

DESCRIPTION

Title of Invention: STRAIGHT WEB-TYPE SHEET PILE AND
STRUCTURE AND METHOD FOR REINFORCING STRUCTURAL OBJECT BY
USING THE STRAIGHT WEB-TYPE SHEET PILE

Technical Field

[0001]

The present invention relates to a straight web-type sheet pile and a structure and method for reinforcing a structural object by using the straight web-type sheet pile.

Background Art

[0002]

Straight web-type sheet piles are generally used in such a way that they are connected to each other by fitting joints at both ends thereof so as to form a circular or elliptical shape, thereby forming a closed wall structure for reinforcing a structural object.

A winding-up reinforcement construction method is an example of a method for reinforcing a structural object. In this method, the straight web-type sheet piles are driven around an existing structural object so as to form an external wall, and filling concrete is poured into the gap between the existing structural object and the straight web-type sheet piles, so that the existing structural object is reinforced by being integrated with the straight web-type sheet piles (see Patent Literature 1).

Examples of shapes of the straight web-type sheet piles used for the purpose of reinforcement include the FL-type and FXL-type (see Non Patent Literature 1).

Citation List

Patent Literature

[0003]

PTL 1: Japanese Unexamined Patent Application

Publication No. 2007-297826

Non Patent Literature

[0004]

NPL 1: Koukankui Kyoukai: Kouyaita Sekkei kara sekou made (Japanese Association for Steel Pipe Piles: Steel Piles From Design to Construction) pp. 337-338, 2007

Summary of Invention

Technical Problem

[0005]

Before describing a problem to be solved by the invention, the shape of a joint portion of a general straight web-type sheet pile will be described with reference to Fig. 5.

As illustrated in Fig. 5, a straight web-type sheet pile 50 includes a joint portion 51, which includes a main-claw portion 51a and a sub-claw portion 51b, and a web portion 52 that connects the joint portion 51 to the other joint portion 51. In this specification, a distance from

the center of the web portion 52 (the center position is indicated by the one-dot chain line in Fig. 5) to the outermost edge of the sub-claw portion 51b is referred to as an effective height h .

[0006]

A problem to be solved by the present invention will be described with reference to Figs. 6 to 8. Figs. 6 to 8 are diagrams disclosed in Patent Literature 1.

In Fig. 6, 53 denotes an existing structural object (pier in Patent Literature 1), 55 denotes a footing, and 57 denotes the ground surface. In Figs. 7 and 8, 59 denotes filling concrete (solidification material in Patent Literature 1), and 61 denotes reinforcing bars (61a denotes main reinforcements and 61b denotes hoop bars).

[0007]

In the above-described "winding-up reinforcement construction method" (see Fig. 6), the existing structural object 53 and the sheet pile wall (sheet pile wall formed of the straight web-type sheet piles 50) are brought as close to each other as possible to reduce the construction site area.

However, as illustrated in Fig. 7, there may be a case where the reinforcing bars 61 are placed in the gap between the existing structural object 53 and the sheet pile wall. In this case, since the space from the portions of the

joints of the straight web-type sheet piles 50 to the reinforcing bars 61 is small, there is a risk that, when the filling concrete 59 is poured into the gap, concrete aggregates (maximum diameter is about 20 mm) will be caught, causing voids (weak portions) being not filled with the concrete.

This will be described below in more detail with reference to Fig. 8.

[0008]

According to Patent Literature 1, a near distance (near distance B) of the existing structural object 53 and the sheet pile wall is about 200 mm.

According to the Specifications for Highway Bridges, for example, a cover thickness k to the reinforcing bars 61 is required to be 70 mm or more to ensure sufficient quality. Therefore, the distance from the existing structural object 53 to the reinforcing bars 61 is 70 mm at a minimum. It is also provided, from the viewpoint of ensuring sufficient quality, that the main reinforcement diameter d_1 is 16 mm at a minimum and the hoop bar diameter d_2 is 13 mm at a minimum.

[0009]

Examples of shapes of straight web-type sheet piles 50 that are presently used include the FL-type and FXL-type (see Non Patent Literature 1). The effective heights h of the FL-type and FXL-type are 44.5 mm and 47.0 mm,

respectively. The total height ($h \times 2$) of the FL-type sheet piles, for example, is 89 mm.

Therefore, in a reinforcing structure including the FL-type sheet piles, the space (narrowest portion) S from the straight web-type sheet piles 50 to the reinforcing bars 61 is $S = B - k - d_1 - d_2 - (h \times 2) = 200 - 70 - 16 - 13 - 89 = 12$ mm. Even when the FL-type sheet piles, which include the joint portions 51 with the smallest effective height h , is used, the space S is smaller than a general maximum concrete aggregate diameter, which is 20 mm.

For this reason, there is a risk that the concrete aggregates will be caught.

[0010]

If the shape (height) of the joints of the sheet piles can be made smaller to address the above-described problem, the space from the joints of the straight web-type sheet piles to the reinforcing bars can be increased. As a result, the problem that the concrete aggregates will be caught can be solved.

However, when the shape of the joints of the sheet piles is simply made smaller, the strength of the joint fitting portions will be reduced problematically.

In the case of a reinforcing structure using the straight web-type sheet piles, the structural bearing force is mainly increased by the restraint effect of the sheet

pile wall. The inventors have considered that the joint portions of the sheet piles are the key portions that provide the peripheral restraint effect of the sheet pile wall, and that when the tensile bearing force of the joint fitting portions, at which the joint portions are fitted together, decreases, the peripheral restraint effect of the sheet pile wall also decreases.

[0011]

The present invention has been made to solve the above-described problem. An object of the present invention is to provide a straight web-type sheet pile in which the shape (height) of the joints is made as small as possible to increase the workability in the filling concrete pouring process and the structural reliability without reducing the tensile bearing force of the joint fitting portions, and to provide a reinforcing structure and reinforcing method in which the straight web-type sheet pile is used.

Solution to Problem

[0012]

(1) A straight web-type sheet pile according to the present invention includes joint portions at both ends, each joint portion including a main-claw and a sub-claw. A main-claw height g of a joint is 6.0 mm or more, a ratio $f3/f1$ of a main-claw thickness $f3$ to a web-portion plate thickness $f1$ is 0.82 or more, a ratio $f2/f1$ of a sub-claw thickness $f2$ to

the web-portion plate thickness f_1 is 1.16 or more, a ratio c/f_3 of a joint opening height c to the main-claw thickness f_3 is 1.25 or more, and a distance h (effective height) from a center position of a web portion to an outermost edge of a sub-claw portion is 40 mm or less.

[0013]

(2) A straight web-type sheet pile according to the present invention includes joint portions at both ends, each joint portion including a main-claw and a sub-claw. A main-claw height g of a joint is 6.0 mm or more, a ratio f_3/f_1 of a main-claw thickness f_3 to a web-portion plate thickness f_1 is 0.82 or more, a ratio f_2/f_1 of a sub-claw thickness f_2 to the web-portion plate thickness f_1 is 1.16 or more, a ratio c/f_3 of a joint opening height c to the main-claw thickness f_3 is 1.25 or more, and a distance h (effective height) from a center position of a web portion to an outermost edge of a sub-claw portion is 37 mm or less.

[0014]

(3) A structure for reinforcing a structural object according to the present invention is a structure for reinforcing a structural object by arranging straight web-type sheet piles around the structural object. The straight web-type sheet piles, each according to (1) or (2), are arranged around the structural object such that a near distance of the structural object and a wall of the straight

web-type sheet piles is 200 mm or less, a reinforcing bar is disposed in a gap between the structural object and the straight web-type sheet piles, and the gap is filled with a solidification material.

[0015]

(4) A method for reinforcing a structural object according to the present invention is a method for reinforcing a structural object by arranging straight web-type sheet piles around the structural object. The method includes a step of arranging the straight web-type sheet piles, each according to (1) or (2), around the structural object such that a near distance of the structural object and a wall of the straight web-type sheet piles is 200 mm or less; a step of removing dirt existing between the structural object and the straight web-type sheet piles; and a step of placing a reinforcing bar in a gap between the structural object and the straight web-type sheet piles and filling the gap with a solidification material.

Advantageous Effects of Invention

[0016]

In the straight web-type sheet pile according to the present invention, the main-claw height g of the joint is 6.0 mm or more, the ratio $f3/f1$ of the main-claw thickness $f3$ to the web-portion plate thickness $f1$ is 0.82 or more, the ratio $f2/f1$ of the sub-claw thickness $f2$ to the web-

portion plate thickness f_1 is 1.16 or more, the ratio c/f_3 of the joint opening height c to the main-claw thickness f_3 is 1.25 or more, and the effective height h is 40 mm or less. Thereby, the shape of the joints can be made smaller while the strength and workability of the joint fitting portion are maintained. This leads to an increase in the economic efficiency.

In addition, since the effective height h of the joint portions is 40 mm or less, the space S from the straight web-type sheet piles to the bars (see Fig. 2) is increased, and the concrete aggregates are prevented from being caught.

Brief Description of Drawings

[0017]

[Fig. 1] Fig. 1 illustrates the shape of a joint portion of a straight web-type sheet pile according to an embodiment of the present invention.

[Fig. 2] Fig. 2 illustrates a reinforcing structure including joint portions of straight web-type sheet piles according to the embodiment of the present invention.

[Fig. 3] Fig. 3 illustrates a load transmission mechanism of a joint fitting portion of straight web-type sheet piles according to the embodiment of the present invention.

[Fig. 4] Fig. 4 illustrates an analysis model used in an experiment method according to Example 1 of the present

invention.

[Fig. 5] Fig. 5 illustrates a joint portion of a general straight web-type sheet pile.

[Fig. 6] Fig. 6 is a perspective view of a reinforcing structure including joint portions of straight web-type sheet piles according to the related art.

[Fig. 7] Fig. 7 is a plan view of the reinforcing structure including the joint portions of the straight web-type sheet piles according to the related art.

[Fig. 8] Fig. 8 illustrates the reinforcing structure including the joint portions of the straight web-type sheet piles according to the related art.

Description of Embodiments

[0018]

[First Embodiment]

[0019]

The shape of a straight web-type sheet pile 1 according to an embodiment of the present invention will be described with reference to Fig. 1.

Fig. 1 is an enlarged plan view of a joint portion 3 of the straight web-type sheet pile 1 that is installed in an upright position. As illustrated in Fig. 1, the straight web-type sheet pile 1 includes the joint portion 3, which includes a main-claw portion 3a and a sub-claw portion 3b, and a web portion 5 that connects the joint portion 3 to the

other joint portion 3.

In Fig. 1, g denotes a main-claw height, f_1 denotes a web-portion plate thickness, f_2 denotes a sub-claw thickness, f_3 denotes a main-claw thickness, c denotes a joint opening height, and h denotes an effective height.

The main-claw height g is the claw height in a region where the claw depth in the main-claw portion 3a is at a maximum in the height direction (main-claw deepest part).

The sub-claw thickness f_2 is the thickness in a region where the claw depth in the sub-claw portion 3b is at a maximum in the height direction (sub-claw deepest part), more specifically, the distance between the sub-claw deepest part and the outermost edge of the sub-claw portion.

The main-claw thickness f_3 is the thickness at the main-claw deepest part of the main-claw portion 3a, more specifically, the distance between the main-claw deepest part and a point at which a line extending from the main-claw deepest part orthogonally to the axis of straight web-type sheet pile 1 crosses the outer edge of the main-claw.
[0020]

In the straight web-type sheet pile 1 according to the present embodiment, the main-claw height g of the joint is 6.0 mm or more, the ratio f_3/f_1 of the main-claw thickness f_3 to the web-portion plate thickness f_1 is 0.82 or more, the ratio f_2/f_1 of the sub-claw thickness f_2 to the web-

portion plate thickness f_1 is 1.16 or more, the ratio c/f_3 of the joint opening height c to the main-claw thickness f_3 is 1.25 or more, and the effective height h is 40 mm or less or 37 mm or less.

The shape of the straight web-type sheet pile 1 is determined on the basis of the following Findings (i) to (vi) obtained as a result of the studies described below.

The studies were carried out with regard to requirements for preventing concrete aggregates from being caught and requirements for maintaining the strength of joint fitting portions of the straight web-type sheet piles 1.

[0021]

The findings of the studies on the requirements for preventing concrete aggregates from being caught will be described with reference to Fig. 2.

Fig. 2 illustrates a portion of a reinforcing structure 7 for an existing structural object 53 (hereinafter referred to simply as a "reinforcing structure 7"). The reinforcing structure 7 includes straight web-type sheet piles 1. In Fig. 2, components similar to those in Fig. 8 are denoted by the same reference numerals, and the description thereof is omitted. In the reinforcing structure 7 illustrated in Fig. 2, it is assumed that the near distance B is 200 mm or less. The cover thickness k , the main reinforcement diameter d_1 ,

and the hoop bar diameter d_2 are the same as those in Fig. 8. The reinforcing structure 7 will be described in detail in a second embodiment.

[0022]

The inventors have studied the shape of the joints for enabling the space S to be as large as (or larger than) the maximum concrete aggregate diameter to prevent the concrete aggregates from being caught. As a result, it has been found that the overall height ($h \times 2$) of the sheet piles is preferably 81 mm ($= B - k - d_1 - d_2 - S = 200 - 70 - 16 - 13 - 20$) or less, that is, that the effective height h of the joint portions is preferably 40 mm or less (Finding (i)).

[0023]

According to Specifications for Highway Bridges, for example, the space may be required to be greater than or equal to four thirds of the maximum concrete aggregate diameter. When the maximum aggregate diameter is 20 mm, a space of $20 \times 4/3 = 26$ mm or more may be required. In this case, the effective height h of the joint portions is preferably 37 mm or less (Finding (ii)).

[0024]

Among the conventional straight web-type sheet piles, the FL-type includes joint portions having the smallest effective height h , which is $h = 44.5$ mm. However, according to Findings (i) and (ii), the effective height h

of the joint portions is required to be smaller, that is, 40 mm or less, and 37 mm or less in some cases. From the viewpoint of ensuring sufficient strength of the joint fitting portions, the effective height h is preferably more than 30 mm.

[0025]

The findings of the studies on the requirements for maintaining the strength of the joint fitting portions of the straight web-type sheet piles 1 will now be described.

It is most practical that the tensile strength of the joint fitting portions of the straight web-type sheet piles 1 be set so as to be close to the tensile strength of the web portions 5 of the straight web-type sheet piles 1.

The inventors have found, in the studies based on experiments and analyses, that the main-claw height g , the sub-claw thickness f_2 , the main-claw thickness f_3 , and the web-portion plate thickness f_1 of the joints mainly affect the tensile strength of the joint fitting portions of the straight web-type sheet piles 1. Further, from the viewpoint of workability in fitting the joint portions together, the joint opening height c is important. This will be described in detail with reference to Fig. 3.

[0026]

Fig. 3 illustrates a load transmission mechanism of a joint fitting portion with a contour display of the stress

distribution. In Fig. 3, components similar to those in Fig. 1 are denoted by the same reference numerals. In Fig. 3, the regions in lighter colors are basically the regions where the stress is higher.

[0027]

(Load Transmission Mechanism of Joint Fitting Portion)

When the tensile strength of the joint fitting portion is below the tensile strength of the web portions 5, a weak portion is generated and the stability of the winding-up structure (cell structure) formed by the straight web-type sheet piles 1 is reduced.

On the other hand, it is useless to set the tensile strength of the joint fitting portion excessively higher than the tensile strength of the web portions 5.

In consideration of the above-described facts, according to JIS SY295, which is the standards for straight web-type sheet piles, the standard tensile strength of a joint fitting portion (per 1 m) is set to 3.92 MN/m.

It is necessary that the tensile strength of the joint fitting portion be no less than the above-mentioned standard value.

[0028]

Referring to Fig. 3, when the tensile yield load of the web portions 5 (per unit depth, that is, per unit length of the sheet piles) is T_1 , T_1 can be expressed as follows:

$$T1 = f1 \times \sigma_y$$

where T1 is the tensile yield load of the web portions 5 (per unit depth);

f1 is the web-portion plate thickness; and

σ_y is the material strength of the straight web-type sheet piles 1 (tensile yield stress).

[0029]

As illustrated in Fig. 3, the joint fitting portion has two contact points P2 and P3, and the tensile load applied to each web portion 5 is allocated to two component forces applied to the sub-claw portion 3b and the main-claw portion 3a. This can be expressed as follows:

$$T1 = T2 + T3$$

where T2 is a tensile-load component force applied to the sub-claw (per unit depth); and

T3 is a tensile-load component force applied to the main-claw (per unit depth).

[0030]

The yield strength of each component force in the above equation can be expressed as follows:

$$T2 \times X2 = (f2)^2 / 6 \times \sigma_y$$

$$T3 \times X3 = (f3)^2 / 6 \times \sigma_y$$

where X2 is the distance from the central axis of the web portion to the point of application of the sub-claw component force;

X3 is the distance from the central axis of the web portion to the (average) point of application of the main-claw component force;

f2 is the sub-claw thickness; and

f3 is the main-claw thickness.

[0031]

As is clear from Fig. 3, the distance X3 from the central axis of the web portion to the (average) point of application of the main-claw component force is less than the distance X2 from the central axis of the web portion to the (average) point of application of the sub-claw component force. This means that, compared to the component force T2 of the sub-claw, the component force T3 of the main-claw generates a couple of forces of a smaller magnitude and enables the tensile load to be transmitted more efficiently.

Accordingly, from the viewpoint of making the cross sectional shape (thickness of the joint portion) smaller, it is effective to increase the proportion of T3 in the component forces of T1 (T2 and T3).

T3 is determined by the load transmission performance at the contact point P3; accordingly, to increase the ratio of T3, it is necessary to increase the load transmission performance at the contact point P3. The load transmission performance is determined by the bearing capacity $F (= T3)$ of the steel material at the contact point, and the bearing

capacity F can be expressed as the product of the effective contact height and the material strength of the steel material (see the equation given below). The effective contact height can be determined by multiplying the main-claw height g by the sine of the contact angle θ ($\sin\theta$) (see the equation given below). Therefore, to increase the load transmission performance at the contact point P3, it is important that the main-claw height g of the joint be sufficiently high.

$$F = g \times \sigma_y \times \sin\theta$$

where θ is the angle between the central axis of the web portion and the tangent line L at the contact point P3 (contact angle).

[0032]

When the web-portion plate thickness f_1 is 9.5 mm, which is the standard value for the FL-type, and the minimum contact angle θ is 50° (as the load increases, the deformation of the joint increases and the contact angle θ decreases), T_1 and F ($= T_3$) can be expressed as follows based on the above equations:

$$T_1 = f_1 \times \sigma_y = 9.5 \times \sigma_y$$

$$F = g \times \sigma_y \times \sin 50^\circ = 0.77 \times g \times \sigma_y$$

The relationship of the above equations shows that, to transmit the load that is at least as large as about half of T_1 at the contact point P3, the main-claw height g needs to

be equal to or greater than about 6.0 mm (Finding (iii)). On the other hand, the main-claw height g is necessary to be about 12.0 mm in order for all of T_1 to be transmitted at the contact point P_3 .

[0033]

To ensure sufficient load transmission performance (strength) of the main-claw, the main-claw thickness f_3 probably needs to be greater than the web-portion plate thickness f_1 by a predetermined thickness or more.

It has been found in the studies based on analyses and the like, that f_3/f_1 needs to be 0.82 or more to avoid breakage of the main-claw portion in the early stage and prevent the joint fitting strength from becoming lower than or equal to a predetermined value (Finding (iv)).

[0034]

When the ratio of T_3 is excessively increased, the structure of the joint fitting portion changes from the two-point contact structure and becomes close to a one-point contact structure, which is unstable. Therefore, it is necessary to ensure balanced load transmission performance (strength) also by the sub-claw. In other words, the sub-claw thickness f_2 probably needs to be greater than the web-portion plate thickness f_1 by a predetermined value or more.

It has been found in the studies based on analyses, for example, that f_2/f_1 needs to be 1.16 or more to avoid

ductile bending deformation of the sub-claw portion in the early stage and prevent the joint fitting strength from becoming lower than or equal to a predetermined value (Finding (v)).

[0035]

In consideration of the workability in fitting the joints together, it is necessary for the joint opening height c to have an appropriate allowance relative to the main-claw thickness f_3 .

It has been found in the studies based on analyses and the like, that c/f_3 needs to be 1.25 or more to prevent an increase in the joint fitting resistance due to, for example, elastic deformation of the sheet piles during construction (Finding (vi)). On the other hand, it is to be noted that when the joint opening height c is greater than the sum of the main-claw thickness f_3 and the main-claw height g , the risk that the joints will become disengaged from each other increases.

[0036]

In the present embodiment, the main-claw height g is 6.0 mm or more, the ratio f_3/f_1 of the main-claw thickness f_3 to the web-portion plate thickness f_1 is 0.82 or more, the ratio f_2/f_1 of the sub-claw thickness f_2 to the web-portion plate thickness f_1 is 1.16 or more, the ratio c/f_3 of the joint opening height c to the main-claw thickness f_3

is 1.25 or more, and the effective height h is 40 mm or less or 37 mm or less. Thereby, the shape of the joints can be made smaller while the strength and workability of the joint fitting portion are maintained. This leads to an increase in the economic efficiency. The strength of the joint fitting portion is confirmed in Example 1.

[0037]

Since the effective height h of the joint portions is 40 mm or less, as illustrated in Fig. 2, the reinforcing structure 7 including the straight web-type sheet piles 1 may have a space S from the straight web-type sheet piles 1 to the bars that is greater than that according to the related art. Therefore, the filling concrete can be poured into the space S without causing the concrete aggregates to be caught, and voids (weak portions) are not generated.

The upper limits of f_3/f_1 , f_2/f_1 , and c/f_3 are determined by the effective height h , but do not exceed the values of the existing type, which are $f_3/f_1 = 0.95$, $f_2/f_1 = 1.36$, and $c/f_3 = 1.57$.

The reinforcing structure 7 will be described in the second embodiment.

[0038]

[Second Embodiment]

As shown in Fig. 2, the reinforcing structure 7 for the existing structural object 53 according to the second

embodiment is formed by arranging the straight web-type sheet piles 1 according to the first embodiment around the existing structural object 53 such that the near distance B of the existing structural object 53 and the sheet pile wall is 200 mm or less, placing the reinforcing bars 61 in the gap between the existing structural object 53 and the straight web-type sheet piles 1, and filling the gap with the filling concrete 59 that serves as a solidification material. The filling concrete 59 is not illustrated in Fig. 2.

An example of the reinforcing structure including the straight web-type sheet piles 1 will be described in Example 2.

[0039]

As described above, the reinforcing structure 7 includes the straight web-type sheet piles 1 according to the first embodiment, so that the workability in the filling concrete pouring process can be increased. In addition, since the tensile bearing force of the joint fitting portions is not reduced, the peripheral restraint effect of the sheet pile wall is not reduced and sufficient structural reliability can be obtained.

[0040]

The reinforcing structure 7 for the existing structural object 53 can be established by a reinforcing method

including the following steps.

Specifically, the reinforcing method for the existing structural object 53 includes a step of arranging the straight web-type sheet piles 1 around the existing structural object 53; a step of removing dirt from the space between the existing structural object 53 and the straight web-type sheet piles 1; and a step of placing the reinforcing bars 61 in the gap between the existing structural object 53 and the straight web-type sheet piles 1 and filling the gap with the filling concrete 59 that serves as a solidification material.

Example 1

[0041]

The results of experiments carried out to confirm the strength of the joint fitting portions of the straight web-type sheet piles 1 according to the present invention will now be described.

The experiments were performed to determine, by the FEM structural analysis, the tensile bearing force of the joint fitting portions of the existing FL-type sheet piles and FL-type sheet piles in which cross-sectional shapes were changed (including sheet piles according to the present invention).

[0042]

The structural analysis is analogy to a joint tensile

test for the straight web-type sheet piles 1 (JIS A 5528, hot rolling steel sheet piles). Simulation was performed by a two-dimensional elasto-plastic analysis (plane strain condition model) for a period in which the fitted joints of the straight web-type sheet piles 1 were pulled in a web longitudinal direction until the joints were separated from each other or the calculation stopped converging. Fig. 4 illustrates an analysis model. In Fig. 4, components similar to those in Fig. 1 are denoted by the same reference numerals.

The material strength properties were of a bilinear type with a Young's modulus of $205,000 \text{ N/mm}^2$. The material yield strength was 295 N/mm^2 , and the material tensile strength was 450 N/mm^2 (specified lower limit of steel sheet pile material SY295).

[0043]

The cross sectional shape was changed by using the effective height h of the joint portions, the main-claw height g of the joints, the web-portion plate thickness f_1 , the sub-claw thickness f_2 , the main-claw thickness f_3 , and the joint opening height c as the analysis parameters.

In Invention Examples 1 to 4, the above-mentioned analysis parameters were set within the ranges of the present invention. More specifically, the main-claw height g of the joints was 6.0 mm or more, the ratio f_3/f_1 of the

main-claw thickness f_3 to the web-portion plate thickness f_1 was 0.82 or more, the ratio f_2/f_1 of the sub-claw thickness f_2 to the web-portion plate thickness f_1 was 1.16 or more, the ratio c/f_3 of the joint opening height c to the main-claw thickness f_3 was 1.25 or more, and the effective height h was 40 mm or less.

[0044]

For comparison, in Comparative Examples 1 to 3, one of the above-mentioned analysis parameters was set so as to be outside the range of the present invention. More specifically, in Comparative Example 1, the main-claw height g was 5.5 mm (not 6.0 mm or more); in Comparative Example 2, f_3/f_1 was 0.74 (not 0.82 or more); in Comparative Example 3, f_2/f_1 was 1.11 (not 1.16 or more).

The analysis parameters and the analysis results are shown in Table 1.

[0045]

[Table 1]

Case Name	Effective Height h	Main-Claw Height g	Web-Portion Plate Thickness f1	Main-Claw Thickness f3 (f3/f1)	Sub-Claw Thickness f2 (f2/f1)	Joint Opening Height c (c/f3)	Joint Fitting Tensile Bearing Force
Existing FL-Type	44.5 mm	7.9 mm	9.5 mm	9.0 mm (0.95)	12.9 mm (1.36)	14.1 mm (1.57)	4.80 MN/m
Invention Example 1	40.0 mm	7.5 mm	9.5 mm	8.5 mm (0.89)	12.2 mm (1.28)	12.0 mm (1.41)	4.75 MN/m
Invention Example 2	37.0 mm	6.5 mm	9.5 mm	8.3 mm (0.87)	11.8 mm (1.24)	11.4 mm (1.37)	4.55 MN/m
Invention Example 3	32.0 mm	6.0 mm	9.5 mm	7.8 mm (0.82)	11.0 mm (1.16)	10.5 mm (1.35)	4.02 MN/m
Invention Example 4	31.0 mm	6.0 mm	9.5 mm	7.8 mm (0.82)	11.0 mm (1.16)	9.8 mm (1.25)	3.98 MN/m
Comparative Example 1	30.0 mm	<u>5.5 mm</u>	9.5 mm	7.8 mm (0.82)	11.0 mm (1.16)	9.8 mm (1.25)	<u>3.65 MN/m</u>
Comparative Example 2	30.0 mm	6.0 mm	9.5 mm	<u>7.0 mm</u> (0.74)	11.0 mm (1.16)	9.8 mm (1.40)	<u>3.56 MN/m</u>
Comparative Example 3	30.0 mm	6.0 mm	9.5 mm	7.8 mm (0.82)	<u>10.5 mm</u> (1.11)	9.8 mm (1.25)	<u>3.43 MN/m</u>
Comparative Example 7	36.0 mm	6.5 mm	9.5 mm	8.5 mm (0.89)	<u>10.5 mm</u> (1.11)	10.7 mm (1.26)	<u>3.53 MN/m</u>
Comparative Example 8	32.0 mm	6.5 mm	9.5 mm	<u>7.0 mm</u> (0.74)	12.2 mm (1.28)	9.8 mm (1.40)	<u>3.59 MN/m</u>

[0046]

Table 1 shows that, in Invention Example 1, the joint-fitting-portion tensile bearing force is about as high as that of the existing FL-type.

Either in Invention Examples 2, 3, and 4, although the joint-fitting-portion tensile bearing force is somewhat lower than that of the existing FL-type, the strength is above the standard tensile strength of the joint fitting portions, which is 3.92 MN/m.

In Comparative Examples 1 to 3 and Comparative Examples 7 and 8, the strength was below the standard tensile

strength.

[0047]

Thus, it was verified that, in the straight web-type sheet piles 1 according to the present invention, although the shape of the joints is small, the strength of the joint fitting portions is higher than the standard tensile strength because the main-claw thickness f_3 , the sub-claw thickness f_2 , and the joint opening height c are set so as to achieve balanced load transmission performance (strength).

Example 2

[0048]

The relationship between the effective height h of the joint portions and the near distance B in the reinforcing structure 7 according to the present invention is summarized and will be described with reference to Fig. 2.

In this example, the cover thickness k was set to 70 mm, the main reinforcement diameter d_1 was set to 16 mm, and the hoop bar diameter d_2 was set to 13 mm.

Assuming that filling concrete having a maximum concrete aggregate diameter of 20 mm was used, to avoid clogging of concrete aggregates, the space S from the straight web-type sheet piles 1 to the bars was set to 20 mm.

The relationship between the effective height h of the joint portions and the near distance B under the above conditions is summarized and shown in Table 2.

[0049]

[Table 2]

Case Name	Effective Height h (mm)	Cover Thickness k (mm)	Main Reinforcement Diameter d1 (mm)	Hoop Bar Diameter d2 (mm)	Space S from Sheet Piles to Bars (mm, Maximum Aggregate Diameter)	Minimum Near Distance B
Existing FL-Type	44.5	70	16	13	20	208
Comparative Example 4	41	70	16	13	20	201
Invention Example 5	40	70	16	13	20	199
Invention Example 6	37	70	16	13	20	193
Invention Example 7	35	70	16	13	20	189
Invention Example 8	33	70	16	13	20	185

[0050]

Table 2 shows that, in Invention Examples 5 to 8 in which the effective height h was 40 mm or less, the near distance B was 200 mm or less.

[0051]

Next, assuming that filling concrete having a maximum concrete aggregate diameter of 20 mm was used and the space was required to be four thirds of the maximum concrete aggregate diameter or more, a case in which the space S was set to 26 mm will be described.

With regard to other conditions, as in the cases shown in Table 2, the cover thickness k was set to 70 mm, the main reinforcement diameter d1 was set to 16 mm, and the hoop bar diameter d2 was set to 13 mm.

The relationship between the effective height h of the joint portions and the near distance B under the above conditions is summarized and shown in Table 3.

[0052]

[Table 3]

Case Name	Effective Height h (mm)	Cover Thickness k (mm)	Main Reinforcement Diameter d_1 (mm)	Hoop Bar Diameter d_2 (mm)	Space S from Sheet Piles to Bars (mm, Maximum Aggregate Diameter)	Minimum Near Distance B
Existing FL Type	44.5	70	16	13	26	214
Comparative Example 5	41	70	16	13	26	207
Comparative Example 6	40	70	16	13	26	205
Invention Example 9	37	70	16	13	26	199
Invention Example 10	35	70	16	13	26	195
Invention Example 11	33	70	16	13	26	191

[0053]

Table 3 shows that, in Invention Examples 9 to 11 in which the effective height h was 37 mm or less, the near distance B was 200 mm or less in this case.

Reference Signs List

[0054]

- 1 straight web-type sheet pile
- 3 joint portion
- 3a main-claw portion
- 3b sub-claw portion
- 5 web portion

7 reinforcing structure

50 straight web-type sheet pile (related art)

51 joint portion

51a main-claw portion

51b sub-claw portion

52 web portion

53 existing structural object (pier)

55 footing

57 ground surface

59 filling concrete

61 reinforcing bar

61a main reinforcement

61b hoop bar

CLAIMS

[Claim 1]

A straight web-type sheet pile including joint portions at both ends, each joint portion including a main-claw and a sub-claw,

wherein a main-claw height g of a joint is 6.0 mm or more, a ratio $f3/f1$ of a main-claw thickness $f3$ to a web-portion plate thickness $f1$ is 0.82 or more, a ratio $f2/f1$ of a sub-claw thickness $f2$ to the web-portion plate thickness $f1$ is 1.16 or more, a ratio $c/f3$ of a joint opening height c to the main-claw thickness $f3$ is 1.25 or more, and a distance h (effective height) from a center position of a web portion to an outermost edge of a sub-claw portion is 40 mm or less.

[Claim 2]

A straight web-type sheet pile including joint portions at both ends, each joint portion including a main-claw and a sub-claw,

wherein a main-claw height g of a joint is 6.0 mm or more, a ratio $f3/f1$ of a main-claw thickness $f3$ to a web-portion plate thickness $f1$ is 0.82 or more, a ratio $f2/f1$ of a sub-claw thickness $f2$ to the web-portion plate thickness $f1$ is 1.16 or more, a ratio $c/f3$ of a joint opening height c to the main-claw thickness $f3$ is 1.25 or more, and a distance h (effective height) from a center

position of a web portion to an outermost edge of a sub-claw portion is 37 mm or less.

[Claim 3]

A structure for reinforcing a structural object by arranging straight web-type sheet piles around the structural object,

wherein the straight web-type sheet piles, each according to Claim 1 or 2, are arranged around the structural object such that a near distance of the structural object and a wall of the straight web-type sheet piles is 200 mm or less, a reinforcing bar is disposed in a gap between the structural object and the straight web-type sheet piles, and the gap is filled with a solidification material.

[Claim 4]

A method for reinforcing a structural object by arranging straight web-type sheet piles around the structural object, the method comprising:

a step of arranging the straight web-type sheet piles, each according to Claim 1 or 2, around the structural object such that a near distance of the structural object and a wall of the straight web-type sheet piles is 200 mm or less;

a step of removing dirt existing between the structural object and the straight web-type sheet piles; and

a step of placing a reinforcing bar in a gap between

the structural object and the straight web-type sheet piles and filling the gap with a solidification material.