

SPECIFICATION

TITLE OF THE INVENTION:

CONNECTED WALL STRUCTURE CONSISTING OF STEEL PIPE SHEET PILES
AND STEEL SHEET PILE, AND METHOD OF CONSTRUCTING SAME

TECHNICAL FIELD

[0001]

This invention relates to a connected wall structure which consists of steel pipe sheet piles and a steel sheet pile and is useful in applications to sheathing walls such as revetments and retaining walls, and also to a method of constructing the same.

BACKGROUND ARTS

[0002]

Such forces that are caused by earth pressure and/or hydraulic pressure to bend sheathing members work on sheathing walls such as revetments and retaining walls, and as a result, the sheathing walls undergo bending deformation in such a direction that the above forces are at work. Thus, it has been feared that the sheathing walls could lead to sliding and/or falling as the case might be.

[0003]

In designing the sheathing walls, it has been suggested that because of the need for penetration up to a sufficient depth to ensure that the amount of wall deformation would be limited to—not more than its specified allowance for a structure in order to prevent the above sliding and/or falling, wall members having sufficient section rigidity could be applied, and from the economical point of view, determination of suitable members, cross section and length could be made within the range which meets these requirements. It has been suggested also that because of the need for the greater length of wall member penetration into the ground depending on wall height, ground conditions and seismic coefficient at the time of earthquake, it would be important that the wall

members are of quite excellently constructable members.

[0004]

Generally available sheathing walls include types of (a) self-supported structure, (b) counterforted structure and (c) strutted structure as shown in FIG. 6, each of which being used in its proper way depending on applications thereof. Particularly, the self-supported structure as shown in FIG. 6(a) has been applied to cases where because of limitations on the rear space for the sheathing wall construction site, there would be not provided any sufficiently ensured space therefor.

[0005]

For the self-supported structure, hat-shaped steel sheet piles 2 as shown in FIG. 7 have been employed, for instance. Meanwhile, in applications to revetments and/or retaining walls of greater wall height, or in cases where the deformation acceptable to the wall is so small that there will be the need for sufficient wall rigidity, use has been frequently made of steel pipe sheet piles 1 excellent in section rigidity, each of which being such that a connecting member 3 adapted to be fitted is mounted on a steel pipe as shown in FIG. 8.

[0006]

The steel sheet piles and the steel pipe sheet piles are excellent also in the property of being allowed for penetration into the ground, and there are various types of construction methods thereof according to the construction site needs as well. It has been thus realized that these sheet piles are of excellently constructable wall members, considering that a construction method such as vibro-hammer method is adaptable to cases where a demand for urgent constructions is made, or otherwise, a hydraulic press-in method which allows for low-vibration and low-noise constructions is applicable to constructions in urban areas where there are private houses and the like in the neighborhood of the

construction site.

[0007]

Further, as for the prior arts, the non-Patent document 1 (i.e., Catalogue in Arcelor Mittal Co., Ltd.) describes one technology which is such that a hooked sectional-shaped joint member 33 mounted on a steel pipe sheet pile 1 and a joint 32c of a Z-shaped steel sheet pile (which is such that two pieces of Z-shaped steel sheet piles 32 are connected together into the substantially same form as a steel sheet pile shown in FIG. 7) are fitted together to form a wall structure, as shown in FIG. 9.

[0008]

Moreover, the Patent document 1 describes, as for breakwaters each constructed using steel pipe sheet piles and a straight-shaped sheet pile, one breakwater which is such that a straight-shaped sheet pile is so interposed between steel pipe sheet piles installed with a predetermined gap therebetween as to range from the bottom ends of the above steel pipe sheet piles to a position which is level with or slightly above the sea-bottom ground surface.

[0009]

In addition to the above, the Patent document 2 describes, as for connected structures of deformed wall-structure constituent members, one arrangement which is such that a cylindrical joint having a slit is mounted to a wall surface in such an intersection position as to interconnect sheet pile walls which are formed such that joints of more than one steel sheet pile are fitted together, thereby allowing the end of the steel sheet pile of the sheet pile wall on the other side to be fitted thereinto.

LITERATURES ON THE PRIOR ARTS

PATENT DOCUMENTS

[0010]

Patent document 1: Japanese Laid-open Patent Publication No. Hei

02-213508

Patent document 2: Japanese Patent Publication No. 4231429

NON-PATENT DOCUMENT

[0011]

Non-Patent document: "Steel Sheet Piling General Catalogue 2008"
Arcelor Mittal, 2008, P.34

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0012]

In the wall structure described in the above non-Patent document 1, it has been generally suggested that the steel pipe sheet piles are first installed by being driven with a predetermined gap therebetween, and afterwards, the steel sheet pile is installed by being driven in the form which is such that the steel pipe sheet piles will be connected together by the steel sheet pile.

[0013]

However, because of narrow spaces each between connecting sections, it has been difficult to perform fitting the connecting sections at the time of construction. Thus, for such works, there has been the need to separately install a template for positioning in order to effect installation by driving and so on under the strict management conditions. For that reason, problems such as the increase in construction cost and much time and/or labor for the works in the construction site have arisen.

[0014]

Further, it has been feared that elongation or shrinkage due to driving at the time of construction could not cause the members to be fitted according to the circumstances, and thus would lead to not only the substantial increase in construction cost but also the prolongation of construction term, such as the need to reinstall the already installed members after having been once drawn out.

[0015]

Meanwhile, it has been considered also that a steel pipe member and a steel sheet pile could be installed alternately by being driven in a wall direction. However, this is of irrational instance because of much construction time and/or labor, together with the substantial increase in construction cost, such as much time and/or labor for installation by driving due to the narrow space between the connecting sections and the need to replace driving machines every member.

[0016]

Moreover, even with considerations of cut-off properties, there has been not provided any space that should be sufficiently charged with a cut-off material, and thus, it has been difficult to satisfactorily fulfill a cut-off function as of a wall.

[0017]

Even for the invention on the structure adapted to connect the steel pipe sheet piles and the straight-shaped sheet pile as described in the Patent document 1, there have been also the same problems as the invention described in the non-Patent document 1.

[0018]

An object of the present invention is to solve the problems in the above prior arts, more specifically, to provide, as to a connected wall structure consisting of steel pipe sheet piles and a steel sheet pile and formed such that the steel pipe sheet piles installed by being driven with a gap therebetween are connected together by the steel sheet pile, a connected wall structure consisting of steel pipe sheet piles and a steel sheet pile and a method of constructing the same, more specifically, a connected wall structure which is such that there is formed a connected structure wherein a certain degree of construction errors is made allowable, with the result that there is provided a rational

connected structure which is excellent in constructability and allows for the reduction in construction cost.

MEANS FOR SOLVING THE PROBLEMS

[0019]

The invention according to Claim 1 of the present application relates to a connected wall structure consisting of steel pipe sheet piles and a steel sheet pile and formed such that the steel pipe sheet piles installed by being driven with a gap therebetween are connected together by the steel sheet pile, wherein there are provided, on the sides of the above steel pipe sheet piles, connecting members having slits continuously extending in the longitudinal direction, the ends of the above steel sheet pile are so fitted into the slits from the longitudinal direction that the above connecting members are connected to the ends of the steel sheet pile, and play for absorbing construction errors between the above steel pipe sheet piles are provided in connecting sections for the connecting members and the ends of the steel sheet pile.

[0020]

The present invention is provided in principle on the supposition that the steel sheet pile is installed by being driven between the steel pipe sheet piles previously installed by being driven with a predetermined gap therebetween in the form which is such that these steel pipe sheet piles will be connected together by the steel sheet pile later. In that case, even when the driving apparatus or method for the steel pipe sheet piles is different from the driving apparatus or method for the steel sheet pile, continuous construction will be provided without the need for changing driving apparatuses or methods on each occasion.

[0021]

Besides, for fitting the ends of the steel sheet pile into the slits of the connecting members mounted on the steel pipe sheet piles, there is provided the predetermined play, and consequently,

the installation position of the steel sheet pile is adjustable in the wall direction to provide smooth construction even if a certain degree of construction errors has occurred in the gap between the steel pipe sheet piles previously installed by being driven.

[0022]

That is, the invention described in the non-Patent document 1 involves the need for highly accurate construction by use of the special template, and thus meets with the difficulty of construction, or in the worst case, the failure in construction. In contrast with the above, the present invention eliminates the need for such excessive construction management, and thus provides improved constructability, together with the shorter construction term and the reduced construction cost.

[0023]

The present invention as defined in Claim 2 is characterized in that in the connected wall structure consisting of the steel pipe sheet piles and the steel sheet pile according to Claim 1, the inside of the above connecting members is charged with a cut-off material.

[0024]

This applies to cases where a cut-off function is required for the wall structure. Thus, the spaces sufficient to be charged with the cut-off material are ensured, together with the play, in connecting sections for the connecting members and the ends of the steel sheet pile, and consequently, the cut-off properties will be given to the wall structure.

[0025]

The present invention as defined in Claim 3 is characterized in that in the connected wall structure consisting of the steel pipe sheet piles and the steel sheet pile according to Claim 1 or 2, the above steel sheet pile has at the end thereof a stopper

member for preventing the steel sheet pile end from slipping out of the above slit.

[0026]

The stopper member has the great effect of preventing the steel sheet pile end from slipping out of the slit of the connecting member into disengagement therefrom particularly in the course of construction.

[0027]

The present invention as defined in Claim 4 is characterized in that in the connected wall structure consisting of the steel pipe sheet piles and the steel sheet pile according to Claim 1, 2 or 3, the above connecting members are in an approximately circular form, and the relation between an outer diameter Φ (mm) of the connecting member and a sheet thickness t (mm) thereof meets the relation given by the following expression (1).

[Expression 1]

$$70 + 2t \leq \Phi \leq 270 \quad \dots (1)$$

[0028]

The steel sheet pile has usually at the opposite ends thereof hooked sections (or joints), in which case, however, a connecting member of not less than 70 mm in inner diameter (and not less than $(70 + 2t)$ mm as in outer diameter), if employed, is adaptable to be easily fitted with the steel sheet pile without the need for any excessive construction management. Meanwhile, it is feared that use of a connecting member whose diameter is too large will be a hindrance to the constructability, whereas there will be provided satisfactory constructability if a connecting member of not more than 270 mm in diameter is used.

[0029]

The present invention as defined in Claim 5 is characterized in that in the connected wall structure consisting of the steel pipe sheet piles and the steel sheet pile according to Claim 4,

the requirements for the outer diameter Φ (mm) and the sheet thickness t (mm) of the above connecting member and besides, for the following expression (2) are met.

[Expression 2]

$$\Phi \leq \frac{\sigma_y \cdot b}{3 \cdot P_y} \cdot t^2 \quad \dots (2)$$

where Φ represents the outer diameter of the connecting member, t represents the sheet thickness of the connecting member, σ_y represents yielding stress of a steel material used for the connecting member, P_y represents working load which causes the steel sheet pile to lead to yielding, and b represents a longitudinal length of which the connecting member and the steel sheet pile are fitted.

[0030]

If the shape of joint members for a steel wall further meets the above expression (2), use of such joint members is more efficient also from the viewpoint of material cost.

[0031]

The present invention as defined in Claim 6 is characterized in that in the connected wall structure consisting of the steel pipe sheet piles and the steel sheet pile according to Claims 1 to 5, the above steel sheet pile includes steel sheet piles each having flat sections at both ends in a cross section orthogonal to the axial direction.

[0032]

Steel sheet piles such as hat-shaped steel sheet piles as shown in FIG. 7 are typically available as such types of steel sheet piles each having at the opposite ends thereof the flat sections.

[0033]

In this case, there is given the play in the form of the gap corresponding to a flat section width, and consequently, the

construction errors corresponding to the above gap will be allowed.

[0034]

The present invention as defined in Claim 7 is characterized in that in the connected wall structure consisting of the steel pipe sheet piles and the steel sheet pile according to Claims 1 to 6, the above steel sheet pile includes U-shaped steel sheet piles.

[0035]

For U-shaped steel sheet piles each having at the opposite ends thereof no flat section, smooth connecting works will be performed by taking advantage of the play in the connecting sections to displace the U-shaped steel sheet pile in the back and forth directions of the wall structure.

[0036]

The present invention as defined in Claim 8 is characterized in that in the connected wall structure consisting of the steel pipe sheet piles and the steel sheet pile according to Claims 1 to 7, the connecting positions of the above steel sheet pile are made eccentric from the neutral axis of the above steel pipe sheet piles.

[0037]

This is mainly for adjustment of a wall surface position of the wall structure, in which case, the increase in constructability caused by the play is basically the same as that in the cases of Claims 1 to 7.

[0038]

The present invention as defined in Claim 9 relates to a method of constructing the connected wall structure consisting of the steel pipe sheet piles and the steel sheet pile according to any one of Claims 1 to 8, the constructing method comprising the steps of first installing the above steel pipe sheet piles by being driven with a predetermined gap therebetween, and then

installing the above steel sheet pile by being driven in the form which is such that the above steel pipe sheet piles will be connected together by the steel sheet pile later.

EFFECTS OF THE INVENTION

[0039]

According to the present invention, there is provided the arrangement which is such that the play suited to the construction errors is ensured in the connecting sections for the steel pipe sheet piles and the steel sheet pile, and accordingly, the steel pipe sheet piles previously installed by being driven will be connected together as they are even if a certain degree of construction errors has occurred in the gap between the above steel pipe sheet piles, thus allowing the excellently constructable connected wall structure consisting of the steel pipe sheet piles and the steel sheet pile to be formed.

[0040]

Further, in cases where there is the need for the cut-off properties, it is possible to easily meet the above need in such a manner that the spaces having the play are charged with the cut-off material.

[0041]

As for slipping-out of the steel sheet pile ends at the time of construction, there are provided the stopper members at the connecting sections for the steel sheet pile, and consequently, it is possible to prevent the steel sheet pile ends from being disengaged from the connecting sections for the steel pipe sheet piles.

BRIEF DESCRIPTION OF THE DRAWINGS

[0042]

[FIG. 1] FIG. 1 illustrates a structure of connecting sections for steel pipe sheet piles and a sheet steel pipe according to one embodiment of the present invention, with FIGS. 1(a), 1(b)

and 1(c) being plan views respectively showing the same in cases where there is no construction error, where a gap between the steel pipe sheet piles is narrower than planned, and where the gap between the steel pipe sheet piles are wider than planned.

[FIG. 2] FIGS. 2(a) and 2(b) are plan views respectively showing instances of a connecting member mounted on a steel pipe sheet pile.

[FIG. 3] FIGS. 3(a) to 3(d) are plan views respectively showing steel sheet piles each adapted to connect the steel pipe sheet piles together, with FIG. 3(a) being one instance of a hat-shaped steel sheet pile, FIG. 3(b) being one instance of a straight-shaped steel sheet pile, FIG. 3(c) being one instance of a U-shaped steel sheet pile, and FIG. 3(d) being one instance of a Z-shaped steel sheet pile.

[FIG. 4] FIGS. 4(a) to 4(c) are plan views respectively showing instances where a stopper member is mounted to a connecting section for the steel sheet pile end.

[FIG. 5] FIGS. 5(a) and 5(b) are plan views respectively showing structures in cases where the steel sheet pile is made eccentric from the steel pipe sheet piles to provide connection therebetween, with FIG. 5(a) being one instance of a hat-shaped steel sheet pile, and FIG. 5(b) being one instance of a straight-shaped steel sheet pile.

[FIG. 6] FIGS. 6(a) to 6(c) respectively illustrate instances of generally available sheathing structures in the prior arts, with FIG. 6(a) being a sectional view showing a self-supported structure, FIG. 6(b) being a sectional view showing a counterforted structure, and FIG. 6(c) being a perspective view showing a strutted structure.

[FIG. 7] FIG. 7 is a sectional view showing the form of a hat-shaped steel sheet pile in the prior arts.

[FIG. 8] FIG. 8 is a plan view showing one instance of a steel pipe sheet pile wall in the prior arts.

[FIG. 9] FIG. 9 illustrates one instance (or a structure described in Non-Patent document 1) of a connected wall structure consisting of steel pipe sheet piles and a Z-shaped steel sheet pile in the prior arts, with FIG. 9(a) being a plan view showing a connected wall structure, and FIG. 9(b) being a plan view showing the details of a joint portion between the steel pipe sheet pile and the Z-shaped steel sheet pile.

[FIG. 10] FIG. 10 is a view of analysis on stress distribution in connecting sections according to the embodiment shown in FIG. 1.

[FIG. 11] FIG. 11 is a graph showing the results of numerical analysis on the relation between a load P and an outer diameter Φ at the time of the occurrence of deformation or behavior on the assumption that a sheet thickness t of a connecting member is fixed at 11 mm, while the outer diameter Φ thereof takes values of 100 mm, 125 mm, 165.2 mm and 200 mm.

[FIG. 12] FIG. 12 is a view showing the structure of a connecting section according to the present invention in the form of a model resulting from replacement by a cantilever beam.

[FIG. 13] FIG. 13 is a graph showing the relation between the sheet thickness t of the connecting member and the diameter Φ thereof as the results obtained from the analysis by use of the cantilever beam shown in FIG. 12.

[FIG. 14] FIG. 14 is a graph showing the relation between the sheet thickness t and the load P as the results of FEM analysis on a joint section on the assumption that the outer diameter Φ of the connecting member is fixed at 200 mm, while the sheet thickness thereof takes values of 11 mm, 14 mm and 16 mm.

MODE FOR EMBODYING THE INVENTION

[0043]

The present invention will be now described with reference to the attached drawings. It is to be understood that the present

invention is not limited to the following embodiments thereof.

[0044]

FIG. 1 shows a structure of connection sections for steel pipe sheet piles and a steel sheet pile according to one embodiment of the present invention, with FIGS. 1(a), 1(b) and 1(c) being plan views respectively showing the same in cases where there is no construction error, where a gap between the steel pipe sheet piles is narrower than planned, and where the gap between the steel pipe sheet piles is wider than planned.

[0045]

A connected wall structure of the present invention is of a structure which is such that steel pipe sheet piles 1 are connected together by a steel sheet pile 2, in which case, there is provided, in the connecting sections for the steel pipe sheet piles and the steel sheet pile, spaces for absorbing construction errors. More specifically, in order that the steel pipe sheet piles 1 installed by being driven with a gap therebetween will be connected together by the steel sheet pile 2 for the purpose of forming a connected wall structure, there are provided, on the sides of the steel pipe sheet piles 1, connecting members 3 having slits 3a continuously extending in the longitudinal direction. Further, the ends of the steel sheet pile 2 are so fitted into the slits 3a from the longitudinal direction that the connecting members 3 and the ends of the steel sheet pile 2 are connected together. Moreover, predetermined play μ for absorbing construction errors between the steel pipe sheet piles 1 is provided in the connection sections for the connecting members 3 and the ends of the steel sheet pile 2.

[0046]

For the connected wall structure consisting of the steel pipe sheet piles 1 and the steel sheet pile 2, there would be the need to make preliminarily arrangements for construction machines

separately for the steel pipe sheet piles 1 and the steel sheet pile 2, as the case might be, in order to form a wall structure. In that case, with considerations of constructability, it is supposed that there are instances where the steel pipe sheet piles 1 are first installed by being driven, and afterwards, the steel sheet pile 2 is installed by being driven and/or its topsy-turvy proceedings.

[0047]

At this time, it is feared that the narrow spaces in the connecting sections for the steel pipe sheet piles 1 and the steel sheet pile 2 meet with the difficulty of construction, or in the worst case, the damages to the connecting sections and/or the failure in installation by driving by reason that the connecting sections would have impact on each other at the time of installation by driving.

[0048]

Therefore, as shown in FIG. 1, the spaces corresponding to the allowable construction errors between the steel pipe sheet piles 1 are sufficiently ensured in the connecting sections for the steel pipe sheet piles 1 and the steel sheet pile 2, and consequently, it would be possible to form the excellently constructable connected wall structure consisting of the steel pipe sheet piles 1 and the steel sheet pile 2. It is noted that even in this case, it would be possible also to perform the construction while making positioning by use of a template for the purpose of providing highly accurate construction.

[0049]

That is, there is provided, in the connecting sections for the steel pipe sheet piles 1 and the steel sheet pile 2, the spaces sufficient to absorb the construction errors, and consequently, it would be possible that the ends of the steel sheet pile 2 may be easily fitted and installed, even if the steel pipe sheet piles

1 undergo elongation (see FIG. 1(b)) or shrinkage (see FIG. 1(c)) due to driving.

[0050]

The connecting members for the steel pipe sheet piles 1 are not particularly limited, and thus may be of a type which is such that spaces sufficient to surely provide the constructability is ensured, such as members 3 (see FIG. 2(a)) each consisting of a steel pipe having a slit 3a and another type of members (see FIG. 2(b)) each consisting of angles 43 which are so combined together that there is formed a slit 43 therebetween, as shown in FIG. 2.

[0051]

Further, the steel sheet pile is not particularly limited in shape, and thus may be of a type adaptable to be fitted into the connecting members of the steel pipe sheet piles 1, such as hat-shaped steel sheet piles 2 (see FIG. 3(a)), straight-shaped steel sheet piles 12 (see FIG. 3(b)), U-shaped steel sheet piles 22 (see FIG. 3(c)) and Z-shaped steel sheet piles 32 (see FIG. 3(d)).

[0052]

Among the above steel sheet piles, the hat-shaped steel sheet piles 2 whose arm sections at the sides of joint sections 2b, 2c have flat sections (or flat parts 2a) are not only more easily adaptable to provide setting of the play μ with respect to the elongation or shrinkage due to driving at the time of construction of the steel pipe sheet piles but also more excellent in constructability, as compared with the usually available U-shaped steel sheet piles 22 (see FIG. 3(c)).

[0053]

The preferred form of the connecting members 3 will now be described by taking the structure (so with that in FIG. 3(a)) shown in FIG. 1 as one instance.

[0054]

The connecting member 3 whose diameter is too small, if employed, makes it hard to be fitted into the steel sheet pile 2. It is thus preferable that the connecting member 3 is not less than 70 mm in inner diameter. For a 900-width hat-shaped steel sheet pile, for instance, there are provided at both ends thereof joint sections 2b, 2c of about 50 mm in length, in which case, however, the connecting member 3 of not less than 70 mm in inner diameter, if employed, is adaptable to be fitted easily into the steel sheet pile 2 without the need for any excessive construction management. Meanwhile, it is preferable that the connecting member 3 is not more than 270 mm in outer diameter from the viewpoint of constructability.

[0055]

Yield strength of the wall structure shown in FIG. 1 is determined depending on either yielding of the steel sheet pile 2 or deformation (see FIG. 10) of the connecting member 3. That is, when either the steel sheet pile or the connecting member undergoes yielding or deformation, the other will have some margin in view of strength. Accordingly, it may be considered that the requirement (or the form) under which the yielding and the deformation as described the above occur at the approximately same time are the most efficient requirement. Such requirement will now be described with use of some calculation instances.

[0056]

In FIG. 11, there are shown the results obtained by numerical analysis on the relation between a load P and an outer diameter Φ at the time of the occurrence of deformation or behavior on the assumption that the sheet thickness t of the connecting member 3 is fixed at 11 mm, while the outer diameter Φ thereof takes values of 100 mm, 125 mm, 165.2 mm and 200 mm. In this instance of analysis, a model of bi-linear type was applied, provided that yielding stress of a steel material is as equivalent as $\sigma = 400\text{N/m}^2$

of generally available steel, and that the connecting member 3 and the steel sheet pile 2 are fitted together over the whole length (or 1 mm as of a unit length in view of calculations) in the longitudinal direction (or the direction perpendicular to the plane as far as the direction shown in FIG. 10 is concerned).

[0057]

It is seen from FIG. 11 that the gradient of a straight line is subject to change at points of not more and not less than 125 mm in outer diameter Φ . This gives that the above deformation or behavior at the time when the load P is reached varies depending on whether the outer diameter is not more or not less than 125 mm, more specifically, the steel sheet pile 2 undergoes yielding mainly when $\Phi < 125$ mm, while the connecting member 3 undergoes deformation mainly when $\Phi > 125$ mm.

[0058]

The relation between the outer diameter Φ of the connecting member 3 and the sheet thickness t thereof in a changing point of gradient as shown in FIG. 11 will be next obtained. Suppose here that as for the structure of the connecting section, there is given a model, for simplification, in the form of a cantilever beam (of length L, depth-directional length b and sheet thickness t) having one end on which a load P is applied, as shown in FIG. 12. It is noted that the length L represents, to be exact, a length ranging from a portion where the connecting member 3 and the steel pipe body of the steel pipe sheet pile 1 are fixed together to a portion where the load will work on the slit 3a of the connecting member 3, in which case, examination was made, provided that the length L is equal with the outer diameter of the connecting member 3, for simplification.

[0059]

In this type of model, bending moment M which will be created at the fixed end of the beam, cross section rigidity I of the beam

and stress σ which will be created in the beam are respectively expressed by the following expressions (a) to (c).

[Expression 3]

$$M = P \cdot L \quad \dots (a)$$

[Expression 4]

$$I = \frac{b \cdot t^3}{12} \quad \dots (b)$$

[Expression 5]

$$\sigma = \frac{M}{I} \cdot y = \frac{P \cdot L}{\frac{b \cdot t^3}{12}} \cdot \frac{1}{2} \cdot t = \frac{6 \cdot P \cdot L}{b \cdot t^2} \quad \dots (c)$$

where b represents a depth-directional length, t represents a sheet thickness of the beam (or the connecting member 3) and y represents a distance ($= t/2$) from the neutral axis to the beam end

[0060]

Suppose here that a working load which causes the sheet pile to lead to yielding is P_y , the working load on the beam on one side will be $P_y/2$. It may be thus considered that the above changing point of gradient is the requirement under which the beam (or the connecting member) and the sheet pile undergo deformation/yielding at the same time, more specifically, the requirement under which the beam stress reaches the yielding stress σ_y at the time when the load $P_y/2$ was at work on the beam. Thus, suppose that the expression (c) is transformed by substitution of these values, this gives:

[Expression 6]

$$L = \frac{\sigma_y \cdot b}{3 \cdot P_y} \cdot t^2 \quad \dots (d)$$

[0061]

Further, with the beam length L replaced by the outer diameter Φ of the connecting member 3 as far as the expression (d) derived from the above cantilever beam model is concerned (that is, the

following expression (2)'), validity on the application of this expression to the structure shown in FIG. 1 will now be verified.
[Expression 7]

$$\Phi = \frac{\sigma_y \cdot b}{3 \cdot P_y} \cdot t^2 \quad \dots (2)'$$

where Φ represents the outer diameter of the connecting member 3, t represents the sheet thickness of the connecting member 3, σ_y represents the yielding stress of the steel material used for the connecting member 3, P_y represents working load which causes the steel sheet pile 2 to lead to yielding, and b represents the longitudinal length of which the connecting member 3 and the steel sheet pile 2 are fitted together.

[0062]

It is seen from FIG. 11 that the working load P_y at the changing point of gradient is $P_y = 0.125$ (kN/mm). Further, suppose that the depth-directional length b is 1 (mm), and the yielding stress σ_y of the steel material used for the connecting member is 400 (N/mm²) which is given on the assumption that the usually available steel material is in use as described the above, substituting these values into the expression (2)' gives the following relation (2)".

[Expression 8]

$$\Phi = \frac{400 \times 1}{3 \times 125} \times t^2 = 1.07 \cdot t^2 \quad \dots (2)''$$

Substitution of $t = 11$ (mm) into the expression (2)'' gives $\Phi \doteq 129.5$ (mm), which agrees well with $\Phi = 125$ mm that is a solution obtained by FEM analysis (see FIG. 13).

[0063]

Moreover, as different verification, FEM analysis was made on the assumption that the outer diameter of the connecting member 3 is fixed at $\Phi = 200$ mm, while the sheet thickness thereof takes values of 11 mm, 14 mm, and 16 mm. The results of the above FEM

analysis are shown in FIG. 14. It is seen from FIG. 14 that the gradient of a straight line is subject to change at points of not more and not less than 14 mm in sheet thickness. Meanwhile, it is seen from the expression (2)" that the sheet thickness t at the time of substitution of $\Phi = 200$ mm is $t \doteq 13.7$ mm, which also agrees well with the changing point of gradient obtained from the FEM analysis.

[0064]

It may be considered that the actual steel pipe sheet pile 1 is subject to a certain degree of variations in diameter and/or slit width or others such as welding at the time of machining and/or installation of the connecting member 3. It is thus preferable that there is provided a structure which is such that the sheet thickness t of the connecting member 3 is equal to or larger than the sheet thickness at the changing point of gradient, that is, a structure which meets the expression (2).

[Expression 9]

$$\Phi \leq \frac{\sigma_y \cdot b}{3 \cdot p_y} \cdot t^2 \quad \dots (2)$$

[0065]

It is noted that the steel sheet pile member does not need to have the same length as the steel pipe sheet pile 1, and thus may be smaller in length than the steel pipe sheet pile 1, in other words, may be of length which is not less than the wall height in order to play a wall role in prevention of outward landslides of earth and sand in the rear.

[0066]

Further, in cases where the cut-off function is desired for the wall structure, some cut-off treatments have been generally taken in such a manner that the connecting sections are charged with a cut-off material. In this case, for the narrow spaces of the connecting sections, it is feared that the connecting sections

are hard to be sufficiently charged with the cut-off material because of the difficulty of charging of the cut-off material therein, resulting in no satisfactory fulfillment of the cut-off function.

[0067]

For that reason, there is provided the connected wall structure which is such that spaces sufficient to be charged with the cut-off material are provided in the connecting sections for the steel pipe sheet piles 1 and the steel sheet pile 2, and consequently, it may be expected that a sufficient cut-off function will be attained, together with the reduced construction cost and less time and/or labor in relation to the cut-off treatments.

[0068]

As for the cut-off treatments, there is one instance where after installation of the wall, the connecting section is excavated using a construction method such as water jetting in order to charge the inside thereof with mortar and/or cut-off material. Accordingly, it is thus preferable that the spaces in the connecting sections for the steel pipe sheet piles and the steel sheet pile will be sized to such an extent that excavation by means of water jetting is executable.

[0069]

The connecting members 3 of the steel pipe sheet piles 1 include, as one instance thereof, connecting members of steel pipe type, each of which being such that a usually available steel pipe having a diameter Φ of 165. 2 mm has an about 30-mm-long slit 3a as shown in FIG. 2(a). Thus, application of such type of connecting members will allow a filling material for cut-off to be fully charged even after connection with the steel sheet pile 2 is made.

[0070]

The sufficiently-sized spaces are provided in the connecting

sections for the steel pipe sheet piles 1 and the steel sheet pile 2, and consequently, the property of installation by driving is increased, together with workability for the cut-off treatments. In this case, however, it is feared that too large spaces, if provided, will cause the connecting sections to be disengaged at the time of installation by driving.

[0071]

In this connection, as shown in FIGS. 4(a) to 4(c), there is provided a stopper member 4 in a joint section 2c (or a hooked section) of the steel sheet pile 2, and consequently, it is possible to prevent disengagement from the connecting sections for the steel pipe sheet piles 1.

[0072]

The stopper member 4 in this case is not particularly limited, and thus may be round steels, deformed steel bars, flat steels and the like, or otherwise, members other than the above are also available. Further, the stopper member 4 does not need to be arranged longitudinally over the whole length of the steel sheet pile 2, and thus may be in dispersed arrangement in order to suppress the machining cost and/or the amount of strain occurring in the steel sheet pile 2 at the time of installation of members.

[0073]

FIG. 5(a) shows one instance where the hat-shaped steel sheet pile 2 is connected to the steel pipe sheet piles in such a manner as to be eccentric therefrom, in which case, the steel sheet pile 2 is so positioned as to be eccentric from the center axis of the steel pipe sheet piles 1 in order to make alignment of the surfaces as of the wall, and consequently, there may be provided the increased constructability in cases where facing panels are installed on the front surface of the wall.

[0074]

Likewise, in FIG. 5(b), there is shown one instance where

the straight-shaped steel sheet pile 12 is connected to the steel pipe sheet piles 1 in such a manner as to be eccentric therefrom.

REPRESENTATIONS OF REFERENCE NUMERALS

[0075]

1 ... Steel pipe sheet pile

2...Steel sheetpile (Hat-shapedsteel sheetpile), 2a...Flat section, 2b, 2c ... Joint section,

3 ... Connecting member, 3a ... Slit

4 ... Stopper member

12 ... Straight-shaped steel sheet pile, 12b ... Joint section

22 ... U-shaped steel sheet pile, 22b ... Joint section

32 ... Z-shaped steel sheet pile, 32b, 32c ... Joint section, 33 ... Joint member

43 ... Angle, 43a ... Slit

u ... Play

CLAIMS

[Claim 1]

In a connected wall structure which consists of steel pipe sheet piles and a steel sheet pile and is formed such that the steel pipe sheet piles installed by being driven with a gap therebetween are connected together by the steel sheet pile, a connected wall structure consisting of steel pipe sheet piles and a steel sheet pile, characterized in that there are provided, on the sides of said steel pipe sheet piles, connecting members having slits continuously extending in the longitudinal direction, the ends of said steel sheet pile are so fitted into said slits from the longitudinal direction that said connecting members and the steel sheet pile ends are connected together, play for absorbing construction errors between said steel pipe sheet piles is provided in the connecting sections for said connecting members and the steel sheet pile ends, said connecting members are in an approximately circular form, the relation between an outer diameter Φ of the connecting member and a sheet thickness t thereof meets the following relation given by the following expression (1) , and the requirements for the outer diameter Φ (mm) and the sheet thickness t (mm) of said connecting member and besides, for the following expression (2) are met.

[Expression 1]

$$70 + 2t \leq \Phi \leq 270 \quad \dots(1)$$

[Expression 2]

$$\Phi \leq \frac{\sigma_y \cdot b}{3 P_y} t^2 \quad \dots(2)$$

where Φ represents the outer diameter of the connecting member, t represents the sheet thickness of the connecting member, σ_y represents yielding stress of a steel material used for the connecting member, P_y represents working load which causes the steel sheet pile to lead to yielding, and b represents a longitudinal

length of which the connecting member and the steel sheet pile are fitted.

[Claim 2]

The connected wall structure consisting of the steel pipe sheet piles and the steel sheet pile according to claim 1, wherein said connecting members are charged with a cut-off material.

[Claim 3]

The connected wall structure consisting of the steel pipe sheet piles and the steel sheet pile according to claim 1 or 2, wherein said steel sheet pile has at the end thereof a stopper member for preventing the steel sheet pile end from slipping out of said slit.

[Claim 4]

The connected wall structure consisting of the steel pipe sheet piles and the steel sheet pile according to any one of claims 1 to 3, wherein said steel sheet piles include steel sheet piles each having flat sections at the opposite ends in the cross section orthogonal to the axial direction.

[Claim 5]

The connected wall structure consisting of the steel pipe sheet piles and the steel sheet pile according to any one of claims 1 to 4, wherein said steel sheet piles include U-shaped steel sheet piles.

[Claim 6]

The connected wall structure consisting of the steel pipe sheet piles and the steel sheet pile according to any one of claims 1 to 5, wherein the connecting positions of said steel sheet pile are made eccentric from the neutral axis of said steel pipe sheet piles.

[Claim 7]

A method of constructing the connected wall structure consisting of the steel pipe sheet piles and the steel sheet pile

according to any one of claims 1 to 6, said method comprising the steps of first installing said steel pipe sheet piles by being driven with a predetermined gap therebetween, and then installing said steel sheet pile by being driven in the form which is such that said steel pipe sheet piles will be connected together by said steel sheet pile later.