

DESCRIPTION

STEEL PIPE SHEET PILE AND COMPOSITE WALL INCLUDING STEEL PIPE SHEET PILE

5 TECHNICAL FIELD

[0001]

The present disclosure relates to a steel pipe sheet pile, and a composite wall including the steel pipe sheet pile.

BACKGROUND ART

10 [0002]

A composite wall, which is a combination of a steel pipe sheet pile and a steel sheet pile, is known to be capable of improving section performance per unit wall weight due to high section performance of the steel pipe sheet pile and lightweight property of the steel sheet pile. In order to construct the composite wall, for instance, the steel pipe sheet piles are driven in advance into the ground at predetermined intervals, and the steel sheet piles are subsequently driven between the steel pipe sheet piles. At this time, it is necessary to drive the steel sheet piles into the ground while interlocks of the steel sheet piles are engaged with corresponding connecting members of the steel pipe sheet piles. Typically, as exemplarily shown by a composite wall 8 in Fig. 14, a connecting member 82 of the same shape as an interlock 11 of a steel sheet pile 10 is attached to a steel pipe body 81 of a steel pipe sheet pile 80. In this case, the position of the interlock 11 of the steel sheet pile 10 that is subsequently driven has to be aligned with the position of the connecting member 82 of the steel pipe sheet pile 80 that has been driven into the ground in advance, making the construction process difficult.

[0003]

In view of the above, Patent Literature 1 discloses, for instance, a composite wall 9 as shown in Fig. 15, where a pipe-shaped connecting member 92 extending in a longitudinal direction is attached to a steel pipe body 91 of a steel pipe sheet pile 90 and an end of the steel sheet pile 10 in a width direction is engaged with a slit 922 formed in the pipe-shaped connecting member 92. According to the above arrangement, even when the steel sheet pile 10 is slightly

shifted in the width direction when being driven, the interlock 11 of the steel sheet pile 10, which is provided inside the pipe-shaped connecting member 92 to serve as a detachment stopper, keeps the engagement. As described above, the composite wall 9, which can tolerate to some degree the construction errors of the steel sheet pile 10 in the width direction when the steel sheet pile 10 is driven, can be easily constructed as compared with the above-described typical composite wall. Patent Literatures 2 and 3 each also disclose a steel pipe sheet pile having a similar pipe-shaped connecting member.

CITATION LIST

10 PATENT LITERATURE(S)

[0004]

Patent Literature 1 JP 4998646 B2

Patent Literature 2 JP 2016-44502 A

Patent Literature 3 JP 2016-113750 A

15 SUMMARY OF THE INVENTION

PROBLEM(S) TO BE SOLVED BY THE INVENTION

[0005]

However, when the end of the steel sheet pile 10 including the interlock 11 is engaged with the slit 922 formed in the pipe-shaped connecting member 92 as in the composite wall 9 shown in Fig. 15, the steel sheet pile 10 can be rotated as, for instance, shown in Fig. 16. The illustrated composite wall 9, which receives a pressure P (e.g. earth pressure and/or water pressure) in a wall-thickness direction, has no specific mechanism for preventing the rotation of the steel sheet pile 10 around edges 923A, 923B of the pipe-shaped connecting member 92 on both sides of the slit 922. Accordingly, the steel sheet pile 10 rotated around an end thereof may be bulged to deform the composite wall 9.

[0006]

In view of the above, an object of the invention is to provide a novel and improved steel pipe sheet pile for a composite wall including the steel pipe sheet pile and a steel sheet pile, the composite wall being capable of tolerating to some degree construction errors when the steel sheet pile is driven into the ground and also capable of preventing a rotation of the steel sheet pile.

MEANS FOR SOLVING THE PROBLEM(S)

[0007]

A steel pipe sheet pile according to an aspect of the invention includes: a steel pipe body; and at least one connecting member extending in a longitudinal direction of the steel pipe body. The connecting member defines a hollow portion
5 extending in the longitudinal direction, and a slit extending in the longitudinal direction and defining a boundary plane between the hollow portion and an outside, and the boundary plane is slanted in a cross section perpendicular to the longitudinal direction with respect to a perpendicular line extending in a direction
10 from a center of the hollow portion through a center of the slit toward the outside.

According to the above arrangement, the edges on both sides of the slit of the hollow portion of the connecting member face the steel sheet pile at mutually different positions with respect to the direction from the center of the slit toward the outside (i.e. a direction in which the steel sheet pile is intended to extend from the
15 connecting member of the steel pipe sheet pile when the steel pipe sheet pile is combined with the steel sheet pile to form the composite wall). Thus, the rotation of the steel sheet pile due to the moment caused by the pressure applied to the steel sheet pile can be prevented.

[0008]

20 In the above-described steel pipe sheet pile, the connecting member may define a spiral in the cross section perpendicular to the longitudinal direction, the spiral having a void in a rotation direction, and the void may define the slit. Alternatively, the connecting member may include a pair of arm portions extending in a direction away from the steel pipe body in the cross section perpendicular to
25 the longitudinal direction, the hollow portion may be defined between the pair of arm portions, and the slit may be defined by distal portions of the pair of arm portions, the distal portions facing each other in an offset manner in the direction from the center of the hollow portion through the center of the slit toward the outside.

[0009]

30 Further, in the above-described steel pipe sheet pile, a rib groove may be formed on a surface of the connecting member, the rib groove extending in a direction angled with respect to the longitudinal direction.

[0010]

In the above-described steel pipe sheet pile, in a rectangle defined by: opposite first and second apexes, the first apex being located at a corner, which is closer to the center of the hollow portion, of one of the edges or the distal portions on both sides of the slit close to the center of the hollow portion, the second apex being located at a corner, which is remote from the center of the hollow portion, of the other of the edges or the distal portions remote from the center of the hollow portion; a first pair of sides parallel to the direction extending from the center of the hollow portion through the center of the slit toward the outside; and a second pair of sides perpendicular to the direction extending from the center of the hollow portion through the center of the slit toward the outside, a length a of each of the first pair of sides of the rectangle and a length b of each of the second pair of sides of the rectangle may satisfy a relationship of $a \leq b$.

[0011]

Further, the above-described steel pipe sheet pile may include a pair of connecting members disposed on both sides of the steel pipe body in the width direction, and an angle by which the boundary plane in one of the pair of connecting members is slanted with respect to the perpendicular line may be opposite to an angle by which the boundary plane in the other of the pair of connecting members is slanted with respect to the perpendicular line.

[0012]

A composite wall according to another aspect of the invention includes: the steel pipe sheet pile according to any one of the above-described arrangements; and a steel sheet pile connected to the steel pipe sheet pile. An end of the steel sheet pile in a width direction is inserted into the slit.

[0013]

In the above-described composite wall, the boundary plane may be slanted, in the cross section perpendicular to the longitudinal direction, with respect to the perpendicular line extending in the direction from the center of the hollow portion through the center of the slit toward the outside in a direction opposite a moment caused by a pressure applied to the steel sheet pile.

[0014]

Further, in the above-described composite wall, an end of the steel sheet pile in the width direction may be provided with a detachment stopper portion.

[0015]

According to the above aspect(s) of the invention, a composite wall including a steel pipe sheet pile and a steel sheet pile can be provided, which, while tolerating to some degree construction errors when the steel sheet pile is driven into the ground, can prevent a rotation of the steel sheet pile.

BRIEF DESCRIPTION OF DRAWING(S)

[0016]

Fig. 1 is a perspective view showing a part of a composite wall including a steel pipe sheet pile according to a first exemplary embodiment of the invention.

Fig. 2 is an enlarged cross-sectional view showing a connecting member of the steel pipe sheet pile shown in Fig. 1.

Fig. 3A illustrates how the connecting member of the steel pipe sheet pile according to the first exemplary embodiment of the invention prevents a rotation of the steel sheet pile.

Fig. 3B illustrates how the connecting member of the steel pipe sheet pile according to the first exemplary embodiment of the invention prevents the rotation of the steel sheet pile.

Fig. 3C illustrates how the connecting member of the steel pipe sheet pile according to the first exemplary embodiment of the invention prevents the rotation of the steel sheet pile.

Fig. 4 illustrates the connecting member shown in Fig. 2 that supports an end of the steel sheet pile at mutually different positions.

Fig. 5 is a cross-sectional view showing how the connecting member of the steel pipe sheet pile is disposed in the first exemplary embodiment.

Fig. 6 is an illustration showing a shape of the connecting member of the steel pipe sheet pile according to the first exemplary embodiment of the invention in another perspective.

Fig. 7 is an enlarged cross-sectional view showing a connecting member of a steel pipe sheet pile according to a second exemplary embodiment of the invention.

Fig. 8 is a cross-sectional view showing a part of a composite wall including a steel pipe sheet pile according to a third exemplary embodiment of the invention.

Fig. 9 is a cross-sectional view showing how the connecting member of the steel pipe sheet pile is disposed in the third exemplary embodiment.

5 Fig. 10 is a perspective view showing a part of a composite wall including a steel pipe sheet pile according to a fourth exemplary embodiment of the invention.

Fig. 11 is an enlarged cross-sectional view showing a connecting member of a steel pipe sheet pile according to a fifth exemplary embodiment of the invention.

10 Fig. 12 is a cross-sectional view showing how the connecting member of the steel pipe sheet pile is disposed in the fifth exemplary embodiment.

Fig. 13 is an illustration showing a shape of the connecting member of the steel pipe sheet pile according to the fifth exemplary embodiment of the invention in another perspective.

15 Fig. 14 is a cross-sectional view showing a part of a composite wall including a typical steel pipe sheet pile.

Fig. 15 is a cross-sectional view showing a part of a composite wall including another typical steel pipe sheet pile.

Fig. 16 is an enlarged cross-sectional view showing a connecting member of the steel pipe sheet pile shown in Fig. 15.

20 DESCRIPTION OF EMBODIMENT(S)

[0017]

Exemplary embodiments of the invention will be described below with reference to attached drawings. It should be noted that the same reference numerals will be attached to components having substantially the same structures and functions to omit duplicated explanations therefor in the specification and drawings.

[0018]

First Exemplary Embodiment

30 Fig. 1 is a perspective view showing a part of a composite wall including a steel pipe sheet pile according to a first exemplary embodiment of the invention. A composite wall 1 according to the first exemplary embodiment, which is constructed, for instance, as a retaining wall or a cut-off wall, receives a pressure P (e.g. earth

pressure or water pressure) in a wall-thickness direction (y direction in Fig 1). As shown in Fig. 1, the composite wall 1 includes at least one hat-shaped steel sheet pile 10 and at least one steel pipe sheet pile 20. The steel sheet pile 10 includes interlocks 11, a flange 12, webs 13, and arms 14. The arms 14 are provided to
5 respective ends of the steel sheet pile 10 in a width direction (x direction in Fig. 1). The interlocks 11 are each formed at an end of each of the arms 14. The steel pipe sheet pile 20 includes a steel pipe body 21 and connecting members 22 extending in a longitudinal direction (z direction in Fig. 1) of the steel pipe body 21. The steel pipe body 21 is bonded with the connecting members 22 through, for instance,
10 welding. Each of the connecting members 22 (sometimes referred to as “the connecting member 22” in a singular form hereinafter) defines therein a hollow portion 221 and a slit 222 extending in the longitudinal direction. One of the arms 14 of the steel sheet pile 10 (sometimes referred to as “the arm 14” in a singular form hereinafter) is inserted into the slit 222. At this time, the interlock 11 formed at the
15 end of the arm 14 is located within the hollow portion 221 of the connecting member 22. As described later, an opening width B of the slit 222 is made smaller than a width h of the interlock 11, so that the interlock 11 serves as a detachment stopper that keeps the engagement between the connecting member 22 of the steel pipe sheet pile 20 and the steel sheet pile 10.

20 [0019]

Fig. 2 is an enlarged cross-sectional view showing the connecting member of the steel pipe sheet pile shown in Fig. 1. As shown in the cross section in Fig. 2 (i.e. a cross section perpendicular to the longitudinal direction of the steel pipe body 21), the connecting member 22 is a (imperfect) spiral having a void in a rotation
25 direction. The term “spiral” is defined herein as a curve that goes away from the center as it turns. In the illustrated example, edges 223A and 223B of the connecting member 22 define a start point and an end point of the spiral, respectively. Further, the spiral having a void in the rotation direction means that the spiral does not go full circle around the center. A gap (i.e. the void, which
30 defines the slit 222) is present between the edge 223A and the edge 223B as viewed from the center of the spiral.

[0020]

It should be noted that the cross-sectional profile described herein refers to a cross-sectional profile before the steel pipe sheet pile and the steel sheet pile of the composite wall are driven into the ground, unless otherwise specified. As described above, the composite wall receives the earth pressure and/or water pressure in the wall-thickness direction. Accordingly, the shape and positional relationship of the steel pipe sheet pile and the steel sheet pile may sometimes change due to the pressure after the composite wall is driven into the ground. To put it the other way around, the cross-sectional profiles of the steel pipe sheet pile and the steel sheet pile described herein without any reservation are basically profiles before the pressure is applied. Further, before the steel pipe sheet pile and the steel sheet pile are driven into the ground, the steel pipe sheet pile and the steel sheet pile have the cross-sectional profiles as illustrated and described over the entire longitudinal length thereof. However, for instance, in order to correct misalignment at the time of being driven into the ground, dimensions of some details of the cross-sectional profile may be changed in the longitudinal direction. Further, since the earth pressure and water pressure applied after the composite wall is driven into the ground may be different depending on the depth, the cross-sectional profiles of the steel pipe sheet pile and the steel sheet pile after being driven into the ground may be deformed unevenly in the longitudinal direction. However, it is not necessary to exclude the steel pipe sheet pile and the composite wall after being driven into the ground as long as the cross-sectional profiles of the steel pipe sheet pile and the composite wall before being driven into the ground are within the requirements (e.g. when no earth pressure and/or water pressure large enough for collapsing the composite wall is applied).

[0021]

In the above-described cross-sectional profile of the connecting member 22, the slit 222 defines a boundary plane 222S between the hollow portion 221 surrounded by the connecting member 22 and an outside of the connecting member 22. In the illustrated example, the boundary plane 222S is a plane connecting a plate-thickness center of the edge 223A (i.e. the center of the cross section of the edge) and a plate-thickness center of the edge 223B (i.e. the center of the cross section of the edge). In the first exemplary embodiment, the boundary

plane 222S is slanted by an angle θ with respect to a perpendicular line 221E that is perpendicular to a line in a direction 221D extending from a center 221C of the hollow portion 221 through the cross-sectional center of the slit 222 toward the outside. Thus, the edges 223A and 223B face mutually different points on the arm 14 (or the interlock 11) of the steel sheet pile 10 in the direction 221D (i.e. a direction in which the steel sheet pile 10 is intended to extend from the connecting member 22). Accordingly, when a moment M is caused by the pressure P applied to the steel sheet pile 10 as described later, the edges 223A and 223B contact the steel sheet pile 10 at two points, restraining rotation of the steel sheet pile 10. The angle θ is preferably, for instance, 20 degrees or more, 25 degrees or more, 30 degrees or more, or 33 degrees or more. The upper limit of the angle θ , which is not necessary to be determined, does not exceed 90 degrees by definition. The angle θ may be determined to be 80 degrees or less or 70 degrees or less, as necessary.

[0022]

It should be noted that the center 221C of the hollow portion 221 is the center of a figure of the cross-sectional profile of the hollow portion 221 defined by the connecting member 22 and the boundary plane 222S. The center of the figure of the cross-sectional profile is also a center of mass of the cross section.

[0023]

Further, the direction 221D, in which the steel sheet pile 10 is intended to extend from the connecting member 22 in the above example, is substantially aligned with a direction in which the steel sheet pile 10 extends from the connecting member 22 in, for instance, a design drawing and the like. Alternatively, with the use of the hat-shaped steel sheet pile 10, the steel sheet pile 10 extends from the connecting member 22 in the width direction (x direction in the figure) of the composite wall 1. Accordingly, the width direction (x direction in the figure) of the composite wall 1 is substantially aligned with the direction 221D.

[0024]

In the pipe-shaped connecting member 92 of the typical steel pipe sheet pile 90 described herein with reference to Figs. 15 and 16, a boundary plane 922S defined by the slit 922 is substantially aligned with a perpendicular line 921E that is perpendicular to a direction from a center 921C of a hollow portion 921 through a

cross-sectional center of the slit 922 toward an outside (i.e. in a direction 921D in which the steel sheet pile 10 is intended to extend from the pipe-shaped connecting member 92). In such an arrangement, edges 923A, 923B of the pipe-shaped connecting member 92 face respective opposite sides of the arm 14 of the steel sheet pile 10 at the same point in the direction 921D. Accordingly, when the moment M is caused by the pressure P applied to the steel sheet pile 10, the edges 923A and 923B contact the steel sheet pile 10 substantially at the same point or at points close to each other, failing to prevent the rotation of the steel sheet pile 10.

[0025]

The connecting member 22 of the steel pipe sheet pile 20 according to the first exemplary embodiment may be formed by, for instance, preparing a pipe member having the same slit as that of the pipe-shaped connecting member 92 described above with reference to Fig. 15, and inwardly pressing only one of edges defining the slit. In this case, the pressed side of the slit is the edge 223A, which is close to the center of the hollow portion, in the example shown in Fig. 2. Alternatively, the connecting member 22 may be formed by preparing a similarly slitted pipe member and outwardly pulling only one of the edges defining the slit. In this case, the pulled-out one of the edges defining the slit is the edge 223B, which is remote from the center of the hollow portion, in the example shown in Fig. 2. In a non-limiting example, the connecting member 22 can be formed by preparing a slitted pipe member having an arc cross section, and pulling only one of the edges defining the slit to enlarge a major axis of the cross section (a length from a bonding portion between the connecting member 22 and the steel pipe body 21 to an outer corner of the edge 223A in the example shown in Fig. 2) to, for instance, approximately 1.07 times as large as the diameter of the original arc cross section. In still another example, the connecting member 22 may be formed by preparing two (gutter-shaped) members of semi-circular cross sections with mutually different radii and each having first and second ends, and bonding the first end of the members. The connecting member 22, whose cross section is shaped into a spiral through the above process, is bonded to the steel pipe body 21 through, for instance, welding. Alternatively, after the pipe member is bonded to the steel pipe body 21, the pipe member may be shaped into the connecting member 22 having

the spiral cross section through the above process. A plate-shaped connecting member may be interposed between the pipe member and the steel pipe body 21.

[0026]

The shortest distance between the edges 223A and 223B, which is, for instance, a distance between a corner of the edge 223A remote from the center of the hollow portion and a corner of the edge 223B close to the center of the hollow portion in the example shown in Fig. 2, is defined as an opening width B of the slit 222. The opening width B is greater than a plate thickness t of the steel sheet pile 10. A lower limit of the opening width B may be defined as 1.2t, 1.4t, 1.6t or 1.8t with reference to the plate thickness t of the steel sheet pile 10. Similarly, an upper limit of the opening width B may be 3.5t, 3.0t, or 2.5t. The opening width B, which is smaller than a width h of the interlock 11 of the steel sheet pile 10, may be defined as 0.9h or less, 0.8h or less, or 0.7h or less. The preferable ranges of the opening width B of the slit 222 can be defined as below without relying on the plate thickness t and the width h. The lower limit of the opening width B may be 10 mm, 13 mm, 15 mm, 17 mm or 20 mm. The upper limit of the opening width B may be 40 mm, 35 mm, 30 mm, or 25 mm.

[0027]

Figs. 3 are plan views each schematically showing the connecting member of the steel pipe sheet pile and the steel sheet pile, which illustrate how the connecting member of the steel pipe sheet pile according to the first exemplary embodiment of the invention prevents the rotation of the steel sheet pile. A thin line in each of Figs. 3 shows the moment M applied to the connecting member and the steel sheet pile 10. Fig. 3A shows an example of the connecting member without restraining the rotation of the steel sheet pile 10, which specifically is an example of the pipe-shaped connecting member 92 described above with reference to Figs. 15 and 16. In this arrangement, the steel sheet pile 10 freely rotates in the pipe-shaped connecting member 92, where an end of the steel sheet pile 10 in the width direction is supported by the first edge 923B as shown in Fig. 16. Accordingly, the moment M caused by the pressure P applied to the steel sheet pile 10 is zero at the pipe-shaped connecting members 92 on both sides of the steel sheet pile 10 in the width direction (x direction in the figure), and is maximized at a central portion of the

steel sheet pile 10. Consequently, the steel sheet pile 10 is deformed to be prominently bulged at the central portion. When, for instance, a plurality of steel sheet piles 10 interposed between the steel pipe sheet piles 90 are mutually connected through the interlock 11 at the central portion thereof as shown in the example shown in Fig. 15, the bulging steel sheet piles 10 apply a large load on the interlock 11 at the central portion. Accordingly, the above deformation is not preferable in terms of stability of the structure.

[0028]

Fig. 3B shows an example of the connecting member restraining the rotation of the steel sheet pile 10, which specifically is an example of the connecting member 82 described above with reference to Fig. 14. In this arrangement, the connecting member 82 bears the reaction moment, so that the moment M at the central portion of the steel sheet pile 10 becomes smaller than that in the above example shown in Fig. 3A. Accordingly, the central portion of the steel sheet pile 10 of the example shown in Fig. 3B is less prominently bulged than the example shown in Fig. 3A. However, in this arrangement, the connecting member 82, which bears the reaction moment, may be deformed or damaged. Further, the connecting member 82 configured as in the example shown in Fig. 14, which requires strict management of the construction errors of the steel sheet pile 10, is not easily constructed, as described above.

[0029]

Fig. 3C shows an example, in which the ends of the steel sheet pile 10 in the width direction are each supported at two supporting points not directly restraining the rotation of the steel sheet pile 10 (specifically, the edges 223A, 223B of the connecting member 22 described above with reference to Fig. 2 support the mutually different points of the steel sheet pile 10 as shown in Fig. 4). In this arrangement, the edges 223A, 223B bear the reaction moment, so that the moment M at the central portion of the steel sheet pile 10 becomes smaller than that in the above example shown in Fig. 3A and is slightly larger than the example shown in Fig. 3B, which can be reduced substantially to the same level. Accordingly, the central portion of the steel sheet pile 10 of the example shown in Fig. 3C is also less prominently bulged than the example shown in Fig. 3A. Meanwhile, since the

edges 223A, 223B do not directly restrain the rotation of the steel sheet pile 10 (i.e. permits the rotation of the steel sheet pile 10 to some degree), the components are far less likely to be deformed or damaged than the example shown in Fig. 3B. Further, the connecting member 22 of the steel pipe sheet pile 20 according to the first exemplary embodiment tolerates, to some degree, the construction errors in the width direction of the steel sheet pile 10 when the steel sheet pile 10 is driven into the ground, as in the pipe-shaped connecting member 92 in the example shown in Fig 15.

[0030]

The above advantages of the first exemplary embodiment are offered by a proper positional relationship between the spiral cross section of the connecting member 22 and the pressure P applied to the steel sheet pile 10, as shown in Fig. 2. Specifically, as in the example shown in Fig. 2, the connecting member 22 is disposed so that the boundary plane 222S of the spiral cross section is slanted with respect to the perpendicular line 221E in a direction opposite the moment M caused by the pressure P. With the above arrangement, the edge 223B that is to be a supporting point at a side not applied with the pressure P is located remote from the center 221C of the hollow portion 221 with respect to the edge 223A that is to be a supporting point at a side applied with the pressure P. Thus, the two-point support by the edges 223A, 223B can reduce the moment M caused by the pressure P as shown in Fig. 3C. In order to provide the above advantage, the boundaries 222S of the pair of connecting members 22 disposed on both sides of the steel pipe body 21 of the steel pipe sheet pile 20 in the width direction (x direction in the figure) are slanted with respect to the perpendicular line 221E by the angle θ in mutually opposite directions as shown in Figs. 2 and 5. Specifically, as shown in Fig. 5, while the angle θ of the connecting member 22 illustrated at the right of the steel pipe body 21, which is the same as the connecting member shown in Fig. 2, is counterclockwise, the angle θ of the connecting member 22 illustrated at the left of the steel pipe body 21 is clockwise.

[0031]

In the two connecting members attached to respective sides of the steel sheet pile in the width direction, when an edge close to the center of the hollow

portion of one of the two connecting members and an edge remote from the center of the hollow portion of the other of the two connecting members are positioned at the same side with respect to the wall-thickness direction (the direction perpendicular to the width direction (i.e. y direction in Fig. 1)), one of the connecting members cannot bear the reaction moment unlike an instance shown in Fig. 3C. Accordingly, the edges close to the center of the respective hollow portions of the two connecting members attached to both sides of the steel sheet pile in the width direction are located at the same side with respect to the wall-thickness direction (y direction in the figure) of the steel sheet pile as shown in Fig. 5. Similarly, the edges remote from the center of the respective hollow portions are located at the same side with respect to the wall-thickness direction of the steel sheet pile.

[0032]

It should be noted that the edges 223A, 223B of the connecting member 22 are not necessarily, from the outset, in contact with the steel sheet pile 10 to form the supporting points of the steel sheet pile 10 in the composite wall 1 described above with reference to Fig. 1. since the composite wall 1 is driven into the ground, when, for instance, relatively small earth pressure and/or water pressure is applied to the composite wall 1, the steel sheet pile 10 may sometimes be kept at a predetermined position without being in contact with any one of the edges 223A, 223B. In this case, when a large moment M is applied to the steel sheet pile 10 due to, for instance, increased earth pressure and/or water pressure after the composite wall 1 is completed, at least one of the edges 223A, 223B is brought into contact with the steel sheet pile 10 to define the supporting point of the steel sheet pile 10. Alternatively, at least one of the edges 223A, 223B may be in contact with the steel sheet pile 10 when the composite wall 1 is driven into the ground, specifically, for instance, when the arm 14 of the steel sheet pile 10 is inserted into the slit 222.

[0033]

The above-described steel pipe sheet pile 20 according to the first exemplary embodiment of the invention as described above, which is configured to receive an end of the steel sheet pile 10 in the width direction in the slit 222 of the connecting member 22, can tolerate to some degree the construction errors when the steel sheet pile 10 is being driven into the ground. Further, the boundary plane

222S of the steel pipe sheet pile 20, which is defined by the slit 222 between the hollow portion of the connecting member 22 and the outside, is slanted with respect to a perpendicular line 221E perpendicular to a line in the direction 221D extending from the center of the hollow portion 221 through the cross-sectional center of the slit 222 toward the outside. Thus, the edges 223A and 223B face mutually different points on the steel sheet pile 10 in the direction 221D (i.e. a direction in which the steel sheet pile 10 is intended to extend from the connecting member 22 when the composite wall 1 is constructed). Accordingly, when the moment M is caused by the pressure P applied to the steel sheet pile 10, the rotation of the steel sheet pile 10 can be prevented.

[0034]

Fig. 6 is an illustration showing the shape of the connecting member of the steel pipe sheet pile according to the first exemplary embodiment of the invention in another perspective. Fig. 6, which is an enlarged cross-sectional view of the connecting member 22 of the steel pipe sheet pile 20 similar to Fig. 2, has no line indicating the boundary plane 222S and the like, but instead shows a rectangle R defined by corners E_1 , E_2 of the two edges 223A, 223B as opposite apexes, a pair of sides parallel to the direction 221D, and a pair of sides perpendicular to the direction 221D. The corner E_1 is a corner of the edge 223A, which is one of the edges 223A, 223B closer to the center 221C of the hollow portion 221, located at a side close to the center 221C. In contrast, the corner E_2 is a corner of the edge 223B, which is one of the edges 223A, 223B remote from the center 221C, located at a side remote from the center 221C. In the thus defined rectangle R, a length a of the side of the rectangle R perpendicular to the direction 221D and a length b of the side parallel to the direction 221D preferably satisfy a relationship of $a \leq b$. The lengths may satisfy a relationship of $a < b$, as necessary.

[0035]

Second Exemplary Embodiment

Fig. 7 is an enlarged cross-sectional view showing a connecting member of a steel pipe sheet pile according to a second exemplary embodiment of the invention. In the second exemplary embodiment, the steel pipe sheet pile 20 including the steel pipe body 21 and the connecting member 22 is configured in the

same manner as in the above-described first exemplary embodiment. The second exemplary embodiment is different from the first exemplary embodiment in that a bent portion 15 is provided at an end of the arm 14 of the steel sheet pile 10A in place of the interlock 11. The bent portion 15 serves as a detachment stopper in the same manner as the interlock 11 of the example shown in Fig. 2. It should be noted that the detachment stopper is not necessarily provided by the interlock 11 in the first exemplary embodiment and the bent portion 15 in the second exemplary embodiment, but may be configured in any manner as long as an end of the steel sheet pile in the width direction is thickened or bent in the plate thickness direction (i.e. the wall-thickness direction of the composite wall) of the steel sheet pile. Herein, the above part of the steel sheet pile is sometimes referred to as a "detachment stopper portion." According to the thus arranged steel sheet pile, the pair of edges 223A, 223B at opposite sides of the slit 222 also face the arm 14 (or the bent portion 15) at different points on the steel sheet pile 10A, thereby preventing the rotation of the steel sheet pile 10A when the moment M is caused. It should be noted that the steel sheet pile 10A including the bent portion 15 is produced by, for instance, bending a steel sheet through cold forming. According to the second exemplary embodiment, since the bent portion 15 serves as the detachment stopper, it is not necessary for the width h (i.e. the width in a direction perpendicular to a longitudinal direction and a width direction of the steel sheet pile (y direction in the figure)) of the bent portion to be larger than the opening width B of the slit 222.

[0036]

Third Exemplary Embodiment

Fig. 8 is a cross-sectional view showing a part of a composite wall including a steel pipe sheet pile according to a third exemplary embodiment of the invention. In the third exemplary embodiment, each of the steel pipe body 21 and the connecting member 22 of the steel pipe sheet pile 20B is configured in the same manner as in the above-described first exemplary embodiment. The third exemplary embodiment is different from the first exemplary embodiment in that a U-shaped steel sheet pile 10U is used in the third exemplary embodiment and, consequently, the slit 222 of the connecting member 22 is oriented in a direction different from that in the first exemplary embodiment. Specifically, in the third exemplary embodiment,

the boundary plane 222S defined by the slit 222 is also slanted by the angle θ in a direction opposite the moment M with respect to the perpendicular line 221E perpendicular to the direction 221D. However, in the third exemplary embodiment, the direction 221D (i.e. the direction for the steel sheet pile 10U to be intended to extend from the connecting member 22) is slanted with respect to the width direction (x direction in the figure) of the steel sheet pile 10U. Consequently, the direction of the boundary plane 222S determined based on the direction 221D (i.e. the direction for the slit 222 to be oriented) is different from that in the first exemplary embodiment. The angle θ is preferably, for instance, 20 degrees or more, 25 degrees or more, 30 degrees or more, or 33 degrees or more.

[0037]

The boundaries 222S of the pair of connecting members 22 disposed on both sides in the width direction (x direction in the figure) of the steel pipe body 21 of the steel pipe sheet pile 20B according to the third exemplary embodiment are slanted with respect to the perpendicular line 221E by the angle θ in mutually opposite directions as shown in Figs. 8 and 9. Specifically, while the angle θ of the connecting member 22 illustrated at the right of the steel pipe body 21 in Fig. 9, which is the same as the connecting member shown in Fig. 8, is counterclockwise, the angle θ of the connecting member 22 illustrated at the left of the steel pipe body 21 is clockwise.

[0038]

According to the third exemplary embodiment, the pair of edges 223A, 223B at both sides of the slit 222 also face the arm 14 (or the interlock 11) at mutually different points on the steel sheet pile 10U, preventing the rotation of the steel sheet pile 10U when the moment M is caused. In some other exemplary embodiments, the rotation of the steel sheet pile caused by the moment M can be similarly prevented in steel sheet piles of various cross-sectional profiles (e.g. Z-shaped steel sheet pile and linear steel sheet pile) by orienting the slit 222 in an appropriate direction.

[0039]

Fourth Exemplary Embodiment

Fig. 10 is a perspective view showing a part of a composite wall including a

steel pipe sheet pile according to a fourth exemplary embodiment of the invention. As shown in Fig. 10, a composite wall 4 according to the fourth exemplary embodiment is configured in the same manner as in the first exemplary embodiment except that rib grooves 224 are formed on the surface of a connecting member 22C of a steel pipe sheet pile 20C. The rib grooves 224 extend in a direction angled with respect to the longitudinal direction (z direction in the figure) of the connecting member 22C. For instance, the rib grooves 224 may be perpendicular to the longitudinal direction of the connecting member 22C. Alternatively, the rib grooves 224 may be slanted with respect to the longitudinal direction of the connecting member 22C. In this case, the rib groove(s) 224 defines a part of a spiral extending in the longitudinal direction of the connecting member 22C.

[0040]

An example of the rib grooves 224 provided on the pipe-shaped connecting member 92 as described with reference to Fig. 15 is disclosed in, for instance, JP 2016-44502 A. JP 2016-44502 A discloses various shapes of the rib grooves. Similarly, the rib grooves 224 according to the fourth exemplary embodiment can be formed in various shapes. The rib grooves 224 thus formed improve cross-sectional rigidity of the connecting member 22. Accordingly, for instance, when the moment M is caused due to the pressure P applied to the steel sheet pile 10, the slit 222 is kept from being widened by the reaction moment applied to the edge 223B defining the supporting point of the steel sheet pile 10. In the fourth exemplary embodiment, since larger reaction moment is applied on the edge 223B than on the edge 223A, the rib grooves 224 may be provided only on the side of the edge 223B and not necessarily provided on the side of the edge 223A. Further, in order to strengthen the bonding (e.g. welding) between the steel pipe body 21 and the connecting member 22, the rib grooves 224 may be omitted at the bonding portion between the connecting member 22 and the steel pipe body 21.

[0041]

Fifth Exemplary Embodiment

Fig. 11 is an enlarged cross-sectional view showing a connecting member of a steel pipe sheet pile according to a fifth exemplary embodiment of the invention.

In the fifth exemplary embodiment, a steel pipe sheet pile 30 includes the steel pipe body 21 and a connecting member 32 extending in a longitudinal direction (z direction in Fig. 1) of the steel pipe body 21. The steel pipe body 21 is bonded with the connecting member 32 through, for instance, welding. As shown in the cross section in Fig. 11 (i.e. a cross section perpendicular to the longitudinal direction of the steel pipe body 21), the connecting member 32 includes a pair of arm portions 323A, 323B extending in a direction away from the steel pipe body 21. A hollow portion 321 is defined between the arm portions 323A, 323B. Further, a slit 322 is defined between distal portions 324A, 324B of the respective arm portions 323A, 323B. As illustrated, the distal portions 324A, 324B are formed by bending the arm portions 323A, 323B to come close to each other. The distal portions 324A, 324B, which face each other across the slit 322, are offset in a direction 321D from a center 321C of the hollow portion 321 through the center of the slit 322 to the outside. The above center 321C of the hollow portion 321 refers to the center of a figure of the hollow portion 321.

[0042]

The difference D, which is defined between the plate-thickness centers of the distal portions 324A, 324B, is $0.5t$ or more with reference to the plate thickness t of the steel sheet pile 10, more preferably, for instance, $0.5t \leq D \leq 1.5t$. Supposing that the above relationship is applied to a typical range of the plate thickness t (10 mm to 20 mm), the lower limit of the difference D is preferably 5 mm, and the range of the difference D is preferably defined as, for instance, $5 \text{ mm} \leq D \leq 30 \text{ mm}$. Further, the opening width B (i.e. the shortest distance between the distal portion 324A and the distal portion 324B) of the slit 322 is defined as $t < B < h$ with reference to the plate thickness t of the steel sheet pile 10 and the width h of the interlock 11 as described in the first exemplary embodiment. The opening width B is preferably in a range of, for instance, $16 \text{ mm} \leq B \leq 40 \text{ mm}$ for a typical plate thickness t and width h .

[0043]

It should be noted that the illustrated configuration of the arm portions 323A, 323B and the distal portions 324A, 324B are merely exemplary, and the arm portions 323A, 323B and the distal portions 324A, 324B may be configured in

various other shapes. For instance, at least one of the arm portions 323A, 323B and/or at least one of the distal portions 324A, 324B may have an arc-shaped cross-sectional profile with a predetermined curvature. In the illustrated example, the connecting member 32 includes a bridge 325 for maintaining a distance
5 between the arm portions 323A, 323B.

[0044]

In the above-described cross-sectional profile of the connecting member 32, the slit 322 defines a boundary plane 322S between the hollow portion 321 and an outside of the connecting member 321. The boundary plane 322S is also a plane
10 connecting the distal portions 324A, 324B. As illustrated, the boundary plane 322S is slanted by an angle θ with respect to a perpendicular line 321E, which is perpendicular to a direction 321D extending from the center 321C of the hollow portion 321 through the center of the slit 322 toward the outside. Specifically, the boundary plane 322S is slanted by the angle θ with respect to the perpendicular
15 line 321E in a direction opposite the moment M. Thus, the distal portions 324A and 324B face mutually different points on the arm 14 (or the interlock 11) of the steel sheet pile 10 in the direction 321D (i.e. a direction in which the steel sheet pile 10 is intended to extend from the connecting member 32). Accordingly, when a moment M is caused by the pressure P applied to the steel sheet pile 10, the distal portions
20 324A and 324B contact the steel sheet pile 10 at two points, restraining rotation of the steel sheet pile 10. The angle θ is preferably, for instance, 20 degrees or more, 25 degrees or more, 30 degrees or more, or 33 degrees or more.

[0045]

The connecting member 32 according to the fifth exemplary embodiment is
25 provided by, for instance, a hot-extruded steel shape formed through hot-extrusion of a steel material. The connecting member formed of the hot-extruded steel shape, which can be formed into any desired shape, is not necessarily configured as shown in the example shown in Fig. 11, but may have any shape as long as the hollow portion and the slit extending in the longitudinal direction are defined. Further,
30 the method of manufacturing the connecting member is not limited to hot-extrusion, but may be, for instance, cold-extrusion, and hot or cold bending.

[0046]

The boundaries 322S of the pair of connecting members 32 disposed on both sides in the width direction (x direction in the figure) of the steel pipe body 21 of the steel pipe sheet pile 30 according to the fifth exemplary embodiment are slanted with respect to the perpendicular line 321E by the angle θ in mutually opposite directions as shown in Figs. 11 and 12. Specifically, while the angle θ of the connecting member 32 illustrated at the right of the steel pipe body 21 in Fig. 12, which is the same as the connecting member shown in Fig. 11, is counterclockwise, the angle θ of the connecting member 32 illustrated at the left of the steel pipe body 21 is clockwise. In other words, the edges close to the center of the respective hollow portions of the two connecting members attached to opposite sides of the steel sheet pile in the width direction are located at the same side with respect to the wall-thickness direction (y direction in the figure) of the steel sheet pile wall. Similarly, the edges remote from the center of the respective hollow portions are located at the same side with respect to the wall-thickness direction of the steel sheet pile wall.

[0047]

Fig. 13 is an illustration showing the shape of the connecting member of the steel pipe sheet pile according to the fifth exemplary embodiment of the invention in another perspective. Fig. 13, which is an enlarged cross-sectional view of the connecting member 32 of the steel pipe sheet pile 30 similar to Fig. 11, has no line indicating the boundary plane 322S and the like, but instead shows a rectangle R defined by corners E_1 , E_2 of the two distal portions 324A, 324B as opposite apexes, a pair of sides parallel to the direction 321D, and a pair of sides perpendicular to the direction 321D. The corner E_1 is a corner of the distal portion 324A, which is one of the distal portions 324A, 324B closer to the center 321C of the hollow portion 321, located at a side close to the center 321C. In contrast, the corner E_2 is a corner of the distal portion 324B, which is one of the distal portions 324A, 324B remote from the center 321C, located at a side remote from the center 321C. In the thus defined rectangle R, a length a of the side of the rectangle R perpendicular to the direction 321D and a length b of the side parallel to the direction 321D satisfy a relationship of $a \leq b$.

[0048]

Exemplary embodiments of the invention have been described in detail with reference to attached drawings. However, the scope of the invention is not limited to the above exemplary embodiments. It is obvious to those having an ordinary skill in the field of the art pertaining the invention that various modifications and variations are possible within the technical idea recited in claim(s), and it should be understood that these modifications and variations are within the technical scope of the invention.

EXPLANATION OF CODE(S)

[0049]

10 1...composite wall, 10...steel sheet pile, 11...interlock, 12...flange, 13...web, 14...arm, 15...bent portion, 20, 30...steel pipe sheet pile, 21...steel pipe body, 22,32...connecting member, 221, 321...hollow portion, 222, 322...slit, 222S, 322S...boundary plane, 223A, 223B...edge, 224...rib groove, 323A, 323B...arm portion, 324A, 324B...distal portion

15

CLAIM(S)

1. A steel pipe sheet pile comprising:

a steel pipe body; and

at least one connecting member extending in a longitudinal direction of the
5 steel pipe body, wherein

the connecting member defines a hollow portion extending in the longitudinal direction, and a slit extending in the longitudinal direction and defining a boundary plane between the hollow portion and an outside, and

the boundary plane is slanted in a cross section perpendicular to the
10 longitudinal direction with respect to a perpendicular line extending in a direction from a center of the hollow portion through a center of the slit toward the outside.

2. The steel pipe sheet pile according to claim 1, wherein the connecting member defines a spiral in the cross section perpendicular to the longitudinal direction, the spiral having a void in a rotation direction, and

15 the void defines the slit.

3. The steel pipe sheet pile according to claim 1, wherein the connecting member comprises a pair of arm portions extending in a direction away from the steel pipe body in the cross section perpendicular to the longitudinal direction,

the hollow portion is defined between the pair of arm portions, and

20 the slit is defined by distal portions of the pair of arm portions, the distal portions facing each other in an offset manner in the direction from the center of the hollow portion through the center of the slit toward the outside.

4. The steel pipe sheet pile according to any one of claims 1 to 3, wherein a rib groove is formed on a surface of the connecting member, the rib groove
25 extending in a direction angled with respect to the longitudinal direction.

5. The steel pipe sheet pile according to any one of claims 1 to 4, wherein, in a rectangle defined by: opposite first and second apexes, the first apex being located at a corner, which is closer to the center of the hollow portion, of one of the edges or the distal portions on both sides of the slit close to the center of the hollow portion, the second apex being located at a corner, which is remote from the center
30 of the hollow portion, of the other of the edges or the distal portions remote from the center of the hollow portion; a first pair of sides parallel to the direction extending

from the center of the hollow portion through the center of the slit toward the outside; and a second pair of sides perpendicular to the direction extending from the center of the hollow portion through the center of the slit toward the outside, a length a of each of the first pair of sides of the rectangle and a length b of each of the second pair of sides of the rectangle satisfy a relationship of $a \leq b$.

6. The steel pipe sheet pile according to any one of claims 1 to 5, wherein the at least one connecting member comprises a pair of connecting members disposed on both sides of the steel pipe body in the width direction, and

an angle by which the boundary plane in one of the pair of connecting members is slanted with respect to the perpendicular line is opposite to an angle by which the boundary plane in the other of the pair of connecting members is slanted with respect to the perpendicular line.

7. A composite wall comprising:

a steel pipe sheet pile according to any one of claims 1 to 6; and

a steel sheet pile connected to the steel pipe sheet pile, an end of the steel sheet pile in a width direction being inserted into the slit.

8. The composite wall according to claim 7, wherein the boundary plane is slanted, in the cross section perpendicular to the longitudinal direction, with respect to the perpendicular line extending in the direction from the center of the hollow portion through the center of the slit toward the outside in a direction opposite a moment caused by a pressure applied to the steel sheet pile.

9. The composite wall according to claim 7 or 8, wherein an end of the steel sheet pile in the width direction is provided with a detachment stopper portion.

10. The composite wall according to claim 9, wherein a plate thickness t of the steel sheet pile, a width h of the detachment stopper portion, and an opening width B of the slit satisfy a relationship $t < B < h$.