 cut to a spiral, and the inside edge 20 and outside edge 21 of this helical blade 12 are made to bulge to the inside and outside of the tip of steel pipe pile 13. The circumferential direction starting end 18 is provided with an excavation bit 24.

### [0024]

30 As explained previously, a steel pipe pile 10 will sometimes break due to the penetration resistance occurring at the time of penetration into the ground. The inventors analyzed the distribution of stress acting on a steel pipe pile 10 at the time of penetration using the finite element method (FEM) so as to find the cause why a steel pipe pile 10 breaks. FIG. 6A to FIG. 6D are graphs showing the results of analysis of the distribution of stress acting on a steel pipe pile 10 at the time of penetration. FIG. 6A to FIG. 6D show the results of analysis in the case

where no thick wall part explained later is provided and the wall thickness of the steel pipe pile 10 is constant in the entire region. FIG. 6A and FIG. 6B show the stress in the circumferential direction at the point of time of a torsional angle of  $6.15^\circ$ . FIG. 6A shows the stress at the outside surface of the steel pipe pile 10, while FIG. 6B shows the stress at the inside surface of the steel pipe pile 10. Further, FIG. 6C and FIG. 6D show the stress in the axial direction of the steel pipe pile 10 at the time of a torsional angle of  $6.15^\circ$ , FIG. 6C shows the stress at the outside surface of the steel pipe pile 10, while FIG. 6D shows the stress at the inside surface of the steel pipe pile 10. In FIG. 6A to FIG. 6D, it is shown that the higher the density of dots, the higher the stress. Note that the torsional angle is the angle formed by the radius at an initial position of a circle on the top surface at the time of fastening the bottom surface and the radius when there is rotational movement due to action of a torque.

**[0025]**

As will be understood from FIG. 6A to FIG. 6D, the stress generated at the steel pipe pile 10 at the time of penetration becomes higher in the range of a predetermined distance L upward from the lower end of the steel pipe pile 10. At the upper side from the range of the predetermined distance L, the stress generated at the steel pipe pile 10 is within an allowable range. Here, the predetermined distance L is the diameter of the steel pipe or so.

**[0026]**

Further, in particular, at the tip of steel pipe pile 13 which is joined with the helical blade 12, the stress becomes higher at the positions of the starting end 15 first entering the ground and the terminal end 14 last entering the ground and in the vicinity of the step part 16.

**[0027]**

FIG. 7 is a view showing a steel pipe pile 10' according to a comparative example of the present embodiment in which the later explained improvements (1) to (6) are not made and shows the situation where a crack 32 occurs at the time of penetration into the ground. In the steel pipe pile 10' according to the comparative example, if the penetration resistance when penetrating the ground is large, the crack 32 will advance in the rotational direction and the steel pipe pile 10' will break. According to the results of repeated proving tests performed by the inventors, the crack 32 starts from the starting end 15 where the stress is the highest and propagates along the rotational direction. The crack 32 finally advances around the steel pipe pile 10 whereupon the steel pipe pile 10 breaks. Due to this, the steel pipe pile 10 and the helical blade 12 end up separating. The position where the crack 32 first forms corresponds to the position of the starting end 15 where the stress is particularly high in the results of analysis of the stress distribution shown in FIG. 6.

**[0028]**

For this reason, by determining the shape and structure of the steel pipe pile 10 while taking

measures so that the stress at high stress locations is reduced based on the results of analysis of the stress distributions shown in FIG. 6A to FIG. 6D, it is possible to design a steel pipe pile 10 in which breakage at the time of penetration is suppressed.

**[0029]**

In the present embodiment, four measures are taken compared with the steel pipe pile 10' according to the comparative example so as to suppress breakage at the time of penetration. Due to these measures, formation of a crack 32 such as shown in FIG. 7 is suppressed. Furthermore, measures are taken so as to improve the bearing function of the steel pipe pile 10 after penetration. Below, each of the points of improvement will be explained.

**[0030]**

(1) Thick wall part of steel pipe

According to the results of stress analysis shown in FIG. 6A to FIG. 6D, the stress occurring at the steel pipe pile 10 at the time of penetration becomes particularly high in the range of a predetermined distance L upward from the lower end of the steel pipe pile 10. For this reason, as shown in the vertical cross-sectional view of FIG. 2, the wall thickness of the steel pipe pile 10 is made thicker in at least a predetermined range of greater than or equal to a distance (predetermined distance L) corresponding to the steel pipe pile outside diameter  $\phi$  or so from a tip of steel pipe pile 13 in an axial direction of the steel pipe pile 10 compared to outside of the predetermined range. As one example, if the pile diameter of the steel pipe pile 10 is 1000 mm, the wall thickness of the steel pipe pile 10 in the range of the predetermined distance L is  $t_1=22$  mm and outside the range of the predetermined distance L is  $t_2=13$  mm. As explained above, the high stress predetermined distance L is the diameter of the steel pipe pile 10 or so, therefore the steel pipe pile 10 is made a thick wall in the distance from the lower end of the steel pipe pile 10 corresponding to the diameter of the steel pipe pile 10 or so. However, this predetermined distance L is conditional on prevention of breakage in the case of penetration into hard ground of an N value of 50 or more generally considered a bearing stratum. So for example the superstructure of the steel pipe pile 10 is relatively light in weight, and for example when stratum in which an N value of 15 is the bearing stratum, the distance L can be shortened. Note that, from the viewpoint of reducing the stress, it may be considered to make the wall thick over the entire steel pipe pile 10, but the steel pipe pile 10 would increase in weight and the manufacturing cost would also become higher, therefore outside of the range of the predetermined distance L, the steel pipe pile 10 is preferably made thin walled.

**[0031]**

The part of the predetermined distance L where the wall thickness was made a thick wall may be configured as a short pipe. A long pipe at the upper side from the predetermined distance L and this short pipe may be joined by welding. On the other hand, the part of the predetermined

distance L where the wall thickness was made a thick wall and the part at the upper side from the predetermined distance L may be configured by an integral pipe.

**[0032]**

By making the wall thickness of the steel pipe pile 10 a thick wall in the range of the predetermined distance L, the concentration of stress is eased when making the steel pipe pile 10 rotate to penetrate the ground. Therefore, formation of a crack 32 such as shown in FIG. 7 is reliably suppressed.

**[0033]**

On the other hand, even if making the wall thickness of the steel pipe pile 10 a thick wall in the range of the predetermined distance L, stress will concentrate at the vicinity of the boundary 19 where the wall thickness of the steel pipe pile 10 changes from the thick wall to the thin wall and there is a possibility of breakage. For this reason, the ratio of the wall thickness of the steel pipe pile 10 in the predetermined distance L and the wall thickness of the steel pipe pile 10 outside the predetermined distance L or the ratio of the wall thickness of the steel pipe pile 10 in the predetermined distance L and the steel pipe pile outside diameter D is preferably made a suitable value where no breakage occurs. Table 1 shows the results of study by tests and simulations of the suitable values of the wall thickness ratio ( $t_2/t_1$ ) of the wall thickness  $t_1$  of the steel pipe pile 10 in the range of the predetermined distance L shown in FIG. 2 (wall thickness of short pipe) and the wall thickness  $t_2$  of the steel pipe pile 10 outside of the range of the predetermined distance L (wall thickness of long pipe) and the ratio ( $t_1/D$ ) of the wall thickness  $t_1$  and steel pipe pile outside diameter D. As shown in Table 1, it was learned that if the wall thickness ratio ( $t_2/t_1$ ) is 0.5 or more and the ratio of the wall thickness and the pile diameter ( $t_1/D$ ) is 2% or more, it is possible to make the pile penetrate a general bearing stratum ( $N \text{ value} \geq 50$ ) without causing breakage at the changed part of wall thickness where the wall thickness of the steel pipe pile 10 changes from the thick wall to the thin wall in the vicinity of the boundary 19 (“Good” in Table 1). Furthermore, it was learned that if the wall thickness ratio ( $t_2/t_1$ ) is 0.7 or more or the wall thickness ratio ( $t_2/t_1$ ) is 0.5 or more and the ratio ( $t_1/D$ ) of the wall thickness and the pile diameter is 4% or more, it is possible to make the pile penetrate a bearing stratum of gravel ( $N \text{ value} \geq 50$ ) where an uneven load is easily applied without causing breakage at the changed part of wall thickness where the wall thickness of the steel pipe pile 10 changes from the thick wall to the thin wall (“Very good” in Table 1).

**[0034]**

[Table 1]

| Wall thickness ratio ( $t_2/t_1$ ) | Wall thickness/pile diameter<br>( $t_1/D$ ) $\geq 2\%$ | Wall thickness/pile diameter<br>( $t_1/D$ ) $\geq 4\%$ |
|------------------------------------|--------------------------------------------------------|--------------------------------------------------------|
| 0.3                                | Not good                                               | Not good                                               |
| 0.4                                | Not good                                               | Not good                                               |
| 0.5                                | Good                                                   | Very good                                              |
| 0.6                                | Good                                                   | Very good                                              |
| 0.7                                | Very good                                              | Very good                                              |
| 0.8                                | Very good                                              | Very good                                              |
| 0.9                                | Very good                                              | Very good                                              |

### [0035]

FIG. 16 and FIG. 17 are cross-sectional views showing in detail the vicinity of the boundary 19 where the wall thickness of the steel pipe pile 10 changes from the thick wall to the thin wall.

FIG. 16 and FIG. 17 show enlarged the vicinity of the region A4 shown in FIG. 2 in the case where the steel pipe pile 10 is configured as a short pipe 10b in the range of the predetermined distance L where the wall thickness is made the thick wall and the steel pipe pile 10 is configured by joining a long pipe 10a outside of the predetermined distance L and the short pipe 10b by welding. In the example shown in FIG. 16, the end faces of the long pipe 10a and the short pipe 10b in the axial direction are joined by a weld bead 40. The weld bead 40 is formed between the facing end faces along the circumferential direction. According to the example of configuration shown in FIG. 16, the weld bead 40 melts into the space between the facing end faces of the long pipe 10a and the short pipe 10b, so breakage of the changed part of wall thickness at the time of penetration is suppressed. In the example shown in FIG. 17, in addition to the constitution of FIG. 16, a backing plate 42 is provided along the inner circumference of the portion where the long pipe 10a and the short pipe 10b are joined. The backing plate 42 is welded to the inner circumferential surface of either of the long pipe 10a and the short pipe 10b.

### [0036]

(2) Radius of curvature of step part

As explained above, the step part 16 of the starting end 15 and terminal end 14 of the tip of steel pipe pile 13 cut to a spiral is formed into an arc shape. FIG. 8 is a developed view laying out the steel pipe pile 10 in the vicinity of the step part 16. Further, FIG. 9 is a view showing enlarged the region A1 in the plan view shown in FIG. 5.

### [0037]

In the developed view shown in FIG. 8, the radius R of the arc of the step part 16 connecting the starting end 15 and terminal end 14 of the tip of steel pipe pile 13 cut to a spiral is

expressed by the following formula (1) using the spiral pitch P of the helical blade 12. Note that, the spiral pitch P corresponds to the displacement in the axial direction along the spiral tip of steel pipe pile 13 when the steel pipe pile 10 is rotated 360° about the center axis. Further, “k” is a predetermined coefficient. Along with a change in the value of “k”, the angle  $\theta_1$  between the starting end 15 and the terminal end 14 shown in FIG. 9 changes. There is the relationship  $\theta_1 = 360 - 360 \times k$  [deg].

$$R = k \times P \dots (1)$$

#### [0038]

The inventors changed the value of “k” to analyze the stress distribution in the same way as FIG. 6A to FIG. 6D. They examined the level of stress in the vicinity of the step part 16 and obtained the results shown in the following Table 2. In Table 2, “Good” indicates the stress of the step part 16 was 315N/mm<sup>2</sup> or less. On the other hand, in Table 2, “Not good” indicates the stress of the step part 16 was more than 315N/mm<sup>2</sup> (yield point) and a plastic part was formed at the steel pipe. From the results, the value of “k” is preferably  $0.8 \leq k \leq 1.5$ .

#### [0039]

[Table 2]

| k   | Stress concentration in vicinity of step part |
|-----|-----------------------------------------------|
| 0.6 | Not good                                      |
| 0.7 | Not good                                      |
| 0.8 | Good                                          |
| 0.9 | Good                                          |
| 1.0 | Good                                          |
| 1.1 | Good                                          |
| 1.2 | Good                                          |
| 1.3 | Good                                          |
| 1.4 | Good                                          |
| 1.5 | Good                                          |
| 1.6 | Not good                                      |

#### [0040]

In the above way, by making the radius of curvature of the arc of the step part 16 the pitch P or so of the helical blade 12, the concentration of stress at the starting end 15, step part 16, and terminal end 14 which easily become starting points of breakage is eased and breakage of the steel pipe pile 10 due to the penetration resistance is suppressed.

#### [0041]

Note that, in the developed view of FIG. 8, the example where the step part 16 was connected by an arc was shown, but the step part 16 may also be connected by any curve or a combination of an arc or any curve and a straight line.

**[0042]**

FIG. 13 and FIG. 14 are schematic views for further explaining the shape of the step part 16. FIG. 13 shows a side view of the steel pipe pile 10 including the tip of steel pipe pile 13 at the top part and shows a developed view laying out the tip of steel pipe pile 13 including the step part 16 at the bottom part. In FIG. 13, illustration of the blade 12 is omitted. Further, FIG. 14 is a developed view laying out the steel pipe pile 10 at the entire circumference including the step part 16.

**[0043]**

As shown in FIG. 13, if defining the outside diameter of the steel pipe pile 10 as  $D_p$ , the circumferential length of the outside diameter of the steel pipe pile 10 becomes  $\pi \cdot D_p$ . As shown in FIG. 14, the tip of steel pipe pile 13 cut to a spiral forms a slanted straight line on the developed view. A right angle triangle is formed having this straight line as the slanted side, having the pitch  $P$  as the height, and having the circumferential length  $\pi \cdot D_p$  as the bottom side. Note that, in FIG. 14, the case where the pitch  $P$  is 0.3 time the outside diameter  $D_p$  is shown. The area of the triangle formed by the three points of the two ends of the pitch  $P$  ( $=0.3 D_p$ ) and the terminal end 14 is 0.25 time or less of the area of this right angle triangle. That is, the angle between the starting end 15 and terminal end 14 with respect to the center axis of the steel pipe pile 10 is  $(\pi/4) \cdot D_p$  or less. When screwing in the steel pipe pile 10, soil is taken in from the side opening formed by the step part 16 of the tip of steel pipe pile 13 to the inside of the steel pipe pile 10, but if the area of the triangle formed by the three points of the two ends of the pitch  $P$  and the terminal end 14 is 0.25 time or less of the area of the right angle triangle, it is possible to sufficiently secure the distance from the bottom side of the right angle triangle to the terminal end 14 (height of step part 16 in axial direction of steel pipe pile 10), so the side opening becomes larger and soil easily enters into the pipe. Due to this, the penetration resistance is reduced. On the other hand, if the area of the triangle formed by the three points of the two ends of the pitch  $P$  and the terminal end 14 becomes more than 0.25 time the area of the right angle triangle, the distance from the bottom side of the right angle triangle to the terminal end 14 becomes shorter, so the side opening becomes smaller and entry of soil into the pipe becomes difficult. The soil not entering into the pipe has to be pushed out to the surroundings of the steel pipe pile 10, so the penetration resistance becomes larger and as a result the screw piling becomes difficult.

**[0044]**

The shape of the step part 16 (arc, any curve, or combination of an arc or any curve and a

straight line) is determined so as to connect the starting end 15 and terminal end 14 defined in the above way. Here, if the terminal end 14 and starting end 15 defined in the above way are connected by a straight line, a large side opening is secured, so the penetration resistance can be reduced, but stress concentrates at the starting end 15, terminal end 14, and vicinity of the step part 16, so the shape of the step part 16 is preferably defined by connecting the starting end 15 and the terminal end 14 by an arc, any curve, or a combination of an arc or any curve and a straight line. Due to this, a large side opening is secured and the penetration resistance reduced and also concentration of stress at the starting end 15, terminal end 14, and vicinity of the step part 16 is suppressed.

**[0045]**

(3) Shape of welded part of blade lower end and steel pipe

FIG. 10 is a view showing enlarged the vicinity of the starting end 15 of the tip of steel pipe pile 13 and a perspective view showing enlarged the region A2 shown in FIG. 3. FIG. 11 is a view showing the state viewing the vicinity of the starting end 15 from the arrow A3 direction of FIG. 9. In the steel pipe pile 10, the tip of steel pipe pile 13 cut to a spiral is made to abut against the spiral top surface of the helical blade 12 and is joined to the helical blade 12 by welding.

**[0046]**

As shown in FIG. 9 to FIG. 11, a weld bead 30 is formed along the outer circumference of the steel pipe pile 10 whereby the steel pipe pile 10 and helical blade 12 are joined. Furthermore, in the vicinity of the starting end 15, the bead 30 is formed by box welding so as to surround the starting end 15 in a U-shape. That is, the bead 30 is formed in the vicinity of the starting end 15 so as to continue from the outer circumference of the steel pipe pile 10 to the inner circumference.

**[0047]**

Note that, at the inner circumference of the steel pipe pile 10, as shown in FIG. 9, a spiral backing plate 25 may also be placed along the inner circumference of the steel pipe pile at the portion where the tip of steel pipe pile 13 and helical blade 12 are joined. The backing plate 25 is for example made a length in the axial direction of the steel pipe pile 10 of 30 mm or so and a thickness in the diametrical direction of 10 mm or so. At the inner circumference of the steel pipe pile 10, welding is not performed other than at the portion where the box welding is performed, but the weld bead 30 formed along the outer circumference of the steel pipe pile 10 melts through and reaches the backing plate at the inner circumference. The backing plate 25 is for welding from one side (outer circumference side of steel pipe pile 10) to keep the weld metal of the bead 30 at the groove part, so in the case of a box welding part welded from the two sides (outer circumference side and inner circumference side of steel pipe pile 10), the backing plate 25 may be omitted. That is, at the inner circumference of the steel pipe pile 10, the backing plate

25 need not be provided at the part where box welding is performed. On the other hand, at the inner circumference of the steel pipe pile 10, the backing plate 25 may be laid to the position of the starting end 15. Then, it is also possible to provide the backing plate 25 to the part which have been box welding and to together melt through to the backing plate 25 by box welding.

5 **[0048]**

By the bead 30 being formed by box welding at the vicinity of the starting end 15 to continue from the outer circumference of the steel pipe pile 10 to the inner circumference, at the front end of the helical blade 12 in the rotational direction (vicinity of excavation bit 24) in the screw piling, the helical blade 12 is strongly fastened to the tip of steel pipe pile 13 from the outer circumference of the steel pipe pile 10 to the inner circumference via the starting end 15, so movement at the vicinity of the excavation bit 24 of the helical blade 12 at the time of the screw piling is suppressed and the amount of deformation of the front end of the helical blade 12 becomes smaller, so the stress falls. Therefore, breakage of the helical blade 12 or steel pipe pile 10 is suppressed.

15 **[0049]**

The position P1 of the terminal end of the bead 30 at the inner circumference of the steel pipe pile 10, as shown in FIG. 9, is preferably located at the opposite side to the starting end 15 from the one-dot chain line L1 connecting the point P2 where the excavation bit 24 and the inside edge 20 of the helical blade 12 cross (or the point P3 where the excavation bit 24 and the outside edge 21 of the helical blade 12 cross) and the center O of the steel pipe pile 10. At the time of the screw piling, the excavation bit 24 is subjected to a large force, but the position P1 of the terminal end of the bead 30 at the inner circumference of the steel pipe pile 10 is located at the opposite side to the starting end 15 from the one-dot chain line L1, whereby movement in the vicinity of the excavation bit 24 of the helical blade 12 at the time of the screw piling is suppressed and the amount of deformation of the front end of the helical blade 12 becomes smaller, so the stress falls. Therefore, breakage of the helical blade 12 or the steel pipe pile 10 is suppressed.

25 **[0050]**

As shown in FIG. 9 to FIG. 11, at the starting end 15, the weld bead 30 is formed into a slanted surface shape. The bead 30 is formed as a slanted surface crossing the surface of the helical blade 12 by an angle of 45° or less at the starting end 15. More preferably, at the starting end 15, the weld bead 30 is formed as a recessed slanted surface. In other words, at the starting end 15, the bead 30 is made the shape of the bow of a ship. Such a shape is for example formed by forming the bead 30, then using a grinder etc. to cut the bead 30 and finish it smooth. By making bead 30 a recessed slanted surface in the vicinity of the starting end 15 and finishing it smooth, at the time of penetration of the steel pipe pile 10, soil is excavated by the slanted

surface of the bead 30, so the penetration resistance is suppressed and the steel pipe pile 10 is screwed in by a smaller rotational torque. Further, by the soil being excavated by the slanted surface of the bead 30, the stress concentration at the time of penetration of the steel pipe pile 10 is eased, so occurrence of cracks and breakage is suppressed at the steel pipe pile 10.

**[0051]**

(4) Aperture rate of blade

In the illustrated examples, when the outside diameter (D) of the steel pipe pile 10 was made 100 mm to 1600 mm, the outside diameter (D<sub>2</sub>) of the helical blade 12 was made 250 mm to 2400 mm in range.

**[0052]**

By designing the inside edge 20 and outside edge 21 of the helical blade 12 to bulge to the inside and outside of the tip of steel pipe pile 13, an open part 22 is formed at the center part and the screwed steel pile 10 becomes an open end pile. The area of the circular open part 22 of the inside edge 20 when making the outside diameter (D<sub>2</sub>) of the helical blade 12 about 1.2 to 3 times the steel pipe pile outside diameter (D) and viewing the steel pipe pile 10 from the axial direction was made from 0.1 time or more to 0.9 time or less the area of a circle having the outside diameter D of the steel pipe pile 10 as a diameter. The ratio of the area of the open part 22 to the area of the circle having the outside diameter D of the steel pipe pile 10 as a diameter (aperture rate (%)), as shown in the following Table 3, is a value obtained as a result of tests and simulations. If the aperture rate is 0.1 time or more and 0.9 time or less, satisfaction of the two conditions for smooth penetration of a large diameter pile into the ground and securing the bearing function of the steel pipe pile 10 become possible. On the other hand, if departing from this value, smooth satisfaction of the two conditions was difficult. Note that, as shown in Table 3, if the aperture rate is 0.1 time (10%) or more and 0.9 time (90%) or less, the pile can be made to penetrate into ordinary ground (N value≥15) without breakage and the bearing function can be secured (“Good” in Table 3). Furthermore, if the aperture rate is 20 to 50%, smooth penetration and the bearing function can be secured even for the bearing stratum of hard ground (N value≥50) (“Very good” in Table 3)

**[0053]**

[Table 3]

| Aperture rate (%) | Penetration resistance | Bearing function |                |
|-------------------|------------------------|------------------|----------------|
|                   |                        | Pile stability   | Blade rigidity |
| 0                 | Not good               | Very good        | Very good      |
| 10                | Good                   | Very good        | Very good      |
| 20                | Very good              | Very good        | Very good      |
| 30                | Very good              | Very good        | Very good      |
| 40                | Very good              | Very good        | Very good      |
| 50                | Very good              | Very good        | Very good      |
| 60                | Very good              | Very good        | Good           |
| 70                | Very good              | Very good        | Good           |
| 80                | Very good              | Very good        | Good           |
| 90                | Very good              | Good             | Good           |
| 100               | Very good              | Good             | Not good       |

#### [0054]

At the time of penetration of the steel pipe pile 10 into the ground, if soil clogs the inside of the steel pipe pile 10, the rotational torque required for the screw piling will rise and possibility of the steel pipe pile 10 breaking will increase. As shown in Table 3, the penetration resistance and bearing function are in a tradeoff relationship. The larger the aperture rate, the easier it is for soil to enter from the opening to the inside of the steel pipe pile 10, so the penetration resistance falls. On the other hand, the larger the aperture rate, the smaller the area of the helical blade 12 in a plan view, so the area of the steel pipe pile 10 set on the ground becomes smaller and therefore the stability falls and, further, the rigidity of the helical blade 12 falls, so the bearing function bearing the steel pipe pile 10 after penetration falls.

#### [0055]

As a result of tests and simulations, by making the aperture rate 20% to 50% in range, it was possible to satisfy the two conditions explained above even with respect to a bearing stratum of the hard ground (N value $\geq$ 50), but if over 30%, the wall thickness for securing the rigidity required for the blade became larger, so an aperture rate of 20% to 30% was more preferable. In more detail, if the aperture rate was 10% or more, it was possible to make the pile penetrate ordinary ground (N value $\geq$ 15) without breakage, while if the aperture rate was 20% or more, smooth penetration was possible even in a bearing stratum of hard ground (N value $\geq$ 50). Further, if the aperture rate not more than 90%, it was possible to secure both pile stability after penetration as the bearing function and blade rigidity (“Good” in Table 3), but if the aperture rate was not more than 80%, it was possible to secure well the pile stability after penetration as a

bearing function (“Very good” in Table 3) and, further, if the aperture rate was not more than 50%, it was possible to secure well both pile stability and blade rigidity (“Very good” in Table 3).

**[0056]**

5 (5) Shape of blade

FIG. 12 is a vertical cross-sectional view showing enlarged the vicinity of the helical blade 12 of FIG. 2. As shown in FIG. 12, the helical blade 12 has an inside edge 20 and outside edge 21 positioned horizontally or is slanted so as to be positioned higher the further to the inside edge 20 and to be positioned lower the further to the outside edge 21.

10 **[0057]**

The steel pipe pile 10 receives a large load downward in the vertical direction after being inserted into the ground. If the outside edge 21 of the helical blade 12 is positioned above the inside edge 20 in the vertical direction, when receiving a downward load in the vertical direction, the outside of the helical blade 12 will easily flex in the upper direction. Further, if the outside of the helical blade 12 ends up flexing in the upper direction, the bearing function of the steel pipe pile 10 will end up falling. Therefore, it is preferable that the inside edge 20 and outside edge 21 be positioned horizontally or that the blade 12 be slanted so as to be positioned higher the further to the inside edge 20 and to be positioned lower the further to the outside edge 21.

**[0058]**

20 (6) Asymmetric lower end shape

The tip of steel pipe pile 13 has an asymmetric lower end shape seen from the side surface. If the tip of steel pipe pile 13 is a symmetric shape, the force trying to make the steel pipe pile 10 penetrate and the reaction force of the hard ground are counterbalanced and penetration easily becomes difficult. As opposed to this, if making the tip of steel pipe pile 13 having an asymmetric lower end shape seen from the side surface rotate, the force trying to make the steel pipe pile 10 penetrate and the reaction force become difficult to counterbalance each other and penetration is improved.

**[0059]**

FIG. 15 is a side view showing an example of a tip of steel pipe pile 13 having an asymmetric lower end shape seen from a side surface. As a tip of steel pipe pile 13 having an asymmetric lower end shape seen from a side surface, in addition to a shape having a step part 16, one having a slanted surface 34 such as shown in FIG. 15 may be mentioned.

**[0060]**

In the above explained embodiments, a helical blade 12 was illustrated as the blade fastened to the steel pipe pile 10, but the blade fastened to the steel pipe pile 10 is not limited to a spiral. For example, the blade may also be configured from a flat plate. Further, the helical blade 12

was illustrated as being split at a single location of the step part 16 in the circumferential direction, but the helical blade 12 may also be split at a plurality of locations.

#### REFERENCE SIGNS LIST

|    |               |                                        |
|----|---------------|----------------------------------------|
| 5  | <b>[0061]</b> |                                        |
|    | 10            | screwed steel pile                     |
|    | 12            | helical blade                          |
|    | 13            | tip of steel pipe pile                 |
|    | 14            | terminal end                           |
| 10 | 15            | starting end                           |
|    | 16            | step part                              |
|    | 17            | circumferential direction terminal end |
|    | 18            | circumferential direction starting end |
|    | 19            | boundary                               |
| 15 | 20            | inside edge                            |
|    | 21            | outside edge                           |
|    | 22            | open part                              |
|    | 25, 42        | backing plate                          |
|    | 30            | bead                                   |
| 20 | 32            | crack                                  |
|    | 34            | slanted surface                        |

## CLAIMS

### [Claim 1]

A bladed screwed steel pile provided with a blade at its tip and screwed into the ground by the blade excavating the soil while rotating,

in the screwed steel pile, the blade provided with an open part of 0.1 time or more and 0.9 time or less of an area of a circle having a steel pipe pile outside diameter as its diameter being welded concentrically to a tip of steel pipe pile having an asymmetrical end shape when viewed from a side surface and the blade made to bulge to an inside and outside of the steel pipe pile.

### [Claim 2]

The screwed steel pile according to claim 1, wherein a wall thickness of the steel pipe pile is made thicker in at least a predetermined range of greater than or equal to a distance corresponding to the steel pipe pile outside diameter from the tip of steel pipe pile in an axial direction of the steel pipe pile compared to outside of the predetermined range.

### [Claim 3]

The screwed steel pile according to claim 2, wherein a ratio of the wall thickness outside of the predetermined range to the wall thickness of the predetermined range is 0.5 or more and a ratio of the wall thickness of the predetermined range to the steel pipe pile outside diameter is 0.02 or more.

### [Claim 4]

The screwed steel pile according to any one of claims 1 to 3, wherein the blade is a helical blade and is welded to the tip of steel pipe pile which is cut to a spiral.

### [Claim 5]

The screwed steel pile according to any one of claims 1 to 4, wherein the tip of steel pipe pile is cut to a spiral, a step part of a starting end and terminal end of the tip of steel pipe pile cut to a spiral is made a shape comprised of an arc, any curve, or a combination of an arc or any curve and a straight line, and, when laying out flat the spiral shape tip of steel pipe pile and viewing a right angle triangle having a circumferential length of an outer circumference of the steel pipe pile as a bottom side, having a pitch of the spiral as a height, and having the spiral shaped tip of steel pipe pile made a slanted side, an area of a triangle having the height of the right angle triangle as a bottom side and having the terminal end as the vertex is 0.25 time or less of an area of the right angle triangle.

[Claim 6]

The screwed steel pile according to any one of claims 1 to 5, wherein the tip of steel pipe pile is cut to a spiral, a step part of a starting end and terminal end of the tip of steel pipe pile cut to a spiral is formed into an arc shape, and a radius R of the arc is defined by the following formula (1):

$$R=k \times P \dots (1)$$

where, in formula (1), P is the spiral pitch and “k” is a predetermined coefficient ( $0.8 \leq k \leq 1.5$ ).

[Claim 7]

The screwed steel pile according to any one of claims 1 to 6, wherein at a starting end in the rotational direction in a screw piling, a bead welding together the blade and the tip of steel pipe pile is formed so as to continue from an outer circumference of the steel pipe pile to an inner circumference.

[Claim 8]

The screwed steel pile according to any one of claims 1 to 7, wherein, at a starting end in the rotational direction in a screw piling, a cross-sectional shape along the rotational direction of a bead welding together the blade and the tip of steel pipe pile forms a slanted surface forming an acute angle with respect to a surface of the blade.

[Claim 9]

The screwed steel pile according to any one of claims 1 to 8, wherein in an upright state with the tip of steel pipe pile facing down, the blade is arranged so that an outside edge is lower than an inside edge or an inside edge and outside edge are positioned at equal heights.