

[Document Type] Specification

[Title of the Invention] JOINT STRUCTURE FOR STEEL PIPE PILE

[Technical Field of the Invention]

[0001]

The present invention relates to a joint structure for a steel pipe pile.

Priority is claimed on Japanese Patent Application No. 2015-231400, filed on November 27, 2015, the content of which is incorporated herein by reference.

[Related Art]

[0002]

In the related art, in order to realize easy construction on a narrow area or to reduce a construction period, there has been a demand for non-welding mechanical joints. For example, for the purpose of coupling a plurality of steel pipe piles in an axial direction using a mechanical joint, joint structures for a steel pipe pile disclosed in Patent Documents 1 and 2 have been proposed.

[0003]

In the joint structure for a steel pipe pile disclosed in Patent Document 1, a pair of an outer fitting end section and an inner fitting end section freely fitted to each other is individually formed in a first pile and a second pile adjacent to each other in the axial direction. In this joint structure, in a state where the outer fitting end section and the inner fitting end section are fitted to each other, an engagement section and an engagement target section which engage with each other by relatively rotating around an axial center are formed. In the joint structure for a steel pipe pile disclosed in Patent Document 1, separation preventing units are provided in the engagement section and the engagement target section in order to prevent the engagement section and the engagement target section in an engaged state from being separated in a radial

direction of the first pile or the second pile.

[0004]

In the joint structure for a steel pipe pile disclosed in Patent Document 2, a pair of an outer fitting end section and an inner fitting end section freely fitted to each other is individually formed in a first pile and a second pile adjacent to each other in the axial direction. In this joint structure, in a state where the outer fitting end section and the inner fitting end section are fitted to each other, a plurality of engagement protrusions and a plurality of engagement target protrusions which respectively engage with each other by relatively rotating around an axial center are formed in the axial direction. In the joint structure for a steel pipe pile disclosed in Patent Document 2, the outer fitting end section is formed such that a location for forming the engagement protrusion provided on a front end portion side has a diameter larger than a location for forming the engagement protrusion provided on a base end portion side. In addition, the inner fitting end section is formed such that a location for forming the engagement target protrusion provided on the front end portion side has a diameter smaller than a location for forming the engagement target protrusion provided on the base end portion side.

[Prior Art Document]

[Patent Document]

[0005]

[Patent Document 1] Japanese Unexamined Patent Application, First Publication No. H11-43937

[Patent Document 2] Japanese Unexamined Patent Application, First Publication No. H11-43936

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0006]

Here, in a joint structure for a steel pipe pile, in a state where a plurality of steel pipe piles are coupled to each other in an axial direction, forces for compression, tension, and bending act on a joint section. In a joint structure for a steel pipe pile disclosed in Patent Document 1, although a burden rate of forces for compression, tension, and bending varies from a base end side to a front end side of an outer fitting end section and an inner fitting end section, a plate thickness of an engagement target section is entirely the same in the axial direction. Therefore, in the joint structure for a steel pipe pile disclosed in Patent Document 1, a vain part increases particularly in the plate thicknesses of the outer fitting end section and the inner fitting end section on the front end side, thereby resulting in a problem that the plate thicknesses increase unnecessarily and cost increases.

[0007]

In contrast, in a joint structure for a steel pipe pile disclosed in Patent Document 2, a burden rate of forces for compression, tension, and bending is taken into consideration by gradually reducing plate thicknesses of engagement target protrusions from a base end side toward a front end side of an outer fitting end section and an inner fitting end section. However, in the joint structure for a steel pipe pile disclosed in Patent Document 2, the plate thicknesses of the engagement target protrusions are the same in the outer fitting end section and the inner fitting end section, thereby resulting in a problem that a steel weight of the entire joint increases unnecessarily and cost increases.

[0008]

The joint structure for a steel pipe pile disclosed in Patent Document 2 is

formed to be tapered in the axial direction by gradually reducing the plate thicknesses of the engagement target protrusions from the base end side toward the front end side of the outer fitting end section and the inner fitting end section. However, in the joint structure for a steel pipe pile disclosed in Patent Document 2, the ratio of the protruding height of a compressive surface and the protruding height of a tensile surface is less than 0.50. Therefore, it is not possible to minimize the steel weight of the entire joint for ensuring equal proof stress for compression, tension, and bending, thereby resulting in a problem that material cost increases.

[0009]

The present invention has been made in consideration of the foregoing circumstances, and an object thereof is to provide a joint structure for a steel pipe pile, in which workability is improved through weight reduction.

[Means for Solving the Problem]

[0010]

(1) According to an aspect of the present invention, there is provided a joint structure for a steel pipe pile, in which a first steel pipe pile having an outer fitting end section and a second steel pipe pile having an inner fitting end section are coupled to each other in a state where the outer fitting end section and the inner fitting end section share the same axial line. The joint structure includes, in a case of being seen in a cross section along the axial line, outer fitting stepped sections that are provided at a plurality of positions along the axial line on an inner side of the outer fitting end section such that diameters increase in steps toward the second steel pipe pile, in which each of the outer fitting stepped sections has an outer fitting peak section relatively close to the second steel pipe pile and an outer fitting valley section adjacent to the outer fitting peak section; and inner fitting stepped sections that are provided at a

plurality of positions along the axial line on an outer side of the inner fitting end section such that diameters decrease in steps toward the first steel pipe pile, in which each of the inner fitting stepped sections has an inner fitting peak section relatively close to the first steel pipe pile and an inner fitting valley section adjacent to the inner fitting peak section. Each of the inner fitting peak sections is interlocked with each of the outer fitting peak sections in a state where the inner fitting end section is inserted into the outer fitting end section and is relatively rotated about the axial line. In each of the outer fitting peak sections, a ratio obtained by dividing a protruding height of the outer fitting peak section next to the outer fitting peak section relatively close to the second steel pipe pile by a protruding height of the outer fitting peak section relatively close to the second steel pipe pile ranges from 0.5 to 0.9. In each of the inner fitting peak sections, a ratio obtained by dividing a protruding height of the inner fitting peak section next to the inner fitting peak section relatively close to the first steel pipe pile by a protruding height of the inner fitting peak section relatively close to the first steel pipe pile ranges from 0.5 to 0.9. A plate thickness of the outer fitting valley section closest to the second steel pipe pile is smaller than a plate thickness of the inner fitting valley section closest to the first steel pipe pile, and a ratio obtained by dividing the plate thickness of the outer fitting valley section closest to the second steel pipe pile by the plate thickness of the inner fitting valley section closest to the first steel pipe pile is equal to or greater than 0.84.

[0011]

According to the joint structure for a steel pipe pile having the configuration described above, a joint for a steel pipe pile can be reduced in weight, so that workability is improved.

[0012]

(2) In the joint structure for a steel pipe pile according to (1), a ratio obtained by dividing the plate thickness of the outer fitting valley section closest to the second steel pipe pile by the plate thickness of the inner fitting valley section closest to the first steel pipe pile may range from 0.84 to 0.94.

[0013]

In this case, a joint for a steel pipe pile can be further reduced in weight.

[0014]

(3) In the joint structure for a steel pipe pile according to (1) or (2), in each of the outer fitting peak sections, a ratio obtained by dividing the protruding height of the outer fitting peak section next to the outer fitting peak section relatively close to the second steel pipe pile by the protruding height of the outer fitting peak section relatively close to the second steel pipe pile may range from 0.6 to 0.8. In each of the inner fitting peak sections, a ratio obtained by dividing the protruding height of the inner fitting peak section next to the inner fitting peak section relatively close to the first steel pipe pile by the protruding height of the inner fitting peak section relatively close to the first steel pipe pile may range from 0.6 to 0.8.

[0015]

In this case, a joint for a steel pipe pile can be reduced in weight while the strength of the joint for a steel pipe pile is maintained.

[Effects of the Invention]

[0016]

According to the joint structure for a steel pipe pile of the aspect of the present invention, workability is improved by reducing the weight of a joint.

[Brief Description of the Drawings]

[0017]

FIG. 1 is a perspective view showing a joint structure for a steel pipe pile according to a first embodiment of the present invention.

FIG. 2 is a view showing an outer fitting end section of the same joint structure for a steel pipe pile and is a cross-sectional view in a case of being seen in a cross section including an axial line.

FIG. 3 is a view showing the outer fitting end section of the same joint structure for a steel pipe pile and is a part of a cross-sectional view of a part A in FIG. 2.

FIG. 4 is a side view showing an inner fitting end section of the same joint structure for a steel pipe pile.

FIG. 5 is a view showing the inner fitting end section of the same joint structure for a steel pipe pile and is a part of a cross-sectional view of a part B in FIG. 4.

FIG. 6 is a perspective view showing the inner fitting end section being inserted into the outer fitting end section in the same joint structure for a steel pipe pile.

FIG. 7 is a perspective view showing a state where the inner fitting end section is rotated with respect to the outer fitting end section in the same joint structure for a steel pipe pile and shows a part of the outer fitting end section in a cross section.

FIG. 8 is a part of a cross-sectional view of a part C in FIG. 7 and is a view showing a tensile force acting on a tensile surface of the same joint structure for a steel pipe pile.

FIG. 9 is a part of a cross-sectional view of the part C in FIG. 7 and is a view showing a compressive force acting on a compressive surface of the same joint structure for a steel pipe pile.

FIG. 10 is a part of a cross-sectional view showing plate thicknesses of outer fitting stepped sections and inner fitting stepped sections of the same joint structure for a steel pipe pile.

FIG. 11 is a view showing a joint structure for a steel pipe pile in the related art and is a part of a cross-sectional view showing plate thicknesses of outer fitting stepped sections and inner fitting stepped sections.

FIG. 12 is a part of a cross-sectional view showing a modification example of an outer fitting extra length section and an inner fitting extra length section in the same joint structure for a steel pipe pile.

FIG. 13 shows parts of cross-sectional views of joint structures for a steel pipe pile, in which (a) shows the plate thicknesses of the outer fitting stepped sections and the inner fitting stepped sections of the joint structure according to the embodiment, (b) shows the plate thicknesses of the outer fitting stepped sections and the inner fitting stepped sections of the joint structure in the related art, and (c) shows a comparison between the plate thicknesses of (a) and (b).

FIG. 14 is a graph showing a relationship, in the joint structure for a steel pipe pile according to the embodiment, between a radius thickness ratio of an outer diameter of the steel pipe pile and the plate thickness of the outer fitting end section, and a ratio of a maximum bending moment to the a plastic bending moment of the steel pipe pile.

FIG. 15A is a graph showing a relationship between a radius thickness ratio and a proof stress ratio of the inner fitting end section and is a graph showing a relationship between a radius thickness ratio and a proof stress ratio of the inner fitting end section in the joint structure for a steel pipe pile according to the embodiment.

FIG. 15B is a graph showing a relationship between a radius thickness ratio

and a proof stress ratio of the inner fitting end section and is a graph showing a relationship between a radius thickness ratio and a proof stress ratio of the outer fitting end section in the joint structure for a steel pipe pile according to the embodiment.

FIG. 16 is a graph showing a relationship between a ratio of a protruding height of the compressive surface to a protruding height of the tensile surface, and a joint thickness ratio at which tensile proof stress and compressive proof stress equal to those of the steel pipe pile can be acquired, in the same joint structure for a steel pipe pile.

FIG. 17 is a part of a cross-sectional view for describing a relationship between the protruding heights in consideration of a clearance in the same joint structure for a steel pipe pile.

FIG. 18 is a graph showing a result of a bending test in which the protruding height of the tensile surface is varied, in the same joint structure for a steel pipe pile.

FIG. 19 is a graph showing a relationship between a radius thickness ratio and a plate thickness ratio in a joint structure for a steel pipe pile according to a second embodiment of the present invention.

[Embodiments of the Invention]

[0018]

Hereinafter, embodiments of the present invention will be described with reference to the drawings. The present invention is not limited to only the embodiments.

[0019]

<First Embodiment>

A joint structure 7 for a steel pipe pile according to the present embodiment is utilized for a landslide pile, a bearing pile, a friction pile, and the like. As shown in

FIG. 1, a first steel pipe pile 1 and a second steel pipe pile 2 having a substantially circular cross-sectional shape or the like are coupled to each other in an axial direction Y.

[0020]

The joint structure 7 for a steel pipe pile includes an outer fitting end section 3 and an inner fitting end section 5 which are freely fitted to each other. The outer fitting end section 3 is attached to an end portion of the first steel pipe pile 1 by welding or the like, and the inner fitting end section 5 is attached to an end portion of the second steel pipe pile 2 by welding or the like. In a state where the outer fitting end section 3 and the inner fitting end section 5 share the same axial line L, the outer fitting end section 3 and the inner fitting end section 5 are configured to be a pair facing each other in the axial direction Y parallel to the axial line L.

[0021]

In the joint structure 7 for a steel pipe pile, mainly, outer fitting groove sections 32 are formed inside the outer fitting end section 3, and inner fitting groove sections 52 are formed outside the inner fitting end section 5. The joint structure 7 for a steel pipe pile is applied to a gear joint in which a plurality of outer fitting peak sections 31 and a plurality of inner fitting peak sections 51 are formed on substantially the same circumference in a circumferential direction W. Here, for example, each of the first steel pipe pile 1 and the second steel pipe pile 2 is targeting a steel pipe pile having an outer diameter D_p ranging approximately from 318.5 mm to 1,625.6 mm, and a steel pipe pile having a plate thickness t ranging approximately from 6.0 mm to 30.0 mm.

[0022]

The outer fitting end section 3 has the plurality of outer fitting peak sections

31 formed to protrude inward in an axial center orthogonal direction X, a plurality of outer fitting groove sections 32 formed to be adjacent to the outer fitting peak sections 31 in the circumferential direction W, and outer fitting valley sections 33 formed on a base end side B of the outer fitting peak sections 31 in the axial direction Y. In the outer fitting end section 3, the outer fitting peak sections 31 and the outer fitting valley sections 33 are formed to be alternately adjacent to each other in the axial direction Y.

[0023]

In the outer fitting end section 3, the outer fitting peak sections 31 and the outer fitting groove sections 32 are alternately formed in the circumferential direction W. The plurality of outer fitting peak sections 31 are disposed substantially in a row in the axial direction Y and the circumferential direction W, and the plurality of outer fitting groove sections 32 are disposed substantially in a row in the axial direction Y and the circumferential direction W. The outer fitting end section 3 is configured to have an outer fitting extra length section 38 as a part which is attached to the end portion of the first steel pipe pile 1 by welding or the like.

[0024]

The inner fitting end section 5 has the plurality of inner fitting peak sections 51 formed to protrude outward in the axial center orthogonal direction X, a plurality of inner fitting groove sections 52 formed to be adjacent to the inner fitting peak sections 51 in the circumferential direction W, and inner fitting valley sections 53 formed on the base end side B of the inner fitting peak sections 51 in the axial direction Y. In the inner fitting end section 5, the inner fitting peak sections 51 and the inner fitting valley sections 53 are formed to be alternately adjacent to each other in the axial direction Y.

[0025]

In the inner fitting end section 5, the inner fitting peak sections 51 and the

inner fitting groove sections 52 are alternately formed in the circumferential direction W. The plurality of inner fitting peak sections 51 are disposed substantially in a row in the axial direction Y and the circumferential direction W, and the plurality of inner fitting groove sections 52 are disposed substantially in a row in the axial direction Y and the circumferential direction W. The inner fitting end section 5 is configured to have an inner fitting extra length section 58 as a part which is attached to the end portion of the second steel pipe pile 2 by welding or the like.

[0026]

As shown in FIG. 2, the outer fitting peak sections 31 are formed to have a substantially rectangular shape or the like protruding further toward a central axis of the first steel pipe pile 1 in the axial direction Y than the outer fitting groove sections 32 adjacent to each other in the circumferential direction W, and the outer fitting valley sections 33 adjacent to each other in the axial direction Y. In this case, as shown in FIG. 3, the outer fitting peak sections 31 are formed to have predetermined protruding heights H_e and H_t in the axial center orthogonal direction X respectively from the adjacent outer fitting valley sections 33 on a front end side A and the base end side B in the axial direction Y.

[0027]

In the outer fitting valley sections 33, a plurality of outer fitting stepped sections 4 are respectively provided from the front end side A to the base end side B in the axial direction Y. Each of the outer fitting stepped sections 4 is formed to have a predetermined plate thickness in the axial center orthogonal direction X. In the outer fitting valley sections 33, the outer fitting stepped section 4 farthest to the base end side B in the axial direction Y is formed to be adjacent, in the axial direction Y, to the outer fitting extra length section 38 having a predetermined plate thickness D in the

axial center orthogonal direction X.

[0028]

In the outer fitting valley sections 33, particularly, the outer fitting stepped section 4 farthest to the front end side A in the axial direction Y becomes a first outer fitting stepped section 41. For example, when the outer fitting stepped sections 4 are provided over four steps in the axial direction Y, the outer fitting valley sections 33 are configured to have the first outer fitting stepped section 41, a second outer fitting stepped section 42, a third outer fitting stepped section 43, and a fourth outer fitting stepped section 44 in order from the front end side A to the base end side B in the axial direction Y.

[0029]

That is, in the outer fitting end section 3, in a case of being seen in a cross section including the axial line L, the outer fitting stepped sections 4 are respectively provided at a plurality of positions along the axial line L on the inner side of the outer fitting end section 3, such that the diameters increase in steps toward the second steel pipe pile 2. Each of the outer fitting stepped sections 4 has the outer fitting peak section 31 relatively close to the second steel pipe pile 2, and the outer fitting valley section 33 adjacent to the outer fitting peak section 31.

In the cross-sectional views of FIGS. 3, 5, 8 to 13, and 16, hatching is omitted to make the drawings easy to see.

[0030]

As shown in FIG. 4, the inner fitting peak sections 51 are formed to have a substantially rectangular shape or the like protruding further toward a side opposite to a central axis of the second steel pipe pile 2 in the axial direction Y than the inner fitting groove sections 52 adjacent to each other in the circumferential direction W, and

the inner fitting valley sections 53 adjacent to each other in the axial direction Y. In this case, as shown in FIG. 5, the inner fitting peak sections 51 are formed to have the predetermined protruding heights H_e and H_t in the axial center orthogonal direction X respectively from the adjacent inner fitting valley sections 53 on the front end side A and the base end side B in the axial direction Y.

[0031]

In the inner fitting valley sections 53, a plurality of inner fitting stepped sections 6 are respectively provided from the front end side A to the base end side B in the axial direction Y. Each of the inner fitting stepped sections 6 is formed to have a predetermined plate thickness in the axial center orthogonal direction X. In the inner fitting valley sections 53, the inner fitting stepped section 6 farthest to the base end side B in the axial direction Y is formed to be adjacent, in the axial direction Y, to the inner fitting extra length section 58 having the predetermined plate thickness D in the axial center orthogonal direction X. The plate thickness D of the inner fitting extra length section 58 does not necessarily have to coincide with the plate thickness D of the outer fitting extra length section 38.

[0032]

In the inner fitting valley sections 53, particularly, the inner fitting stepped section 6 farthest to the front end side A in the axial direction Y becomes a first inner fitting stepped section 61. For example, when the inner fitting stepped sections 6 are provided over four steps in the axial direction Y, the inner fitting valley sections 53 are configured to have the first inner fitting stepped section 61, a second inner fitting stepped section 62, a third inner fitting stepped section 63, and a fourth inner fitting stepped section 64 in order from the front end side A to the base end side B in the axial direction Y.

[0033]

That is, in the inner fitting end section 5, in a case of being seen in a cross section along the axial line L, the inner fitting stepped sections 6 are respectively provided at a plurality of positions along the axial line L on the outer side of the inner fitting end section 5, such that the diameters decrease in steps toward the first steel pipe pile 1. Each of the inner fitting stepped sections 6 has the inner fitting peak section 51 relatively close to the first steel pipe pile 1, and the inner fitting valley section 53 adjacent to the inner fitting peak section 51.

[0034]

In the joint structure 7 for a steel pipe pile, as shown in FIGS. 6 and 7, the first steel pipe pile 1 and the second steel pipe pile 2 are configured to be coupled to each other in the axial direction Y by causing the outer fitting end section 3 and the inner fitting end section 5 to be fitted to each other.

[0035]

In the joint structure 7 for a steel pipe pile, first of all, as shown in FIG. 6, the inner fitting end section 5 attached to the second steel pipe pile 2 is inserted into the outer fitting end section 3 attached to the first steel pipe pile 1. In this case, in the joint structure 7 for a steel pipe pile, since the protruding heights of the outer fitting peak sections 31 and the inner fitting peak sections 51 are equal to or smaller than the depths of the inner fitting groove sections 52 and the outer fitting groove sections 32 in the axial center orthogonal direction X, the outer fitting peak sections 31 and the inner fitting peak sections 51 are configured to pass through the inner fitting groove sections 52 and the outer fitting groove sections 32.

[0036]

In the joint structure 7 for a steel pipe pile, next, as shown in FIG. 7, in a state

where the inner fitting end section 5 is inserted into the outer fitting end section 3, the first steel pipe pile 1 and the second steel pipe pile 2 are relatively rotated in the circumferential direction W around the axial line L. In this case, in the joint structure 7 for a steel pipe pile, since the protruding heights of the outer fitting peak sections 31 and the inner fitting peak sections 51 are equal to or smaller than the depths of the inner fitting valley sections 53 and the outer fitting valley sections 33 in the axial center orthogonal direction X, the outer fitting peak sections 31 and the inner fitting peak sections 51 are configured to be fitted to the inner fitting valley sections 53 and the outer fitting valley sections 33.

[0037]

In the joint structure 7 for a steel pipe pile, the lengths of the outer fitting peak sections 31 in the axial direction Y are caused to be equal to or smaller than the lengths of the inner fitting valley sections 53 in the axial direction Y, and the lengths of the inner fitting peak sections 51 in the axial direction Y are caused to be equal to or smaller than the lengths of the outer fitting valley sections 33 in the axial direction Y. In this case, in the joint structure 7 for a steel pipe pile, in a state where the inner fitting end section 5 is inserted into the outer fitting end section 3 is relatively rotated in the circumferential direction W, the outer fitting peak sections 31 and the inner fitting peak sections 51 are configured to be interlocked with each other in the axial direction Y. In regard to the outer fitting end section 3 and the inner fitting end section 5, it is preferable to provide 4, 16, or 32 outer fitting peak sections 31 and inner fitting peak sections 51 each in the circumferential direction W.

[0038]

In the joint structure 7 for a steel pipe pile, as shown in FIG. 8, in a state where the outer fitting peak sections 31 and the inner fitting peak sections 51 are

interlocked with each other, a tensile force P_t acts in a direction in which the first steel pipe pile 1 and the second steel pipe pile 2 are separated from each other in the axial direction Y. In this case, in the outer fitting peak sections 31, the tensile force P_t is transferred from the inner fitting peak sections 51 to tensile surfaces 31a on the base end side B in the axial direction Y. In addition, at the same time, in the inner fitting peak sections 51, the tensile force P_t is transferred from the tensile surfaces 31a of the outer fitting peak sections 31 to tensile surfaces 51a on the base end side B in the axial direction Y.

[0039]

In the joint structure 7 for a steel pipe pile, the tensile surfaces 31a of the outer fitting peak sections 31 and the tensile surfaces 51a of the inner fitting peak sections 51 become the predetermined protruding heights H_t in the axial center orthogonal direction X. In addition, the tensile forces P_t having substantially the same magnitude are transferred to the tensile surfaces 31a of the outer fitting peak sections 31 and the tensile surfaces 51a of the inner fitting peak sections 51. In this case, in each of the outer fitting stepped sections 4 and the inner fitting stepped sections 6, a burden rate for the tensile force P_t transferred to each of the outer fitting peak sections 31 and the inner fitting peak sections 51 gradually increases from the front end side A toward the base end side B in the axial direction Y. As a result, the burden rate for the tensile force P_t becomes the maximum in the fourth outer fitting stepped section 44 and the fourth inner fitting stepped section 64 farthest to the base end side B.

[0040]

In addition, in the joint structure 7 for a steel pipe pile, as shown in FIG. 9, in a state where the outer fitting peak sections 31 and the inner fitting peak sections 51

are interlocked with each other, a compressive force P_c acts in a direction in which the first steel pipe pile 1 and the second steel pipe pile 2 approach each other in the axial direction Y. In this case, in the outer fitting peak sections 31, the compressive force P_c is transferred from the inner fitting peak sections 51 to compressive surfaces 31b on the front end side A in the axial direction Y. In addition, at the same time, in the inner fitting peak sections 51, the compressive force P_c is transferred from the compressive surfaces 31b of the outer fitting peak sections 31 to compressive surfaces 51b on the front end side A in the axial direction Y.

[0041]

In the joint structure 7 for a steel pipe pile, the compressive surfaces 31b of the outer fitting peak sections 31 and the compressive surfaces 51b of the inner fitting peak sections 51 become the predetermined protruding heights H_c in the axial center orthogonal direction X. In addition, the compressive forces P_c having substantially the same magnitude are transferred to the compressive surfaces 31b of the outer fitting peak sections 31 and the compressive surfaces 51b of the inner fitting peak sections 51. In this case, in each of the outer fitting stepped sections 4 and the inner fitting stepped sections 6, a burden rate for the compressive force P_c transferred to each of the outer fitting peak sections 31 and the inner fitting peak sections 51 gradually increases from the front end side A toward the base end side B in the axial direction Y. As a result, the burden rate for the compressive force P_c becomes the maximum in the fourth outer fitting stepped section 44 and the fourth inner fitting stepped section 64 farthest to the base end side B.

[0042]

In the joint structure 7 for a steel pipe pile according to the present embodiment, as shown in FIG. 10, the outer fitting valley sections 33 and the inner

fitting valley sections 53 are formed to have the predetermined plate thicknesses in the axial center orthogonal direction X respectively in the outer fitting stepped sections 4 and the inner fitting stepped sections 6.

[0043]

In the outer fitting valley sections 33, the outer fitting valley section 33 in the first outer fitting stepped section 41 has a plate thickness tb1, the outer fitting valley section 33 in the second outer fitting stepped section 42 has a plate thickness tb2, the outer fitting valley section 33 in the third outer fitting stepped section 43 has a plate thickness tb3, and the outer fitting valley section 33 in the fourth outer fitting stepped section 44 has a plate thickness tb4. In the outer fitting valley sections 33, particularly, of the outer fitting stepped sections 4 adjacent to each other in the axial direction Y, the plate thickness of the outer fitting valley section 33 in the outer fitting stepped section 4 on the base end side B in the axial direction Y is configured to be greater than the plate thickness of the outer fitting valley section 33 in the outer fitting stepped section 4 on the front end side A in the axial direction Y.

[0044]

In this case, when the outer fitting stepped sections 4 are provided over four steps from the front end side A to the base end side B in the axial direction Y, in the outer fitting valley sections 33, the plate thickness tb2 in the second outer fitting stepped section 42 becomes greater than the plate thickness tb1 in the first outer fitting stepped section 41. In addition, in the outer fitting valley sections 33, the plate thickness tb3 in the third outer fitting stepped section 43 is configured to be greater than the plate thickness tb2 in the second outer fitting stepped section 42, and the plate thickness tb4 in the fourth outer fitting stepped section 44 is configured to be greater than the plate thickness tb3 in the third outer fitting stepped section 43.

[0045]

In the inner fitting valley sections 53, the inner fitting valley section 53 in the first inner fitting stepped section 61 has a plate thickness tp1, the inner fitting valley section 53 in the second inner fitting stepped section 62 has a plate thickness tp2, the inner fitting valley section 53 in the third inner fitting stepped section 63 has a plate thickness tp3, and the inner fitting valley section 53 in the fourth inner fitting stepped section 64 has a plate thickness tp4. In the inner fitting valley sections 53, particularly, of the inner fitting stepped sections 6 adjacent to each other in the axial direction Y, the plate thickness of the inner fitting valley section 53 in the inner fitting stepped section 6 on the base end side B in the axial direction Y is configured to be greater than the plate thickness of the inner fitting valley section 53 in the inner fitting stepped sections 6 on the front end side A in the axial direction Y.

[0046]

In this case, when the inner fitting stepped sections 6 are provided over four steps from the front end side A to the base end side B in the axial direction Y, in the inner fitting valley sections 53, the plate thickness tp2 in the second inner fitting stepped section 62 becomes greater than the plate thickness tp1 in the first inner fitting stepped section 61. In addition, in the inner fitting valley sections 53, the plate thickness tp3 in the third inner fitting stepped section 63 is configured to be greater than the plate thickness tp2 in the second inner fitting stepped section 62, and the plate thickness tp4 in the fourth inner fitting stepped section 64 is configured to be greater than the plate thickness tp3 in the third inner fitting stepped section 63.

[0047]

In the joint structure 7 for a steel pipe pile, in a state where the outer fitting end section 3 and the inner fitting end section 5 are relatively rotated, the outer fitting

stepped sections 4 and the inner fitting stepped sections 6 are respectively disposed at positions corresponding to each other in the axial direction Y. In the outer fitting valley sections 33 and the inner fitting valley sections 53, the outer fitting peak sections 31 and the inner fitting peak sections 51 are interlocked with each other in the axial direction Y in the outer fitting stepped sections 4 and the inner fitting stepped sections 6 disposed at positions corresponding to each other.

[0048]

In this case, in the outer fitting valley sections 33 and the inner fitting valley sections 53, the outer fitting peak section 31 of the first outer fitting stepped section 41 and the inner fitting peak section 51 of the fourth inner fitting stepped section 64 are interlocked with each other, and the outer fitting peak section 31 of the second outer fitting stepped section 42 and the inner fitting peak section 51 of the third inner fitting stepped section 63 are interlocked with each other. In addition, in the outer fitting valley sections 33 and the inner fitting valley sections 53, the outer fitting peak section 31 of the third outer fitting stepped section 43 and the inner fitting peak section 51 of the second inner fitting stepped section 62 are interlocked with each other, and the outer fitting peak section 31 of the fourth outer fitting stepped section 44 and the inner fitting peak section 51 of the first inner fitting stepped section 61 are interlocked with each other.

[0049]

In the joint structure 7 for a steel pipe pile, particularly, the plate thickness $tb1$ of the outer fitting valley section 33 in the first outer fitting stepped section 41 is smaller than the plate thickness $tp1$ of the inner fitting valley section 53 in the first inner fitting stepped section 61. In addition, the plate thickness $tb2$ of the outer fitting valley section 33 in the second outer fitting stepped section 42 is smaller than the plate

thickness $tp2$ of the inner fitting valley section 53 in the second inner fitting stepped section 62. In addition, the plate thickness $tb3$ of the outer fitting valley section 33 in the third outer fitting stepped section 43 is smaller than the plate thickness $tp3$ of the inner fitting valley section 53 in the third inner fitting stepped section 63. In addition, the plate thickness $tb4$ of the outer fitting valley section 33 in the fourth outer fitting stepped section 44 is smaller than the plate thickness $tp4$ of the inner fitting valley section 53 in the fourth inner fitting stepped section 64.

[0050]

In addition, while having a difference Δb between the plate thicknesses of the outer fitting valley sections 33 adjacent to each other in the axial direction Y in the outer fitting stepped sections 4, and a difference Δp between the plate thicknesses of the inner fitting valley sections 53 adjacent to each other in the axial direction Y in the inner fitting stepped sections 6, the joint structure 7 for a steel pipe pile is characterized in that the outer fitting valley sections 33 and the inner fitting valley sections 53 can be fitted to each other by causing $\Delta b1=(tb2-tb1)$ and $\Delta p3=(tp4-tp3)$ to be substantially the same as each other, causing $\Delta b2=(tb3-tb2)$ and $\Delta p2=(tp3-tp2)$ to be substantially the same as each other, and causing $\Delta b3=(tb4-tb3)$ and $\Delta p1=(tp2-tp1)$ to be substantially the same as each other. Therefore, the joint structure 7 for a steel pipe pile is characterized in that all of $tb1$, $tb2$, $tb3$, $tb4$, $tp1$, $tp2$, $tp3$, and $tp4$ can be drawn out by determining the plate thickness $tp1$, and a plate thickness ratio $(tb1/tp1)$ which is a ratio of the plate thickness $tb1$ to the plate thickness $tp1$.

[0051]

For example, in a joint structure 9 for a steel pipe pile in the related art disclosed in Patent Document 2, as shown in FIG. 11, the plate thickness $tb1$ is the same as the plate thickness $tp1$, the plate thickness $tb2$ is the same as the plate

thickness tp_2 , the plate thickness tb_3 is the same as the plate thickness tp_3 , and the plate thickness tb_4 is the same as the plate thickness tp_4 . Therefore, in the joint structure 9 for a steel pipe pile in the related art, in a case where the first inner fitting stepped section 61 and the first outer fitting stepped section 41 are compared to each other, the first inner fitting stepped section 61 present on the inner side in a radial direction has a small cross-sectional area. In addition, similarly in the second inner fitting stepped section 62, the third inner fitting stepped section 63, and the fourth inner fitting stepped section 64, the inner fitting stepped sections 6 have a cross-sectional area smaller than that of the outer fitting stepped sections 4. Consequently, the inner fitting end section 5 has a cross-sectional area smaller than that of the outer fitting end section 3. Therefore, in the joint structure 9 for a steel pipe pile in the related art, proof stress of the inner fitting end section 5 and the outer fitting end section 3 is determined based on fracture of the inner fitting end section 5 having a small cross-sectional area, thereby having a disadvantage of excessive design of the outer fitting end section 3.

[0052]

In addition, when a tensile force acts, the outer fitting end section 3 is generally deformed to expand outward in the axial center orthogonal direction X toward a side opposite to the central axis of the first steel pipe pile 1 in the axial direction Y. On the other hand, the inner fitting end section 5 is generally deformed to contract inward in the axial center orthogonal direction X toward the central axis of the second steel pipe pile 2 in the axial direction Y. Therefore, in a case of considering the spread of stress in the circumferential direction when a tensile force acts, the inner fitting end section 5 is deformed to contract inward so that stress is unlikely to spread in the circumferential direction. On the other hand, the outer fitting

end section 3 is deformed to expand outward so that stress is likely to spread in the circumferential direction, and stress concentration in the outer fitting end section 3 is relaxed. Therefore, in addition to the viewpoint of the cross-sectional area, the joint structure 9 for a steel pipe pile in the related art has a disadvantage of excessive design of the outer fitting end section 3 from a viewpoint of the spread of stress in the circumferential direction and the relaxation of stress concentration.

[0053]

In contrast, in the joint structure 7 for a steel pipe pile according to the present embodiment, as shown in FIG. 10, the plate thickness $tb1$ of the outer fitting valley section 33 in the first outer fitting stepped section 41 is set to be smaller than the plate thickness $tp1$ of the inner fitting valley section 53 in the first inner fitting stepped section 61, and the plate thickness ratio ($tb1/tp1$) which is a ratio of the plate thickness $tb1$ to the plate thickness $tp1$ is caused to be equal to or greater than 0.84.

That is, in the joint structure 7 for a steel pipe pile according to the present embodiment, the plate thickness of the outer fitting valley section 33 closest to the second steel pipe pile 2 is smaller than the plate thickness of the inner fitting valley section 53 closest to the first steel pipe pile 1, and a ratio obtained by dividing the plate thickness of the outer fitting valley section 33 closest to the second steel pipe pile 2 by the plate thickness of the inner fitting valley section 53 closest to the first steel pipe pile 1 is equal to or greater than 0.84.

[0054]

In addition, in the joint structure 7 for a steel pipe pile, the size of the plate thickness $tp1$ is determined by causing $Ab1=(tb2-tb1)$ and $Ap3=(tp4-tp3)$ to be substantially the same as each other, causing $\Delta b2=(tb3-tb2)$ and $\Delta p2=(tp3-tp2)$ to be substantially the same as each other, and causing $Ab3=(tb4-tb3)$ and $Ap1=(tp2-tp1)$ to

be substantially the same as each other. Moreover, the plate thickness of the outer fitting valley section 33 closest to the second steel pipe pile 2 is smaller than the plate thickness of the inner fitting valley section 53 closest to the first steel pipe pile 1, and a ratio obtained by dividing the plate thickness of the outer fitting valley section 33 closest to the second steel pipe pile 2 by the plate thickness of the inner fitting valley section 53 closest to the first steel pipe pile 1 is caused to be equal to or greater than 0.84. Accordingly, the cross-sectional area of the outer fitting end section 3 can be designed based on fracture of the inner fitting end section 5 having a small cross-sectional area. Accordingly, in the joint structure 7 for a steel pipe pile, the outer fitting end section 3 can be designed to have a small cross-sectional area in accordance with the inner fitting end section 5 having a small cross-sectional area. Accordingly, excessive design of the outer fitting end section 3 is avoided, and the plate thickness of the outer fitting end section 3 can be reduced compared to the joint structure 9 for a steel pipe pile in the related art.

[0055]

As shown in FIG. 12, the shapes of the outer fitting extra length section 38 and the inner fitting extra length section 58 may be deformed. In such shapes, the joint structure 7 for a steel pipe pile can be reduced in weight.

Here, as shown in (a) of FIG. 13, in the joint structure 7 for a steel pipe pile according to the present embodiment, the plate thickness of the outer fitting valley section 33 closest to the second steel pipe pile 2 is smaller than the plate thickness of the inner fitting valley section 53 closest to the first steel pipe pile 1. In contrast, in the joint structure 9 for a steel pipe pile in the related art as shown in (b) of FIG. 13, the plate thickness of the inner fitting valley section 53 closest to the first steel pipe pile 1 and the plate thickness of the outer fitting valley section 33 closest to the second steel

pipe pile 2 are the same as each other. The drawing (c) of FIG. 13 is a view showing a comparison between (a) of FIG. 13 and (b) of FIG. 13. In (c) of FIG. 13, the joint structure 9 for a steel pipe pile in the related art in (b) of FIG. 13 is indicated with a dotted line. According to the drawing, it is ascertained that the thickness of the outer fitting end section 3 in its entirety is reduced particularly in the joint structure 7 for a steel pipe pile according to the present embodiment.

[0056]

Here, FIG. 14 shows numerical analysis and an experimental result of proof stress of a joint corresponding to a steel pipe pile to be joined, in the joint structure for a steel pipe pile according to the present embodiment. The shape ratio according to the present embodiment is applied to grant a design safety factor in design. In order to obtain proof stress of the joint, the steel pipe pile is calculated as a material of a perfect elastic body in the numerical analysis. In addition, a steel pipe having strength stronger than a steel pipe corresponding to the original joint is used in the experiment such that the joint fractures in advance.

As a range for the steel pipe pile to which the joint was applied, the outer diameter D_p ranged from 400.0 mm to 1,600.0 mm, and the plate thickness t_p of the steel pipe pile ranged from 6.0 mm to 30.0 mm. SKK40 stipulated in JIS A 5525 and SM570 stipulated in JIS G 3106 were employed as material standards. In the graph of FIG. 14, the horizontal axis indicates a radius thickness ratio (D_p/t_p) of the outer diameter D_p to the plate thickness t_p of the steel pipe pile to be joined, and the vertical axis indicates a ratio (M_{max}/M_p) of a maximum bending moment M_{max} (joint part) and full plastic bending moment M_p of a steel pipe pile (steel pipe part) of the joint structure 7 for a steel pipe pile according to the present embodiment calculated by FEM analysis. From FIG. 14, it is ascertained that the maximum bending moment

Mmax of the joint exceeds full plastic bending moment Mp of the steel pipe to be joined even in a case where the plate thickness tb of the outer fitting end section 3 is reduced. In addition, it is ascertained that since the joint is stronger than the steel pipe, this joint does not fracture prior to the steel pipe. Table 1 shows numeric data of FIG. 14.

[0057]

[Table 1]

	No.	Dp (mm)	tp (mm)	Dp tp	Kinds of steel	Mmax (kN·m)	Mp (kN·m)	Mmax Mp
Numerical analysis	1	400.0	6.0	66.67	SKK400	513	219	2.35
	2	400.0	30.0	13.33	SM570	3125	1852	1.69
	3	800.0	9.0	88.89	SKK400	2415	1323	1.83
	4	800.0	16.0	50.00	SKK490	5552	3098	1.79
	5	800.0	24.0	33.33	SKK490	8523	4554	1.87
	6	1219.2	30.0	40.64	SKK490	24517	13367	1.83
	7	1600.0	16.0	100.00	SKK400	15541	9434	1.65
	8	1600.0	19.0	84.21	SKK400	20724	11161	1.86
	9	1600.0	25.0	64.00	SKK490	33248	19537	1.70
	10	1600.0	30.0	53.33	SM570	59571	33280	1.79
Numerical analysis (analysis of reproduced experiment)	11	800.0	9.0	88.89	SKK400	2287	1323	1.73
	12	800.0	9.0	88.89	SKK400	2305	1323	1.74
	13	800.0	13.0	61.54	SKK400	3507	1892	1.85
Experiment	14	800.0	9.0	88.89	SKK400	2083	1323	1.57
	15	800.0	9.0	88.89	SKK400	2242	1323	1.69
	16	800.0	13.0	61.54	SKK400	3090	1892	1.63

[0058]

FIGS. 15A and 15B show bases for a difference between the plate thicknesses of the outer fitting valley sections 33 and the inner fitting valley sections 53. In FIG.

15A, the horizontal axis indicates a radius thickness ratio (D_p/t_{p1}) of the outer diameter D_p of the steel pipe pile to the plate thickness t_{p1} of the inner fitting valley section 53 in the first inner fitting stepped section 61. In addition, in FIG. 15A, the vertical axis indicates a proof stress ratio (M_{max}/M_f) of the maximum bending moment M_{max} of the joint structure 7 for a steel pipe pile according to the present embodiment calculated by the FEM analysis to a full plastic bending moment M_f of the inner fitting valley section 53 (in a case where the whole circumference of the valley section of the joint is effective). In FIG. 15B, the horizontal axis indicates a radius thickness ratio (D_p/t_{b1}) of the outer diameter D_p of the steel pipe pile to the plate thickness t_{b1} of the outer fitting valley section 33 in the first outer fitting stepped section 41. In FIG. 15B, the vertical axis indicates the proof stress ratio (M_{max}/M_f) of the maximum bending moment M_{max} of the present invention calculated by the FEM analysis to a full plastic bending moment M_f of the outer fitting valley section 33.

According to FIG. 15A, it is ascertained that in the inner fitting end section 5, in a case where the radius thickness ratio changes, the proof stress ratio also changes, so that the proof stress ratio becomes a linear function of the radius thickness ratio. In contrast, according to FIG. 15B, in the outer fitting valley sections 33, the proof stress ratio becomes constant without depending on the radius thickness ratio. In FIGS. 15A and 15B as well, as the range, the outer diameter D_p of the steel pipe pile ranged from 400.0 mm to 1,600.0 mm, and the plate thickness t of the steel pipe pile ranged from 6.0 mm to 30.0 mm. SKK400 stipulated in JIS A 5525 was indicated as the lower limit value for ordinary material standards of the steel pipe pile, and SM570 stipulated in JIS G 3106 was indicated as the upper limit value for material standards. Table 2 shows numeric data of FIGS. 15A and 15B.

[0059]

[Table 2]

	No.	Dp (m)	Plate thickness t (tp1 or tb1) (mm)	Kinds of steel	Dp t	Mmax (kN·m)	Mf (kN·m)	Mmax Mf
Experiment (fracture of joint)	1	800.0	7.2	SKK490	111.11	2242	3000	0.75
	2	800.0	9.5	SKK490	84.21	3090	4178	0.74
Numerical analysis of inner fitting end section (fracture of joint)	3	400.0	4.3	SKK400	93.02	513	435	1.18
	4	400.0	33.1	SM570	12.08	3093	2871	1.08
	5	800.0	6.3	SKK400	126.98	2416	2697	0.90
	6	800.0	13.0	SKK490	61.54	5565	5606	0.99
	7	800.0	19.5	SKK490	41.03	8782	7850	1.12
	8	1219.2	24.5	SKK490	49.76	26653	23499	1.13
	9	1600.0	11.7	SKK400	136.75	15541	18990	0.82
	10	1600.0	13.1	SKK400	122.14	20723	22609	0.92
	11	1600.0	21.2	SKK490	75.47	33674	36431	0.92
	12	1600.0	35.0	SM570	45.71	59571	60102	0.99
Numerical analysis of outer fitting end section (fracture of joint)	13	400.0	3.8	SKK400	105.26	513	371	1.38
	14	400.0	32.6	SM570	12.27	3093	2835	1.09
	15	800.0	5.4	SKK400	148.15	2416	2242	1.08
	16	800.0	12.1	SKK490	66.12	5565	5189	1.07
	17	800.0	18.6	SKK490	43.01	8782	7496	1.17
	18	1219.2	23.0	SKK490	53.01	26653	22095	1.21
	19	1600.0	9.8	SKK400	163.27	15541	15251	1.02
	20	1600.0	11.2	SKK400	142.86	20723	18824	1.10
	21	1600.0	19.3	SKK490	82.90	33674	32773	1.03
	22	1600.0	32.8	SM570	48.78	59571	55893	1.07
Experiment of inner fitting end section (fracture of steel pipe)	23	400.0	4.3	SKK400	93.02	308	433	0.71
	24	800.0	13.0	SKK490	61.54	4718	5611	0.84
	25	800.0	19.5	SKK490	41.03	5518	7874	0.70
	26	1600.0	13.1	SKK400	122.14	14341	22631	0.63
Experiment of outer fitting end section (fracture of steel pipe)	27	400.0	3.8	SKK400	105.26	308	372	0.83
	28	800.0	12.0	SKK490	66.67	4718	5121	0.92
	29	800.0	18.6	SKK490	43.01	5518	7480	0.74
	30	1600.0	11.2	SKK400	142.86	14341	18741	0.77

[0060]

Here, in the joint structure 7 for a steel pipe pile, the outer fitting end section 3 and the inner fitting end section 5 are formed to have a substantially circular cross-sectional shape. Therefore, the cross-sectional area of the outer fitting valley section

33 becomes $(\pi \times rb1^2 - \pi \times rb2^2)$ by subtracting $\pi \times rb2^2$ calculated based on an inner diameter $rb2$ of the outer fitting valley section 33 from $\pi \times rb1^2$ calculated based on an outer diameter $rb1$ of the outer fitting valley section 33. in each of the outer fitting stepped sections 4. Then, since the inner diameter $rb2$ of the outer fitting valley section 33 is obtained by subtracting the plate thickness tb from the outer diameter $rb1$ of the outer fitting valley section 33, the cross-sectional area of the outer fitting valley section 33 has a proportional relationship with the square of a plate thickness tb of the outer fitting valley section 33. Moreover, similar to the cross-sectional area of the outer fitting valley section 33, the cross-sectional area of the inner fitting valley section 53 also has a proportional relationship with the square of the plate thickness tp of the inner fitting valley section 53 in the inner fitting stepped section 6.

[0061]

In the joint structure 7 for a steel pipe pile, as shown in FIG. 15A, in the inner fitting end section 5, since a bending moment ratio is reduced from 0.70 to 0.50 within a range of the radius thickness ratio from 10.00 to 200.00, it is assumed that 70% to 50% of the whole circumference of the inner fitting valley section 53 is an effective cross section. In contrast, in the outer fitting end section 3, as shown in FIG. 15B, the bending moment ratio becomes constant without depending on the radius thickness ratio, and it is assumed that 70% of the whole circumference of the outer fitting valley section 33 is an effective cross section.

Consequently, if design is performed based on fracture of the inner fitting valley section 53 within a range in which the radius thickness ratio becomes 200.00, the cross-sectional area of the outer fitting valley section 33 can be reduced to 71% ($0.50/0.70 \approx 0.71$). Therefore, since the cross-sectional area of the outer fitting valley section 33 has a proportional relationship with the square of the plate thickness tb of

the outer fitting valley section 33, even if the plate thickness t_b of the outer fitting valley section 33 is reduced to 0.84 times the plate thickness t_p of the inner fitting valley section 53 ($0.84^2 \approx 0.71$), it is possible to ensure the cross-sectional area equal to or greater than that of the inner fitting valley section 53. Thus, equal proof stress can be ensured in the outer fitting valley sections 33 and the inner fitting valley sections 53. In the radius thickness ratio of approximately 50, if design is performed based on fracture of the inner fitting valley section 53, the cross-sectional area of the outer fitting valley section 33 can be reduced to 97% ($0.68/0.70 \approx 0.97$). Therefore, since the cross-sectional area of the outer fitting valley section 33 has a proportional relationship with the square of the plate thickness t_b of the outer fitting valley section 33, even if the plate thickness t_b of the outer fitting valley section 33 is reduced to 0.94 times the plate thickness t_p of the inner fitting valley section 53 ($0.97^2 \approx 0.94$), it is possible to ensure the cross-sectional area equal to or greater than that of the inner fitting valley section 53.

[0062]

In this manner, in the joint structure 7 for a steel pipe pile according to the present embodiment, in each of the outer fitting stepped sections 4 and the inner fitting stepped sections 6, the plate thickness t_b of the outer fitting valley section 33 is smaller than the plate thickness t_p of the inner fitting valley section 53. In the joint structure 7 for a steel pipe pile according to the present embodiment, the plate thickness of the outer fitting valley section 33 closest to the second steel pipe pile 2 is smaller than the plate thickness of the inner fitting valley section 53 closest to the first steel pipe pile 1, and a ratio obtained by dividing the plate thickness of the outer fitting valley section 33 closest to the second steel pipe pile 2 by the plate thickness of the inner fitting valley section 53 closest to the first steel pipe pile 1 is equal to or greater than 0.84.

Accordingly, in the joint structure 7 for a steel pipe pile, compared to the joint structure 9 for a steel pipe pile in the related art, excessive design can be avoided by reducing the cross-sectional area of the outer fitting end section 3. Accordingly, the maximum proof stress for compression, tension, and bending can be acquired with a small used amount of a steel or the like in weight and cubic volume. As a result, efficiency of coupling work can be improved by reducing the weight and the cubic volume of a joint in its entirety, and a rise of material cost of the joint in its entirety can be suppressed.

[0063]

In addition, in the joint structure 7 for a steel pipe pile according to the present embodiment, as shown in FIGS. 8 and 9, of the outer fitting stepped sections 4 adjacent to each other in the axial direction Y, the plate thickness of the outer fitting valley section 33 in the outer fitting stepped section 4 on the base end side B is configured to be greater than the plate thickness of the outer fitting valley section 33 in the outer fitting stepped section 4 on the front end side A. Along with this, of the inner fitting stepped sections 6 adjacent to each other in the axial direction Y, the plate thickness of the inner fitting valley section 53 in the inner fitting stepped section 6 on the base end side B is configured to be greater than the plate thickness of the inner fitting valley section 53 in the inner fitting stepped section 6 on the front end side A. In addition, the protruding heights H_c of the compressive surfaces 31b of the outer fitting peak sections 31 and the compressive surfaces 51b of the inner fitting peak sections 51 are configured to be greater than the protruding heights H_t of the tensile surfaces 31a of the outer fitting peak sections 31 and the tensile surfaces 51a of the inner fitting peak sections 51.

Moreover, in the first outer fitting stepped section 41 and the first inner fitting stepped section 61, the protruding heights H_c of the compressive surfaces 31b of the

outer fitting peak sections 31 and the compressive surfaces 51b of the inner fitting peak sections 51 are greater than those of the second outer fitting stepped section 42 to the fourth outer fitting stepped section 44 and the second inner fitting stepped section 62 to the fourth inner fitting stepped section 64. Accordingly, each of the outer fitting end section 3 and the inner fitting end section 5 is characterized in that compressive proof stress is greater than tensile proof stress.

[0064]

In contrast, for example, in the joint structure 9 for a steel pipe pile in the related art disclosed in Patent Document 2, as shown in FIG. 11, a ratio of H_c to H_t becomes $H_t < 0.5 \times H_c$, and H_c becomes extremely significant compared to H_t . Therefore, in the joint structure 9 for a steel pipe pile in the related art, if calculation is performed based on the ratio of the protruding heights H_c of the compressive surfaces 31b to the compressive surfaces 51b, and the protruding heights H_t of the tensile surfaces 31a and the tensile surfaces 51a, compressive proof stress exceeds twice tensile proof stress. Therefore, in the joint structure 9 for a steel pipe pile in the related art, in a case where tensile proof stress of the joint in its entirety is caused to be equal to or greater than that of the steel pipe pile, compressive proof stress of the joint in its entirety exceeds twice the steel pipe pile. Since tensile proof stress and compressive proof stress are the same as each other in general steel pipe piles, the joint structure 9 for a steel pipe pile in the related art has a disadvantage of excessive design of compressive proof stress.

[0065]

In the joint structure 7 for a steel pipe pile according to the present embodiment, as shown in FIGS. 8 and 9, in each of the outer fitting stepped sections 4 and the inner fitting stepped sections 6, the ratio of the protruding heights H_t of the

tensile surfaces 31a to the tensile surfaces 51a in the outer fitting peak sections 31 and the inner fitting peak sections 51 to the protruding heights H_c of the compressive surfaces 31b and the compressive surfaces 51b in the outer fitting peak sections 31 and the inner fitting peak sections 51 ranges from 0.5 to 0.9. In this case, in the joint structure 7 for a steel pipe pile, the protruding heights H_t become smaller than the protruding heights H_c , and each of the outer fitting stepped sections 4 and the inner fitting stepped sections 6 is formed in a substantially tapered shape in the axial direction Y from the front end side A to the base end side B in the axial direction. Accordingly, in the joint structure 7 for a steel pipe pile, the protruding heights H_t can be reduced until tensile proof stress of the joint in its entirety becomes equal to compressive proof stress by causing the protruding heights H_t to be smaller than the protruding heights H_c . Accordingly, since excessive design of compressive proof stress can be suppressed, compared to the joint structure 9 for a steel pipe pile in the related art, the steel weight of the joint in its entirety can be reduced.

[0066]

Here, FIG. 16 shows a result of a comparison between joint thickness ratios of the joint structure 7 for a steel pipe pile according to the present embodiment to the joint structure 9 for a steel pipe pile in the related art. In FIG. 16, the horizontal axis indicates a ratio (H_t/H_c) of H_c and H_t , and the vertical axis indicates a joint thickness ratio at which tensile proof stress and compressive proof stress equal to those of the steel pipe pile in the related art can be acquired when the ratio of H_c to H_t is changed.

[0067]

In FIG. 16, in a case where $H_t=0.5 \times H_c$ is set (corresponds to the examples of 2, 9, and 16 in Table 3) and the joint thickness ratio at the time of tensile proof stress and compressive proof stress equal to those of the steel pipe pile in the related art is set

as a reference value, the value of the joint thickness ratio in the vertical axis becomes

1. As the joint thickness, the total value of h (corresponds to D in FIG. 5), the plate thickness $tp4$ of the inner fitting valley section 53 in the fourth inner fitting stepped section 64, the plate thickness $tb1$ of the outer fitting valley section 33 in the first outer fitting stepped section 41, and a predetermined clearance $C1$ is employed.

[0068]

In FIG. 16, SKK400 and SKK490 stipulated in JIS A 5525 were indicated as the lower limit values for ordinary material standards of the steel pipe pile, and SM570 stipulated in JIS G 3106 was indicated as the upper limit value for material standards. Table 3 shows numeric data of FIG. 16.

[0069]

[Table 3]

	No.	Ht/Hc	Dp (mm)	h (mm)	tp4 (mm)	tbl (mm)	CL (mm)	Joint thickness ratio
SKK400	1	0.4	1600.0	7.7	54.0	17.4	0.9	1.17
	2	0.5	1600.0	7.7	42.4	17.4	0.9	1.00
	3	0.6	1600.0	7.7	34.7	17.4	0.9	0.89
	4	0.7	1600.0	7.7	31.4	19.4	0.9	0.87
	5	0.8	1600.0	7.7	31.4	23.5	0.9	0.93
	6	0.9	1600.0	7.7	31.4	26.7	0.9	0.97
	7	1.0	1600.0	7.7	31.4	29.3	0.9	1.01
SKK490	8	0.4	1600.0	9.8	69.1	23.1	0.9	1.17
	9	0.5	1600.0	9.8	54.4	23.1	0.9	1.00
	10	0.6	1600.0	9.8	44.6	23.1	0.9	0.89
	11	0.7	1600.0	9.8	41.2	26.5	0.9	0.89
	12	0.8	1600.0	9.8	41.2	31.7	0.9	0.95
	13	0.9	1600.0	9.8	41.2	35.8	0.9	0.99
	14	1.0	1600.0	9.8	41.2	39.1	0.9	1.03
SM570	15	0.4	1600.0	13.4	95.0	32.8	0.9	1.16
	16	0.5	1600.0	13.4	74.9	32.8	0.9	1.00
	17	0.6	1600.0	13.4	61.5	32.8	0.9	0.89
	18	0.7	1600.0	13.4	57.7	38.4	0.9	0.91
	19	0.8	1600.0	13.4	57.8	45.6	0.9	0.96
	20	0.9	1600.0	13.4	57.8	51.1	0.9	1.01
	21	1.0	1600.0	13.4	57.7	55.6	0.9	1.05

[0070]

In the joint structure 7 for a steel pipe pile, as shown in FIG. 16, in SKK400, SKK490, or SM570, particularly within a range of $0.5 \times Hc < Ht < 0.9 \times Hc$, the joint thickness ratio becomes small compared to the joint structure 9 for a steel pipe pile in the related art. Accordingly, it is ascertained that the weight of the joint in its entirety

is reduced. Moreover, in the joint structure 7 for a steel pipe pile, if design is performed within a range of $0.55 \times H_c \leq H_t \leq 0.8 \times H_c$, approximately 5.0% of the joint thickness ratio can be reduced compared to the joint structure 9 for a steel pipe pile in the related art. As a result, approximately 3.5% to 4.0% of the weight of the joint in its entirety after processing can be reduced.

[0071]

In the joint structure 7 for a steel pipe pile, in SKK400 or SKK490, if design is performed within a range of $0.6 \times H_c \leq H_t \leq 0.8 \times H_c$, approximately 10% of the joint thickness ratio can be reduced. Along with this, in SM570, if design is performed within a range of $0.6 \times H_c \leq H_t \leq 0.7 \times H_c$, approximately 10% of the joint thickness ratio can be reduced.

Accordingly, in the joint structure 7 for a steel pipe pile, excessive design of compressive proof stress can be avoided by causing the ratio of the protruding height H_t to the protruding height H_c to range from 0.5 to 0.9 and reducing the protruding height H_c . Accordingly, compared to the joint structure 9 for a steel pipe pile in the related art, the maximum proof stress for compression, tension, and bending can be acquired with a small used amount of a steel or the like in weight and cubic volume. As a result, efficiency of coupling work can be improved by reducing the weight and the cubic volume of a joint in its entirety, and a rise of material cost of the joint in its entirety can be suppressed.

[0072]

In the joint structure 7 for a steel pipe pile according to the present embodiment, in each of the outer fitting peak sections 31, a ratio obtained by dividing the protruding height H_t of a different outer fitting peak section 31 next to the outer fitting peak section 31 relatively close to the second steel pipe pile 2 by the protruding

height H_c of the outer fitting peak section 31 relatively close to the second steel pipe pile 2 ranges from 0.5 to 0.9. In each of the inner fitting peak sections 51, a ratio obtained by dividing the protruding height H_t of a different inner fitting peak section 51 next to the inner fitting peak section 51 relatively close to the first steel pipe pile 1 by the protruding height H_c of the inner fitting peak section 51 relatively close to the first steel pipe pile 1 ranges from 0.5 to 0.9.

[0073]

As shown in FIG. 17, the predetermined clearance CL is generally present in the radial direction which is the axial center orthogonal direction X . Therefore, in consideration of this clearance CL , it is preferable that the above-described relationship ($0.5 \times H_c' \leq H_t' \leq 0.9 \times H_c'$) is established even in the relationship between effective protruding heights H_c' ($=H_c - 1.5 \times CL$) and H_t' ($=H_t - 1.5 \times CL$).

[0074]

In addition, in order to prevent separation between the outer fitting peak sections 31 and the inner fitting peak sections 51 when a tensile force or a bending force acts, it is desirable to set the lower limit value for the protruding height H_t . Here, a bending test was conducted in three cases in which H_t was changed to 2.4 mm, 3.3 mm, and 4.2 mm while the outer diameter D_p of the steel pipe pile is 800.0 mm. As shown in FIG. 18, when $H_t=2.4$ mm, the maximum proof stress was determined due to separation between the outer fitting peak sections 31 and the inner fitting peak sections 51. In contrast, when $H_t=3.3$ mm or greater, the maximum proof stress is determined due to bearing fracture of the outer fitting peak sections 31 or the inner fitting peak sections 51. Therefore, in a case of aiming at stable fracture circumstances of bearing fracture as much as possible, instead of separation between the outer fitting peak sections 31 and the inner fitting peak sections 51, it is desirable to

set $Ht \geq Dp/250$ as the lower limit value for the protruding height Ht .

[0075]

In the joint structure 7 for a steel pipe pile according to the embodiment, a joint can be reduced in weight while desired strength is ensured by causing the plate thickness of the outer fitting valley section 33 positioned farthest to the outer fitting front end side to be smaller than the plate thickness of the inner fitting valley section 53 positioned farthest to the inner fitting front end side, and regulating the ratio of the plate thicknesses. Therefore, the joint for a steel pipe pile can be reduced in weight, so that workability is improved.

[0076]

<Second Embodiment>

A second embodiment of the present invention will be described below. The second embodiment basically corresponds to a modification example of the first embodiment and will be described using the same reference signs as the reference signs used in the first embodiment, and illustration will be omitted.

That is, the present embodiment basically has a configuration similar to that of the first embodiment. However, a ratio obtained by dividing the plate thickness of the outer fitting valley section 33 closest to the second steel pipe pile 2 by the plate thickness of the inner fitting valley section 53 closest to the first steel pipe pile 1 ranges from 0.84 to 0.94.

[0077]

FIG. 19 shows a graph in which the horizontal axis indicates the radius thickness ratio ($Dp/tb1$) of the outer diameter Dp of the steel pipe pile in the related art and the plate thickness $tb1$ of the outer fitting valley section 33 in the first outer fitting stepped section 41, and the vertical axis indicates the plate thickness ratio ($tb1/tp1$) of

the plate thickness t_{p1} of the inner fitting valley section 53 in the first inner fitting stepped section 61 to the plate thickness t_{b1} of the outer fitting valley section 33 in the first outer fitting stepped section 41. According to the drawing, in a case where the material of the steel pipe is the material of SM570, or the plate thickness of the steel pipe is thick, the plate thickness of the outer fitting valley section is in a thick range (range in which D/t_{p1} is equal to or smaller than 50). Therefore, the plate thickness ratio of the inner fitting valley sections 53 to the outer fitting valley sections 33 becomes equal to or greater than 0.94 having little difference with respect to the structure in the related art. Since the weight can be preferably reduced within a range of the radius thickness ratio from 50 to 150, it is preferable that the plate thickness ratio ranges from 0.84 to 0.94. In regard to the plate thickness ratio of the outer fitting valley sections 33 to the inner fitting valley sections 53, a linear relationship is established between the plate thickness ratio and the radius thickness ratio, as indicated in the following Expression 1.

$$(t_{b1}/t_{p1}) = 0.99 - 0.001 \times (D_p/t_{b1}) \dots (\text{Expression 1})$$

[0078]

In the joint structure 7 for a steel pipe pile according to the present embodiment, it is possible to further reduce the plate thickness of the outer fitting end section 3 which affects the weight of the joint more than the inner fitting end section 5, by causing the ratio of the plate thicknesses to be within the range described above, and it is possible to further reduce the weight of the joint in its entirety. Therefore, the joint for a steel pipe pile can be further reduced in weight.

[0079]

< Third Embodiment >

A third embodiment of the present invention will be described below. The

third embodiment basically corresponds to another modification example of the first embodiment and will be described using the same reference signs as the reference signs used in the first embodiment, and illustration will be omitted.

That is, the present embodiment basically has a configuration similar to that of the first embodiment. However, in each of the outer fitting peak sections 31, a ratio obtained by dividing the protruding height of a different outer fitting peak section 31 next to the outer fitting peak section 31 relatively close to the second steel pipe pile 2 by the protruding height of the outer fitting peak section 31 relatively close to the second steel pipe pile 2 ranges from 0.6 to 0.8. In each of the inner fitting peak sections 51, a ratio obtained by dividing the protruding height of a different inner fitting peak section 51 next to the inner fitting peak section 51 relatively close to the first steel pipe pile 1 by the protruding height of the inner fitting peak section 51 relatively close to the first steel pipe pile 1 ranges from 0.6 to 0.8.

[0080]

In the joint structure for a steel pipe pile according to the present embodiment, it is possible to sufficiently ensure the strength in a direction parallel to the axial line L by causing the ratio of the protruding height of the peak section on the base end side to the protruding height of the peak section on the front end side to be within the range described above. Therefore, the joint for a steel pipe pile can be reduced in weight while the strength of the joint for a steel pipe pile is maintained.

[0081]

Hereinabove, each of the embodiments of the present invention has been described in detail. Each of the embodiments described above is merely a specific example for executing the present invention. Thus, the technical scope of the present invention is not to be interpreted in a limited manner.

[0082]

For example, in the joint structure 7 for a steel pipe pile according to each of the embodiments, the outer fitting end section 3 or the inner fitting end section 5 may be provided in the first steel pipe pile 1 or the end portion of the second steel pipe pile 2 itself by cutting the end portions of the first steel pipe pile 1 and the second steel pipe pile 2. In addition, the inner fitting end section 5 may be provided in the first steel pipe pile 1, and the outer fitting end section 3 may be provided in the second steel pipe pile 2.

[Industrial Applicability]

[0083]

In a joint structure for a steel pipe pile according to the present invention, a joint can be reduced in weight while desired strength is ensured. Therefore, the joint for a steel pipe pile can be reduced in weight, and it is possible to provide a steel pipe pile having improved workability. Thus, the present invention has high industrial applicability.

[Brief Description of the Reference Symbols]

[0084]

- 1 FIRST STEEL PIPE PILE
- 2 SECOND STEEL PIPE PILE
- 3 OUTER FITTING END SECTION
- 31 OUTER FITTING PEAK SECTION
- 31a TENSILE SURFACE
- 31b COMPRESSIVE SURFACE
- 32 OUTER FITTING GROOVE SECTION
- 33 OUTER FITTING VALLEY SECTION

38	OUTER FITTING EXTRA LENGTH SECTION
4	OUTER FITTING STEPPED SECTION
41	FIRST OUTER FITTING STEPPED SECTION
42	SECOND OUTER FITTING STEPPED SECTION
43	THIRD OUTER FITTING STEPPED SECTION
44	FOURTH OUTER FITTING STEPPED SECTION
5	INNER FITTING END SECTION
51	INNER FITTING PEAK SECTION
51a	TENSILE SURFACE
51b	COMPRESSIVE SURFACE
52	INNER FITTING GROOVE SECTION
53	INNER FITTING VALLEY SECTION
58	INNER FITTING EXTRA LENGTH SECTION
6	INNER FITTING STEPPED SECTION
61	FIRST INNER FITTING STEPPED SECTION
62	SECOND INNER FITTING STEPPED SECTION
63	THIRD INNER FITTING STEPPED SECTION
64	FOURTH INNER FITTING STEPPED SECTION
7	JOINT STRUCTURE FOR A STEEL PIPE PILE
A	FRONT END SIDE
B	BASE END SIDE
L	AXIAL LINE
W	CIRCUMFERENTIAL DIRECTION
X	AXIAL CENTER ORTHOGONAL DIRECTION
Y	AXIAL DIRECTION

[Document Type] CLAIMS

1. A joint structure for a steel pipe pile, in which a first steel pipe pile having an outer fitting end section and a second steel pipe pile having an inner fitting end section are coupled to each other in a state where the outer fitting end section and the inner fitting end section share the same axial line, the joint structure comprising, in a case of being seen in a cross section along the axial line:

outer fitting stepped sections that are provided at a plurality of positions along the axial line on an inner side of the outer fitting end section such that diameters increase in steps toward the second steel pipe pile,

wherein each of the outer fitting stepped sections has an outer fitting peak section relatively close to the second steel pipe pile and an outer fitting valley section adjacent to the outer fitting peak section; and

inner fitting stepped sections that are provided at a plurality of positions along the axial line on an outer side of the inner fitting end section such that diameters decrease in steps toward the first steel pipe pile,

wherein each of the inner fitting stepped sections has an inner fitting peak section relatively close to the first steel pipe pile and an inner fitting valley section adjacent to the inner fitting peak section,

wherein each of the inner fitting peak sections is interlocked with each of the outer fitting peak sections in a state where the inner fitting end section is inserted into the outer fitting end section and is relatively rotated about the axial line,

wherein in each of the outer fitting peak sections, a ratio obtained by dividing a protruding height of the outer fitting peak section next to the outer fitting peak section relatively close to the second steel pipe pile by a protruding height of the outer fitting peak section relatively close to the second steel pipe pile ranges from 0.5

to 0.9,

wherein in each of the inner fitting peak sections, a ratio obtained by dividing a protruding height of the inner fitting peak section next to the inner fitting peak section relatively close to the first steel pipe pile by a protruding height of the inner fitting peak section relatively close to the first steel pipe pile ranges from 0.5 to 0.9, and

wherein a plate thickness of the outer fitting valley section closest to the second steel pipe pile is smaller than a plate thickness of the inner fitting valley section closest to the first steel pipe pile, and a ratio obtained by dividing the plate thickness of the outer fitting valley section closest to the second steel pipe pile by the plate thickness of the inner fitting valley section closest to the first steel pipe pile is equal to or greater than 0.84.

2. The joint structure for a steel pipe pile according to Claim 1,

wherein a ratio obtained by dividing the plate thickness of the outer fitting valley section closest to the second steel pipe pile by the plate thickness of the inner fitting valley section closest to the first steel pipe pile ranges from 0.84 to 0.94.

3. The joint structure for a steel pipe pile according to Claim 1 or 2,

wherein in each of the outer fitting peak sections, a ratio obtained by dividing the protruding height of the outer fitting peak section next to the outer fitting peak section relatively close to the second steel pipe pile by the protruding height of the outer fitting peak section relatively close to the second steel pipe pile ranges from 0.6 to 0.8, and

wherein in each of the inner fitting peak sections, a ratio obtained by dividing

the protruding height of the inner fitting peak section next to the inner fitting peak section relatively close to the first steel pipe pile by the protruding height of the inner fitting peak section relatively close to the first steel pipe pile ranges from 0.6 to 0.8.