

Description

[Title of the Invention]

Z-TYPE STEEL SHEET PILE

[Technical Field]

[0001]

The present invention relates to a Z-type steel sheet pile used in earth retaining structure, river bank protection structure and the like.

In this specification, the Z-type steel sheet pile is a steel sheet pile where a flange is formed on both ends of webs which are arranged obliquely in a contiguous manner with the webs and the whole shape of the steel sheet pile is formed into an approximately Z shape.

[Background Art]

[0002]

As one of indexes of performance of a steel sheet pile wall constructed by joining joints of the steel sheet piles by fitting engagement, the geometrical moment of inertia (I) indicative of rigidity of the wall is named. In general, the larger the geometrical moment of inertia (I), the smaller a deformation amount of a wall body on which a load such as an earth pressure or water pressure acts becomes.

Although the geometrical moment of inertia (I) can be increased by increasing a plate thickness (t) and a height (H)

of a steel sheet pile, it is desirable to decrease a steel weight (W) by making a cross-sectional area (A) as small as possible from a viewpoint of economic efficiency.

[0003]

On the other hand, large-sizing of a steel sheet pile leads to the increase in penetration resistance (R) of the steel sheet pile. The penetration resistance (R) is a main index which influences the workability (penetration property) of a steel sheet pile and hence, it is desirable to set the penetration resistance (R) as small as possible. That is, the smaller the penetration resistance, the more a working speed and working efficiency of the steel sheet pile are enhanced.

The penetration resistance (R) of the steel sheet pile is mainly constituted of a support force brought about by ground resistance and joint resistance. Here, the support force brought about by ground resistance (distal end + peripheral surface friction) can also be artificially lowered to some extent by temporarily lowering strength of the ground using an auxiliary method such as a water jet method.

[0004]

On the other hand, the joint resistance is mainly brought about by the friction resistance between joints or between the joint and soil and sands in the joint.

Usually, a gap of several mm or less is formed between the joints. Accordingly, when the steel sheet pile is driven

completely parallel to a precedingly driven steel sheet pile, theoretically, friction is minimally generated between the joints.

However, in an actual driving operation, since the steel sheet pile is not a rigid body, a cross section of the steel sheet pile is gradually deformed and the steel sheet pile is deflected due to the support force generated by the ground resistance. As a result, the joints are brought into contact with each other thus giving rise to a friction therebetween.

Although a method in which a lubricant is applied to joints for decreasing the friction resistance may be available, the lubricant peels off due to a friction generated between the joint and soil or sands so that the friction resistance decreasing effect is limited.

When the joint resistance is generated, the steel sheet pile is inclined leading to an even further increase in friction. That is, a vicious cycle of friction and inclination occurs.

Once such a vicious cycle occurs, it is difficult to correct the cycle and hence, a guide frame is used at the time of driving the steel sheet pile so as to prevent as much as possible the steel sheet pile from being inclined, and when the steel sheet pile falls or is displaced, the steel sheet pile is pulled out and is driven in again.

[0005]

To cope with such falling or displacement of the steel

sheet pile, it may be possible to adopt a method which suppresses the joint resistance by making strict standards for construction control. This method, however, brings about lowering of construction efficiency at the same time.

Further, the cause of the friction resistance being increased due to the deformation of the cross section of the steel sheet pile is not eliminated and hence, there exists a drawback that the vicious cycle cannot be corrected even when the steel sheet pile is pulled out and is again driven in.

[0006]

As described above, with respect to setting of a cross section of a steel sheet pile, it is necessary to study the cross section from a viewpoint of economic efficiency and workability. In this respect, with respect to a method of setting a cross-sectional shape of a hat-type steel sheet pile, studies have been made in the following patent documents 1 to 5, for example.

[0007]

Patent documents 1 and 2 disclose a shape setting method and a hat-type steel sheet pile which allow the steel sheet pile to acquire more excellent cross-sectional performances than conventional U-type steel sheet pile or large-width steel sheet pile by satisfying both a newly -defined relational formula between a flange width (B_f) and an effective width (B) and a newly-defined relational formula between the geometrical

moment of inertia (I), a height (H) and B.

[0008]

On the other hand, patent document 3 discloses a hat-type steel sheet pile which can minimize the penetration resistance (R) by limiting a range of web angle θ in a relational formula of the geometrical moment of inertia (I). Patent document 5 also discloses a hat-type steel sheet pile where I, B and a unit weight (W) are set so as to satisfy a relational formula thus ensuring penetration property.

Further, patent document 4 discloses a hat-type steel sheet pile which can enhance economic efficiency by satisfying both a relational formula between a geometrical moment of inertia I and a unit weight W of a hat-type steel sheet pile which is set to exceed a linear relationship between a unit weight (W) and a geometrical moment of inertia (I) of an existing U-type steel sheet pile and a relational formula between an effective width (B) and a flange width (Bf).

[0009]

All these studies have been made on the premise of the hat-type steel sheet pile where an effective width (B) is set to 700 to 1200 mm, a height (H) is set to approximately 200 to 350 mm, and a geometrical moment of inertia (I) is set to approximately 10,000 to 20,000 cm^4/m .

[Prior Art Document]

[Patent Document]

[0010]

[Patent Document 1] JP-A-2008-069631

[Patent Document 2] Japanese Patent 4069030

[Patent Document 3] Japanese Patent 3488233

[Patent Document 4] Japanese Patent 3458109

[Patent Document 5] JP-A-2005-213895

[Summary of the Invention]

[Task to be Solved by the Invention]

[0011]

In the above-mentioned patent documents 1 to 5, in setting a cross-sectional shape of a hat-type steel sheet pile, either economic efficiency or penetration property (workability) is focused on, and the study has been made by specifying the focused-on matter.

However, these studies are not directed to a method of setting a shape of a steel sheet pile based on a clear concept of optimizing both economic efficiency and workability. So far as inventors of the present invention know, there has been no literature which discloses a Z-type steel sheet pile which can optimize all three of the following: economic efficiency, workability and soundness.

[0012]

To enhance economic efficiency, it is necessary to decrease a steel weight per cross-sectional performance as much as possible, and a method which decreases a plate thickness

while enlarging a cross section is considered. However, it is evident that when a cross section is enlarged, the penetration resistance at the time of the construction is increased. Further, when a plate thickness is decreased, there exists a possibility that damage such as local buckling will occur at the time of construction or at the time of transportation thus giving rise to a drawback concerning the performance of the steel sheet pile.

[0013]

The present invention has been made to overcome such drawbacks, and it is an object of the present invention to provide a Z-type steel sheet pile which can optimize both economic efficiency and workability, and also ensure soundness.

[Means for Solving the Problem]

[0014]

The inventors of the present invention have come up with an idea of defining A/I or W/I which is a value obtained by dividing cross-sectional area per wall width of 1 m (A) or a weight per unit wall area (W) by the geometrical moment of inertia per wall width of 1 m (I) as an economic efficiency index. The smaller the index, the more desirable the economic efficiency becomes. That is, this implies that, to consider a manufacturing cost or the like, the smaller the cross-sectional area (A) or a unit weight (W) necessary for

exhibiting with a certain geometrical moment of inertia (I), the more economical the steel sheet pile becomes.

Here, to show an example, in a conventional III type which is a U-type steel sheet pile having a width of 400 mm, W/I is expressed by a formula where $W/I=150/16,800=8.9\times 10^{-3}$, while in a IIIw type which is a large-width steel sheet pile having a width of 600 mm, W/I is expressed by a formula where $W/I=136/32,400=4.2\times 10^{-3}$. Accordingly, economic efficiency is enhanced twice or more.

[0015]

As described above, provided that the cross-sectional performances (geometrical moments of inertia (I) or section modulus (Z)) of steel sheet pile walls are equal, the smaller the weight per unit wall area (W), the more economical the steel sheet pile wall becomes (the reduction of weight of steel material for same cross-sectional performance). That is, provided that a manufacturing cost per unit weight is equal, the smaller the weight per cross-sectional performance (W/I), the more economical the steel sheet pile becomes.

On the other hand, along with the decrease of the weight per cross-sectional performance (W/I), the cross-sectional size (effective width (B), height (H)) of the steel sheet pile is increased and a sheet thickness (t) of the steel sheet pile is decreased. As a result, a deformation amount of the steel sheet pile at the time of construction is increased and hence,

driving of the steel sheet pile becomes difficult. Accordingly, it is safe to say that the larger W/I, the better the workability becomes, that is, the smaller the penetration resistance (R) becomes.

Accordingly, when W/I ($\cong$ manufacturing cost) is decreased, the penetration resistance (R) ($\cong$ construction cost) is increased. On the other hand, it is thought that when W/I is increased, the penetration resistance (R) is decreased. That is, it is safe to say that W/I and R are in the relationship of antinomy.

Accordingly, taking a balance between W/I which is an economic efficiency index and R which is a workability index is important for optimizing both economic efficiency and workability.

[0016]

The present invention has been made based on such a finding, and has the following constitution specifically.

[0017]

(1) A Z-type steel sheet pile according to the present invention is a Z-type steel sheet pile which includes: a web, flanges which are formed on both edges of the web; and joints which are formed on edge portions of the flanges, wherein the relationship among a geometrical moment of inertia per wall width of 1 m I (cm^4/m), a weight per unit wall area W (kg/m^2), penetration resistance (R) and a web angle θ ($^\circ$) when a steel

sheet pile wall is formed is set so as to satisfy either one of a following group of formulae (A) and a following group of formulae (B).

Group of formulae (A):

$$(W/I) \times R \leq 0.004, \text{ and}$$

$$2.65 \times 10^{-4} \times I + 22 \leq \theta \leq 2.80 \times 10^{-4} \times I + 48 \quad (30,000 \leq I < 80,000)$$

$$2.65 \times 10^{-4} \times I + 22 \leq \theta \leq 70 \quad (80,000 \leq I < 180,000)$$

Group of formulae (B):

$$0.004 < (W/I) \times R \leq 0.006, \text{ and}$$

$$2.80 \times 10^{-4} \times I + 44.6 < \theta \leq 80 \quad (30,000 \leq I < 80,000)$$

$$67 < \theta \leq 80 \quad (80,000 \leq I < 200,000)$$

[0018]

(2) The Z-type steel sheet pile according to the present invention is a Z-type steel sheet pile which includes: a web; flanges which are formed on both edges of the web; and joints which are formed on edge portions of the flanges, wherein the relationship among the geometrical moment of inertia per wall width of 1 m I (cm^4/m), a weight per unit wall area W (kg/m^2), penetration resistance (R) and a web angle θ ($^\circ$) when a steel sheet pile wall is formed is set so as to satisfy the above-mentioned group of formulae (A).

[0019]

(3) The Z-type steel sheet pile according to the present invention is a Z-type steel sheet pile which includes: a web; flanges which are formed on both edges of the web; and joints

which are formed on edge portions of the flanges, wherein the relationship among the geometrical moment of inertia per wall width of 1 m I (cm^4/m), a weight per unit wall area W (kg/m^2), penetration resistance (R) and a web angle θ ($^\circ$) when a steel sheet pile wall is formed is set so as to satisfy the above-mentioned group of formulae (B).

[0020]

(4) Further, the Z-type steel sheet pile according to the present invention is the Z-type steel sheet pile described in the above-mentioned (3) and is set so as to satisfy a following group of formulae (C).

Group of formulae (C):

$$0.004 < (W/I) \times R \leq 0.006, \text{ and}$$

$$2.80 \times 10^{-4} \times I + 48 < \theta \leq 80 \quad (30,000 \leq I < 80,000)$$

$$70 < \theta \leq 80 \quad (80,000 \leq I < 200,000)$$

[0021]

(5) In addition to the above, the Z-type steel sheet pile according to the present invention is the Z-type steel sheet pile described in any one of the above-mentioned (1) to (4), wherein the relationship between a height (H) and a web plate thickness (t_w) is set so as to satisfy a following formula.

$$H/t_w \leq 60.0$$

[Advantage of the Invention]

[0022]

According to the present invention, the relationship

among the geometrical moment of inertia per wall width of 1 m I (cm^4/m), the weight per unit wall area W (kg/m^2), the penetration resistance R and the web angle θ ($^\circ$) when the steel sheet pile wall is formed is set so as to satisfy any one of the above-mentioned groups of formulae (A), (B) and (C). Accordingly, it is possible to provide a Z-type steel sheet pile having a cross-sectional shape optimized for satisfying both economic efficiency and workability and for further enhancing workability.

[0023]

According to the present invention, in addition to the above, the relationship between the height (H) and the web plate thickness (t_w) is set so as to satisfy the following formula and hence, buckling/deformation of the steel sheet pile due to the construction-time penetration resistance can be suppressed thus providing the Z-steel sheet pile which ensures soundness.

$$H/t_w \leq 60.0$$

[Brief Description of the Drawings]

[0024]

Fig. 1 is an explanatory view of a Z-type steel sheet pile according to one embodiment of the present invention.

Fig. 2 is an explanatory view of a step in which an optimum cross section is induced in one embodiment of the present invention, and is also a graph showing the relationship between

the geometrical moment of inertia per wall width of 1 m and a weight per unit wall area when a height (H) and a web angle (θ) are changed while setting an effective width (B), a flange plate thickness (t_f), and a web plate thickness (t_w) to fixed values, that is, $B=700$ mm, $t_f=16$ mm and $t_w=8.5$ mm.

Fig. 3 is an explanatory view of a step in which an optimum cross section is induced in one embodiment of the present invention, and is also a graph showing the relationship between the geometrical moment of inertia per wall width of 1 m and a weight per unit wall area when the flange plate thickness (t_f) and the web plate thickness (t_w) are changed while setting the effective width (B) and the height (H) to fixed values, that is, $B=700$ mm and $H=600$ mm.

Fig. 4 is an explanatory view of a step in which an optimum cross section is induced in one embodiment of the present invention, and is also a graph showing the relationship between an economic efficiency index and a web angle when the geometrical moment of inertia per wall width of 1 m I is set to 100,000 ($I=100,000$).

Fig. 5 is an explanatory view of a step in which an optimum cross section is induced in one embodiment of the present invention, and is also a graph showing the relationship between a workability index and a web angle when the geometrical moment of inertia per wall width of 1 m I is set to 100,000 ($I=100,000$).

Fig. 6 is an explanatory view of a step in which an optimum

cross section is induced in one embodiment of the present invention, and is also a graph showing the relationship between an index which is set by taking workability and economic efficiency into consideration and a web angle when the geometrical moment of inertia per wall width of 1 m I is set to 100,000 ($I=100,000$).

Fig. 7 is a graph showing the relationship between the geometrical moment of inertia per wall width of 1 m and a web angle when the Z-type steel sheet pile in one embodiment of the present invention is a steel sheet pile wall.

Fig. 8 is a graph showing the relationship between the geometrical moment of inertia per wall width of 1 m and a web angle when the Z-type steel sheet pile in another mode of one embodiment of the present invention is a steel sheet pile wall.

Fig. 9 is a graph showing the relationship between the geometrical moment of inertia per wall width of 1 m and a web angle when the Z-type steel sheet pile in still another mode of one embodiment of the present invention is a steel sheet pile wall.

Fig. 10 is a graph showing the relationship between the geometrical moment of inertia per wall width of 1 m and a web angle when the Z-type steel sheet pile in still another mode of one embodiment of the present invention is a steel sheet pile wall.

Fig. 11 is a view showing the relationship between

standardized construction-time penetration resistance (maximum load) $P/P45^\circ$ and a workability index $R/R45^\circ$.

Fig. 12 is a view showing the relationship between standardized construction-time penetration resistance (maximum load) $P/P45^\circ$ and a web angle $\theta(^\circ)$.

Fig. 13 is a view showing the relationship between standardized construction-time penetration resistance (maximum load) $P/P67^\circ$ and a workability index $R/R67^\circ$.

Fig. 14 is a view showing the relationship between standardized construction-time penetration resistance (maximum load) $P/P67^\circ$ and a web angle $\theta(^\circ)$.

Fig. 15 is a view showing the relationship between a deformation amount of a specimen and H/t_w which is a height/web thickness ratio.

Fig. 16 is a view showing the relationship between construction-time penetration resistance P and H/t_w which is a height/web thickness ratio.

[Mode for Carrying Out the Invention]

[0025]

With respect to a Z-type steel sheet pile according to one embodiment of the present invention shown in Fig. 1, a method of deciding a shape of the Z-type steel sheet pile is explained.

As parameters for deciding a cross-sectional shape of the Z-type steel sheet pile, an effective width (B), a height

(H), a web angle (θ), a flange width (Bf), a flange plate thickness (tf) and a web plate thickness (tw) are named.

By deciding these parameters, a weight per unit wall area (W) and the geometrical moment of inertia per wall width of 1 m (I) are univocally decided based on following formulae.

$$I = I_0 + \sum A \times y^2$$

$$W = \gamma \times A$$

(I_0 : the geometrical moment of inertia, A: cross-sectional area, y: distance from centroid, γ : unit volume weight)

[0026]

Usually, with respect to the geometrical moment of inertia (I) of a steel sheet pile, a strict solution including a joint portion is calculated based on the above-mentioned formula using CAD data on a cross section of the steel sheet pile.

However, in carrying out the study of the cross-sectional shape or the parametric study in this embodiment, it is extremely cumbersome to calculate the geometrical moment of inertia (I) after forming CAD data every time.

Accordingly, in the calculation of the geometrical moment of inertia (I) of a steel sheet pile wall, inventors of the present invention have come up with the following method. This method is also applicable to a hat-type steel sheet pile besides the Z-type steel sheet pile.

[0027]

As shown in Fig. 1, this embodiment adopts a method which can approximately but simply calculate the geometrical moment of inertia I of a Z-type steel sheet pile by dividing a cross section of the Z-type steel sheet pile into three portions consisting of upper and lower flanges and a web. This method, however, does not take a joint portion into consideration and hence, a value of the geometrical moment of inertia I is calculated as a value smaller by an amount corresponding to the joint portion. To make a trial calculation of the geometrical moment of inertia I , the value obtained by the calculation method becomes approximately 80 to 90% of the strict solution. However, this point is taken into consideration when a straight line described later which defines the shape is obtained by fitting and hence, there arises no problem.

[0028]

As described above, in general, the geometrical moment of inertia (I) is expressed by the following formula.

$$I = I_0 + \sum A \times y^2$$

Here, the Z-type steel sheet pile is divided into three rectangular shapes ((i), (ii), (iii)) as shown in Fig. 1, and geometrical moments of inertia I of respective rectangular shapes are induced as follows.

[Formula 1]

$$(i)(iii): I = \{Bf \times tf^3 / 12 + Bf \times tf \times (h/2)^2\} \times 2 \\ = Bf \times tf / 2 \times (tf^2 / 3 + h^2)$$

$$(ii): I = \int_0^{h/2} [(\Delta h / \sin \theta \times tw) \times h^2] \times 2 \\ = 2 \times tw / \sin \theta \times [h^3 / 3]_0^{h/2} \\ = tw \times h^3 / 12 \times 1 / \sin \theta$$

[0029]

Due to these geometrical moments of inertia, the geometrical moment of inertia I' per one sheet of Z-type steel sheet pile is expressed by the following formula.

$$I' = Bf \times tf / 2 \times (tf^2 / 3 + h^2) + tw \times h^3 / 12 \times 1 / \sin \theta$$

Accordingly, the geometrical moment of inertia per wall width of 1 m (I) is expressed by the following formula (1).

$$I = \{Bf \times tf / 2 \times (tf^2 / 3 + h^2) + tw \times h^3 / 12 \times 1 / \sin \theta\} \times 1000 / B \dots (1)$$

According to this formula (1), the geometrical moment of inertia (I) can be easily calculated based on the effective width (B), the height ($H = h + tf$), the web angle (θ), the flange width (Bf), the flange plate thickness (tf) and the web plate thickness (tw) which are parameters defining a cross-sectional shape of the Z-type steel sheet pile.

[0030]

In the same manner, a weight per unit wall area (W) can be also calculated based on a formula (2).

$$W = (2 \times Bf \times tf + h \times tw / \sin \theta) \times \gamma \times 1000 / B \dots (2)$$

Further, the flange width (Bf) can be expressed by the

following formula.

$$B_f = B/2 - h/(2 \times \tan \theta)$$

[0031]

Fig. 2 shows an example where the geometrical moment of inertia I and the weight W are calculated on a trial basis using the formula (1) and the formula (2). In Fig. 2, the geometrical moment of inertia per wall width of 1 m I (cm^4/m) is taken on an axis of ordinates, and the weight per unit wall area W (kg/m^2) is taken on an axis of abscissas.

In this embodiment, the height (H) and the web angle (θ) are changed while setting the effective width (B), the flange plate thickness (t_f) and the web plate thickness (t_w) to fixed values, that is, $B=700$ mm, $t_f=16$ mm, and $t_w=8.5$ mm.

As shown in Fig. 2, it is understood that along with the increase in the height (H) and the web angle (θ), the geometrical moment of inertia (I) is increased. Since the height (H) largely contributes to the increase in geometrical moment of inertia I particularly, it is economically effective to increase the height H so long as the Z-type steel sheet pile can be manufactured and workability allows the manufacture of such a Z-type steel sheet pile.

[0032]

Further, Fig. 3 shows an example where the geometrical moment of inertia I and the weight W are calculated on a trial basis using the formula (1) and the formula (2), wherein the

flange plate thickness (t_f) and the web plate thickness (t_w) are changed while setting the effective width (B) and the height (H) to fixed values, that is, $B=700$ mm and $H=600$ mm.

In Fig. 3, a web plate thickness t_w is changed among 8.5 mm, 9 mm, 10 mm, 12 mm, 14 mm, and the flange plate thickness t_f is changed among 8.5 mm, 9 mm, 10 mm, 12 mm, 14 mm, 16 mm, 19 mm and 22 mm under a condition of $t_f \geq t_w$. In the graph shown in Fig. 3, each curve in a bundle of rightward and upward curves extending with respect to each web plate thickness t_w indicates the flange plate thickness t_f which can be taken in relation to the web plate thickness t_w .

From Fig. 3, the influence of the flange plate thickness (t_f) and the web plate thickness (t_w) exerted on the geometrical moment of inertia I can be read. That is, although the effective width (B) and the height (H) are set to fixed values, that is, $B=700$ mm and $H=600$ mm, due to a term of two powers of distance y from a centroid in the formula on the geometrical moment of inertia, the effect or the influence exerted by the increase in the flange plate thickness (t_f) remote from the centroid is large.

For example, to focus on a case where the web plate thickness (t_w) is 8.5 mm ($t_w=8.5$ mm) and the web angle (θ) is 90° ($\theta=90^\circ$), the geometrical moment of inertia (I) is 95,000 (cm^4/m) ($I=95,000$ (cm^4/m)) when the flange plate thickness (t_f) is 8.5 mm ($t_f=8.5$ mm), while the geometrical moment of inertia

(I) is 155,000 (cm^4/m) ($I=155,000 (\text{cm}^4/\text{m})$) when the flange plate thickness (t_f) is 16 mm ($t_f=16 \text{ mm}$). On the other hand, as can be understood from Fig. 3, even when the web plate thickness t_w is changed, the geometrical moment of inertia I is not changed largely.

Accordingly, it is effective for the increase in the geometrical moment of inertia I to make the flange plate thickness t_f large and to make the web plate thickness t_w small.
[0033]

What must be noted here is that when one looks at the axis of abscissas with respect to certain geometrical moment of inertia I (for example, $I=100,000 \text{ cm}^4/\text{m}$) taken on the axis of ordinates in Fig. 2 and Fig. 3, the geometrical moment of inertia I intersects with a plurality of lines and hence, it is understood that the various specifications of the Z-type steel sheet piles which can exhibit the same geometrical moment of inertia (I) based on a height (H), a web angle (θ), a flange plate thickness (t_f) and a web plate thickness (t_w) are present.

In view of the above, as the product constitution of the Z-type steel sheet pile, 9 types of Z-type steel sheet piles having the geometrical moment of inertias I of 20,000, 40,000, 60,000, 80,000, 100,000, 120,000, 140,000, 160,000, 180,000 are estimated, and specifications which can produce the respective geometrical moments of inertia I are induced based on parameters shown in the following Table 1. Although the

effective width (B) is set to a fixed value of 700 here for the sake of brevity, it is needless to say that the study which also adopts the effective width (B) as a parameter can be made provided that the Z-type steel sheet pile can be manufactured.

[0034]

[Table 1]

B (mm)	H (mm)	θ ($^{\circ}$)	t_f (mm)	t_w (mm)
700	250	30.0	8.5	8.5
	300	31.0	9.0	9.0
	350	32.0	10.0	10.0
	400	33 to 87 (at a pitch of 1°)	12.0	12.0
	450		14.0	14.0
	500		16.0	
	550		19.0	($t_w \leq t_f$)
	600		22.0	

[0035]

With respect to the large number of induced specifications of the Z-type steel sheet pile, the following study was made so as to determine a cross-sectional shape of the Z-type steel sheet pile which optimizes both economic efficiency and workability as described previously.

Fig. 4 is a graph showing the relationship between an economic efficiency index (W/I) and a web angle (θ) for every height ($H=600, 550, 500, 450$) by taking a Z-type steel sheet pile having the geometrical moment of inertia I of 100,000 ($I=100,000$) (cm^4/m) as an example, wherein the economic efficiency index (W/I) is taken on an axis of ordinates, and

the web angle (θ) is taken on an axis of abscissas.

In the graph shown in Fig. 4, for every flange plate thickness (t_f) in Table 1, a web plate thickness (t_w) is decreased while gradually increasing the web angle (θ) thus decreasing a weight while ensuring the geographical moment of inertia I of 100,000 (cm^4/m). Then, when the Z-type steel sheet pile cannot satisfy the geographical moment of inertia I of 100,000 (cm^4/m), the flange plate thickness t_f is leveled down by one rank and the web plate thickness t_w is leveled up by one rank, and this operation is repeated. Accordingly, in the graph shown in Fig. 4, the graph exhibits a rightward and downward saw-tooth shape.

According to the graph shown in Fig. 4, to look at a straight line for every flange plate thickness t_f , it is understood that along with the increase in the web angle (θ), there is a tendency that the economic efficiency index (W/I) is decreased so that the economic efficiency is enhanced.

In this manner, the close relevancy is recognized between the web angle (θ) and the economic efficiency index (W/I).
[0036]

On the other hand, the workability index (penetration resistance (R)) is defined by the following formula (3). This formula is one example of a formula expressing the penetration resistance obtained by indoor driving experiment of a steel sheet pile model, and a similar formula is indicated also in

patent document 3 introduced previously.

$$R = \tan\theta \times H \times 1/B_f \dots (3)$$

The occurrence of the following phenomenon can be understood by observing this formula.

When a web angle (θ) is increased, a web is raised so that an earth pressure is concentrated in the inside of a groove of a steel sheet pile whereby the steel sheet pile is liable to be deformed thus lowering penetration property.

When a height (H) is increased, ground resistance is increased so that penetration property is lowered.

When a flange width (B_f) is increased, an earth pressure in the inside of the above-mentioned groove can be easily released so that the penetration property is enhanced.

[0037]

As parameters which define the penetration resistance (R), as shown in the formula (3), the web angle (θ), the height (H) and the flange width (B_f) are named.

Fig. 5 shows, in the same manner as the case of Fig. 4, the relationship between a workability index (penetration resistance (R)) and a web angle θ ($^\circ$) for every height (H=600, 550, 500, 450) by taking a Z-type steel sheet pile having the geometrical moment of inertia of 100,000 (cm^4/m) ($I=100,000$ (cm^4/m)) as an example. From this drawing, it is understood that there exists a web angle θ ($^\circ$) where the penetration resistance (R) becomes minimum.

[0038]

As described above, both the economic efficiency index (W/I) and the workability index (R) are closely relevant to the web angle θ ($^{\circ}$) and hence, one index can be made by combining these two indexes, and by such combination, both the economic efficiency and the workability can be evaluated using one index.

As a method of combining the economic efficiency index (W/I) and the workability index (R), the present invention adopts a method where both indexes are multiplied by each other.

$$(\text{economic efficiency index}) \times (\text{workability index}) = \alpha \times (W/I) \times \beta \times (R)$$

Here, α and β are weighting factors of economic efficiency index and workability index respectively. Here, a method where both indexes are multiplied by each other is adopted, and α and β are set to 1 ($\alpha = \beta = 1$).

With respect to the economic efficiency index (W/I) and the workability index (R), the smaller these values, the more excellent economic efficiency and the more excellent workability the steel sheet pile possesses. Accordingly, also with respect to a product of multiplication of these parameters, when a multiplication value is small, it is possible to evaluate that the steel sheet pile is excellent in both the economic efficiency and the workability.

Fig. 6 is a graph showing the relationship between (W/I)

$\times R$ which is the product of economic efficiency index (W/I) and the workability index (R) and a web angle θ ($^\circ$) for every height ($H=600, 550, 500, 450$) with respect to a case where a Z-type steel sheet pile has the geometrical moment of inertia I of $100,000 \text{ (cm}^4\text{/m)}$ ($I=100,000 \text{ (cm}^4\text{/m)}$).

[0039]

As described previously, in the graph shown in Fig. 6, although the smaller a value taken on an axis of ordinates, the more excellent economic efficiency $\cdot$ workability the steel sheet pile possesses, setting of an upper limit value (threshold value) of economic efficiency $\cdot$ workability is important.

In view of the above, the inventors of the present invention have studied this point. When the investigation is made using a steel sheet pile model experiment explained previously or the like, economic efficiency $\cdot$ workability is approximately 0.004 to 0.006 . Accordingly, a web angle θ ($^\circ$) at which economic efficiency $\cdot$ workability becomes 0.006 or less is defined as the specification by which both the economic efficiency and the workability can be secured.

In the existing hat-type steel sheet pile, the value obtained by multiplying both indexes becomes approximately 0.0081 at $10H$ and approximately 0.0097 at $25H$ so that it is understood that the existing hat-type steel sheet pile does not always have a steel sheet pile shape by which both the

economic efficiency and the workability are optimized.

[0040]

Based on the above-mentioned definition, in Fig. 6, a range of the axis of abscissas when the value on the axis of ordinates is set to 0.006 or less is obtained thus obtaining a range of the web angle θ ($^{\circ}$). It is found that the web angle θ ($^{\circ}$) is preferably set to approximately 52 to 76 $^{\circ}$ to optimize both the economic efficiency and the workability (penetration property) when the geometrical moment of inertia I of the steel sheet pile is 100,000(cm^4/m) ($I=100,000$ (cm^4/m)) (see Fig. 6).

By performing such a study method by changing the level of the targeted geometrical moment of inertia I , it is possible to define optimum cross-sectional shapes which can balance the economic efficiency and workability and can satisfy various requested geometrical moments of inertia I .

Table 2 shows preferable ranges of the web angle (θ) obtained with respect to respective geometrical moments of inertia I by performing the similar studies in accordance with steps similar to the steps described above.

[0041]

[Table 2]

I (cm ⁴ /m)	Optimized θ (°)
20,000	32 to 67
40,000	40 to 68
60,000	46 to 74
80,000	49 to 75
100,000	52 to 76
120,000	56 to 77
140,000	62 to 76
160,000	69 to 77
180,000	76

[0042]

With respect to the result shown in Table 2, a graph where the web angle θ (°) is taken on an axis of ordinates and the geometrical moment of inertia I (cm⁴/m) is taken on an axis of abscissas is shown in Fig. 7. In Fig. 7, upper and lower limit values shown in Table 2 are plotted and fitting is made by a straight line.

As described previously, values which are obtained by a simplified calculating method of the geometrical moment of inertia I used here are approximately 80 to 90% of strict solutions and hence, $(W/I) \times R$ shown in Fig. 6 is larger than the strict solution. Further, to take the fact that the graph shown in Fig. 6 is a downwardly convex graph into consideration, since the simplified calculation method is adopted, an optimum range is set narrow compared to an optimum range in a case where the strict solution is adopted. Accordingly, as shown in Fig. 7, although some displacement may take place when fitting of plots obtained by the simplified calculation method is made

by a straight line, the values merely become closer to the strict solutions and hence, there arises no problem.

[0043]

To formulate the straight line shown in Fig. 7, the straight line is expressed by a following formula.

$$2.65 \times 10^{-4} \times I + 22 \leq \theta \leq 80 \quad (30,000 \leq I < 180,000)$$

$$70 \leq \theta \leq 80 \quad (180,000 \leq I < 200,000) \quad \dots \quad (4)$$

[0044]

As described above, the formula (4) is set by taking both economic efficiency and workability into consideration, and the Z-type steel sheet pile which satisfies the range in the formula (4) satisfies both economic efficiency and workability.

[0045]

Here, depending on a condition of a soil into which the Z-type steel sheet pile is driven (hardness using an N value or the like as an index), there may also be a case where workability is more emphasized or, reversely, economic efficiency is more emphasized out of workability and economic efficiency.

That is, when the ground is hard, it may be possible to make the determination that the penetration resistance (R) is decreased to maximize driving possibility, and some increase in weight (W) is unavoidable. On the other hand, when the ground is soft, the determination that the reduction of weight

(W) is advantageous may be made although the penetration resistance (R) is increased to some extent.

Accordingly, hereinafter, optimum shape setting when workability is more emphasized and optimum shape setting when economic efficiency is more emphasized are explained.

[0046]

<Emphasis on workability>

To place more emphasis on workability within a range defined by the above-mentioned formula (4) means that the value of θ is decreased as can be understood by reference to the formula (3) ($R = \tan \theta \times H \times 1/Bf$) which defines workability. On the other hand, by reference to Fig. 6 which shows the relationship between workability·economic efficiency and the web angle θ , it is understood that the decrease of the value of θ is equivalent to lowering of the threshold value.

Accordingly, in shape setting where workability is emphasized, the study substantially equal to the above-mentioned study is carried out by setting a threshold value of $(W/I) \times R$ to 0.004 or less. Web angles $\theta(^{\circ})$ at which the threshold value of $(W/I) \times R$ becomes 0.004 are calculated with respect to respective geometrical moment of inertia I, and the result of calculation is shown in Table 3.

[0047]

[Table 3]

I (cm ⁴ /m)	Web angle $\theta(^{\circ})$ at which threshold value of $(W/I) \times R$ becomes 0.004
20,000	49
40,000	56
60,000	62
80,000	64
100,000	66
120,000	67
140,000	67

[0048]

The following group of formulae (A) are defined based on the result of calculation shown in Table 3.

Group of formulae (A):

$(W/I) \times R \leq 0.004$, and

$2.65 \times 10^{-4} \times I + 22 \leq \theta \leq 2.80 \times 10^{-4} \times I + 48$ ($30,000 \leq I < 80,000$)

$2.65 \times 10^{-4} \times I + 22 \leq \theta \leq 70$ ($80,000 \leq I < 180,000$)

[0049]

Fig. 8 shows the group of formulae (A) in the form of a graph.

[0050]

<Emphasis on economic efficiency (1)>

To place more emphasis on economic efficiency means to decrease an economic efficiency index (W/I) . As can be understood by reference to Fig. 4, the web angle (θ) may be increased to decrease the economic efficiency index (W/I) . On the other hand, by reference to Fig. 6 which shows the relationship between workability-economic efficiency and the web angle θ , it is understood that the increase in the value

of θ is equivalent to the increase in the threshold value. Accordingly, in shape setting where economic efficiency is emphasized, the study substantially equal to the above-mentioned study is carried out by setting the threshold value of $(W/I) \times R$ to 0.004 or more and 0.006 or less. The following group of formulae (B) was defined as the result of the study.

Group of formulae (B):

$$0.004 < (W/I) \times R \leq 0.006, \text{ and}$$

$$2.80 \times 10^{-4} \times I + 44.6 < \theta \leq 80 \quad (30,000 \leq I < 80,000)$$

$$67 < \theta \leq 80 \quad (80,000 \leq I < 200,000)$$

[0051]

Fig. 9 shows the group of formulae (B) in the form of a graph.

[0052]

<Emphasis on economic efficiency (2)>

In the above-mentioned <Emphasis on economic efficiency (1)>, a lower limit value of the web angle θ in a range of $80,000 \leq I < 200,000$ is set to 67° . To consider the actual manufacture of the Z-type steel sheet pile, it may be thought that the numerical value is too fine so that the control of the lower limit value becomes difficult. To take the easiness of manufacture control into consideration, shape setting where economic efficiency is emphasized may be defined by the following group of formulae (C) by setting the lower limit value

of the web angle θ within a range of $80,000 \leq I < 200,000$ to 70° .

Group of formulae (C):

$$0.004 < (W/I) \times R \leq 0.006, \text{ and}$$

$$2.80 \times 10^{-4} \times I + 48 < \theta \leq 80 \quad (30,000 \leq I < 80,000)$$

$$70 < \theta \leq 80 \quad (80,000 \leq I < 200,000)$$

[0053]

Fig. 10 shows the group of formulae (C) in the form of a graph.

[0054]

As described above, in setting a cross-sectional shape (particularly web angle (θ)) of the Z-type steel sheet pile, the Z-type steel sheet pile can basically acquire both economic efficiency and workability (formula (4)), and also can use the region of θ differently depending on whether workability is emphasized more (group of formulae (A)) or economical efficiencies is emphasized more (group of formulae (B) or group of formulae (C)).

Further, the Z-type steel sheet pile which satisfies the range set in the formula (4) satisfies both economic efficiency and workability. The Z-type steel sheet pile which satisfies the range set in the group of formulae (A) satisfies both economic efficiency and workability and is more excellent in workability, and the Z-type steel sheet pile which satisfies the range set in the group of formulae (B) or the group of formulae (C) satisfies both economic efficiency and

workability and is more excellent in economic efficiency.

[0055]

<Securing soundness>

Further, according to the present invention, in addition to the above, the relationship between the height (H) and the web plate thickness (tw) is set so as to satisfy the following formula. Accordingly, buckling/deformation of the steel sheet pile due to the construction-time penetration resistance can be suppressed whereby it is possible to provide the Z-type steel sheet pile which ensures soundness.

$$H/tw \leq 60.0$$

[0056]

[Example 1]

As an example of the present invention, a Z-type steel sheet pile having the following specification was designed.

B=700 mm, H=540 mm, $\theta=75^\circ$, $I=114,810 \text{ cm}^4/\text{m}$

It was confirmed whether or not the Z-type steel sheet pile having the above-mentioned specification falls within the above-mentioned ranges of indexes.

To put the above-mentioned specification of the Z-type steel sheet pile into the formula (4) and the group of formulae (C), the formula (4) and the group of formulae (C) become as follows.

Formula (4):

$$2.65 \times 10^{-4} \times I + 22 \leq \theta \leq 80 \quad (60,000 \leq I < 200,000)$$

$$2.65 \times 10^{-4} \times I + 22 = 2.65 \times 10^{-4} \times 114,810 + 22 = 52.4$$

wherein $52.4 < \theta = 75 < 80$ and hence, θ falls within the range of the formula (4).

The group of formulae (C): $70 < \theta \leq 80$ ($80,000 \leq I < 200,000$) wherein, θ of the above-mentioned Z-type steel sheet pile is 75° ($\theta = 75^\circ$) and hence, a formula $70 < \theta = 75 < 80$ is established whereby the Z-type steel sheet pile satisfies the group of formulae (C).

Accordingly, it is understood that the Z-type steel sheet pile of this embodiment is excellent in both economic efficiency and workability, and is more excellent in economic efficiency.

[Example 2]

[0057]

As the example of the present invention, a Z-type steel sheet pile having the following specification was designed. $B=700$ mm, $H=540$ mm, $\theta=75^\circ$, $I=81,454$ cm⁴/m

To put the above-mentioned specification of the Z-type steel sheet pile into the formula (4) and the group of formulae (C), the formula (4) and the group of formulae (C) become as follows.

Formula (4):

$$2.65 \times 10^{-4} \times I + 22 \leq \theta \leq 80 \quad (60,000 \leq I < 200,000)$$

$$2.65 \times 10^{-4} \times I + 22 = 2.65 \times 10^{-4} \times 81,454 + 22 = 43.6$$

wherein $43.6 < \theta = 75 < 80$ and hence, θ falls within the range of

the formula (4).

The group of formulae (C): $70 < \theta \leq 80$ ($80,000 \leq I < 200,000$) wherein θ of the above-mentioned Z-type steel sheet pile is 75° ($\theta = 75^\circ$) and hence, $70 < \theta = 75 < 80$ whereby the Z-type steel sheet pile satisfies the group of formulae (C).

Accordingly, it is understood that the Z-type steel sheet pile of this embodiment is excellent in both economic efficiency and workability, and is more excellent in economic efficiency.

[0058]

In the above-mentioned explanation, the economic efficiency index and the workability index are multiplied by each other. However, it is also possible to use an addition value of both indexes as an index.

In this case, in adding the economic efficiency index and the workability index, to take weighting of both indexes into consideration, the addition may be expressed as follows.

$$(\text{economic efficiency index}) + (\text{workability index}) = \alpha \times (W/I) + \beta \times (R)$$

[0059]

Further, there exists the reciprocal relationship between a manufacturing cost and cross-sectional performance per wall weight (I/W) and between a construction cost and the inverse number of penetration resistance ($1/R$) respectively and hence, I/W and $1/R$ may also be used as an index of economic

efficiency and an index of workability.

[0060]

[Example 3]

As a study case relating to a method of setting the workability index R according to the present invention, exemplified is an example of a model construction test where a steel sheet pile model of 1/12 magnification (length: 100cm) is driven into a ground prepared using silica sand No. 5 by pushing at a fixed speed.

With respect to cases carried out in the model construction test, shapes converted into an actual size and economic efficiency indexes I/W and workability indexes R which are decided based on the shapes are shown in Table 3. The shapes of the specimens are set such that the geometrical moments of inertia I per specimen of 1 m becomes approximately 55,000 (cm⁴/m) in all cases.

[0061]

[Table 4]

Cases carried out in model construction test

Name of case	Model shape (converted into actual size)					Various indexes (converted into actual size)				
	Web/ flange plate thickness t(mm)	Web angle θ (°)	Height H (mm)	Flange width Bf(mm)	Width B(mm)	Economic efficiency index W/I	Workability index R	Integrated index W/I×R	I (cm ⁴ /m)	Evaluation on compatibility with present invention
(1)-1	9.6	36	636	185	624	0.0016	1.179	0.00194	54,181	good
(1)-2	9.6	36	636	185	624	0.0016	1.179	0.00194	54,181	good
(2)	9.6	45	576	227	576	0.0017	1.270	0.00216	54,398	good
(3)-1	9.6	60	516	262	516	0.0019	1.707	0.00322	54,200	good
(3)-2	9.6	60	516	262	516	0.0019	1.707	0.00322	54,200	good
(4)-1	9.6	75	480	267	480	0.0021	3.355	0.00698	56,032	bad
(4)-2	9.6	75	480	267	480	0.0021	3.355	0.00698	56,032	bad
(5)-1	9.6	82	456	293	456	0.0022	5.544	0.01230	54,292	bad
(5)-2	9.6	82	456	293	456	0.0022	5.544	0.01230	54,292	bad

[0062]

In Table 5, the construction-time penetration resistance (maximum load) (P), the workability index R which is a value of P/P_{45° which is obtained by standardizing the construction-time penetration resistance (P) with the penetration resistance (maximum load) P_{45° in the case (2) ($\theta=45^\circ$), and R/R_{45° which is obtained by standardizing the workability index R with the workability index R_{45° when $\theta=45^\circ$ are shown in comparison.

[0063]

[Table 5]

Comparison between penetration resistance at construction time and workability index in model construction test

Name of case	Evaluation on compatibility to present invention	Web angle θ ($^\circ$)	Construction-time penetration resistance (experiment)		Workability index	
			Penetration resistance (maximum load) P (kN)	Standardized P/P_{45°	Workability index R	Standardized R/R_{45°
(1)-1	good	36	0.67	1.19	1.179	0.90
(1)-2	good	36	0.7	1.24	1.179	0.90
(2)	good	45	0.46	1.00	1.270	1.00
(3)-1	good	60	0.49	1.33	1.707	1.34
(3)-2	good	60	0.42	1.14	1.707	1.34
(4)-1	bad	75	0.78	2.62	3.355	2.69
(4)-2	bad	75	0.73	2.45	3.355	2.69
(5)-1	bad	82	1.08	3.84	5.544	4.46
(5)-2	bad	82	1.29	4.58	5.544	4.46

[0064]

The correspondence between the standardized construction-time penetration resistance (maximum load) P/P_{45° and the standardized workability index R/R_{45° is shown

in Fig. 11. Since both the penetration resistance $P/P45^\circ$ and the workability index $R/R45^\circ$ well correspond to each other, the validity of the workability index of the present invention is confirmed.

Fig. 12 shows the relationship between the standardized construction-time penetration resistance (maximum load) $P/P45^\circ$ and the web angle θ ($^\circ$). The construction-time penetration resistance in the experiment is suppressed to a relatively small value within the range of the present invention ($36.6^\circ \leq \theta \leq 63.4^\circ$), while the construction-time penetration resistance is increased out of the range of the present invention ($\theta = 75^\circ, 82^\circ$). Accordingly, the validity of the present invention is confirmed.

[0065]

[Example 4]

As a study case relating to a method of setting the workability index R according to the present invention, exemplified is an example of a model construction test where a steel sheet pile model of 1/12 magnification (length: 100cm) is driven into a ground prepared using silica sand No. 5 by pushing at a fixed speed.

With respect to cases carried out in the model construction test, shapes converted into an actual size and economic efficiency indexes I/W and workability indexes R which are decided based on the size are shown in Table 6. The shapes

of the specimens are set such that the geometrical moments of inertia I per specimen of 1 m becomes approximately 82000 (cm^4/m) in all cases.

[0066]

[Table 6]

Name of case	Model shape (converted into actual size)					Various indexes (converted into actual size)				
	Web/ flange plate thickness $t(\text{mm})$	Web angle $\theta (^{\circ})$	Height $H (\text{mm})$	Flange width $B_f(\text{mm})$	Width $B(\text{mm})$	Economic efficiency index W/I	Workability index R	Integrated index $W/I \times R$	I (cm^4/m)	Evaluation on compatibility with present invention
(6)	9.6/16.8	67	496	246	696	0.0018	2.372	0.00433	82,028	compatible with only group of formulae (B)
(7)	9.6/16.8	70	484	263	696	0.0019	2.528	0.00475	81,781	compatible with groups of formulae (B) and (C)
(8)	9.6/16.8	75	468	288	696	0.0020	3.037	0.00594	81,615	compatible with groups of formulae (B) and (C)
(9)	9.6/16.8	85	444	329	696	0.0021	7.705	0.01618	81,567	bad

[0067]

The construction-time penetration resistance (maximum load) (P), the workability index R which is a value of $P/P_{67^{\circ}}$ which is obtained by standardizing the construction-time penetration resistance (P) with the penetration resistance (maximum load) $P_{67^{\circ}}$ in the case (6) ($\theta = 67^{\circ}$), and $R/R_{67^{\circ}}$ which is obtained by standardizing the workability index R with the workability index $R_{67^{\circ}}$ when $\theta = 67^{\circ}$ are shown in Table 7 in comparison.

[0068]

[Table 7]

Comparison of construction-time penetration resistance and workability index in model construction test

Name of case	Evaluation on compatibility with present invention	Web angle θ (°)	Construction-time penetration resistance (experiment)		Workability index	
			Penetration resistance (maximum load) P(kN)	Standardized P/P67°	Workability index R	Standardized R/R67°
(6)	good	67	0.75	1.00	2.372	1.00
(7)	good	70	0.74	0.99	2.528	1.07
(8)	good	75	0.92	1.23	3.037	1.32
(9)	bad	85	2.1	2.80	7.705	3.34

[0069]

The correspondence between the standardized construction-time penetration resistance (maximum load) $P/P67^\circ$ and the standardized workability index $R/R67^\circ$ is shown in Fig. 13. Since both the penetration resistance $P/P67^\circ$ and the workability index $R/R67^\circ$ well correspond to each other, the validity of the workability index of the present invention is confirmed.

Fig. 14 shows the relationship between the standardized construction-time penetration resistance (maximum load) $P/P67^\circ$ and the web angle θ (°). The construction-time penetration resistance in the experiment is suppressed to a relatively small value within the range of the present invention ($67^\circ \leq \theta \leq 80^\circ$), while the construction-time penetration resistance is increased out of the range of the present invention ($\theta = 85^\circ$). Accordingly, the validity of the present invention is confirmed.

[0070]

[Example 5]

As an example of the present invention, exemplified is an example of a model construction test where a steel sheet pile model of 1/8.5 magnification (length: 110cm) is driven into a ground prepared using silica sand No. 7 by pushing at a fixed speed.

With respect to cases carried out in the model construction test, shapes converted into an actual size, penetration resistance values P in the test and deformation quantities of a cross section of the model are shown in Table 8.

[0071]

[Table 8]

Case carried out in model construction test

Name of case	Model shape (converted into actual size)							Test result		Evaluation on compatibility with present invention
	Web plate thickness Tw(mm)	Flange plate thickness tf(mm)	Web angle θ (°)	Height H (mm)	Flange width Bf(mm)	Whole width B(mm)	Height/web thickness ratio H/tw	Penetration resistance value P(kN)	Deformation amount (°)	
(1)	8.5	17.0	75	544	276	700	64.0	16.28	15.2	bad
(2)	9.0	17.0	75	544	276	700	60.4	14.22	6.6	good
(3)	10.2	17.0	75	544	276	700	53.3	13.68	2.5	good
(4)	12.8	17.0	75	544	276	700	42.7	13.51	5.1	good
(5)	16.0	17.0	75	544	276	700	32.0	13.24	0.9	good

[0072]

Fig. 15 shows the relationship between a deformation amount and a height/web thickness ratio H/tw of respective specimens. The deformation amount of the specimen indicates a change amount of an intersecting angle (initial angle: 75°) between the web and the flange. The result of the test shows that the deformation amount of the specimen was large when the value of the height/web thickness ratio H/tw was set to 64,

and deformation amount can be suppressed by suppressing the height/web thickness ratio H/tw to approximately 60 or less.

[0073]

Fig. 16 shows the relationship between the construction-time penetration resistance P and the height/web thickness ratio H/tw . The specimens where the value of the height/web thickness ratio H/tw was set to 64 exhibited the increase in penetration resistance. This increase in the penetration resistance is considered to be brought about by the increase in a deformation amount of a cross section of the specimen (see Fig. 15). Accordingly, it is thought that the deformation can be suppressed by suppressing the height/web thickness ratio H/tw to approximately 60 or less thus obviating the possibility of bringing about lowering of workability.

Claims

1. A Z-type steel sheet pile comprising: a web; flanges which are formed on both edges of the web; and joints which are formed on edge portions of the flanges, wherein the relationship among a geometrical moment of inertia per wall width of 1 m I (cm^4/m), a weight per unit wall area W (kg/m^2), penetration resistance R and a web angle θ ($^\circ$) when a steel sheet pile wall is formed is set so as to satisfy a following group of formulae (A) or a following group of formulae (B)

Group of formulae (A):

$$(W/I) \times R \leq 0.004, \text{ and}$$

$$2.65 \times 10^{-4} \times I + 22 \leq \theta \leq 2.80 \times 10^{-4} \times I + 48 \quad (30,000 \leq I < 80,000)$$

$$2.65 \times 10^{-4} \times I + 22 \leq \theta \leq 70 \quad (80,000 \leq I < 180,000)$$

Group of formulae (B):

$$0.004 < (W/I) \times R \leq 0.006, \text{ and}$$

$$2.80 \times 10^{-4} \times I + 44.6 < \theta \leq 80 \quad (30,000 \leq I < 80,000)$$

$$67 < \theta \leq 80 \quad (80,000 \leq I < 200,000).$$

2. The Z-type steel sheet pile according to claim 1, wherein the relationship is set so as to satisfy the group of formulae (A).

3. The Z-type steel sheet pile according to claim 1, wherein the relationship is set so as to satisfy the group of formulae (B).

4. The Z-type steel sheet pile according to claim 3,

wherein the relationship is set so as to satisfy a following group of formulae (C).

Group of formulae (C):

$$0.004 < (W/I) \times R \leq 0.006 \text{ and}$$

$$2.80 \times 10^{-4} \times I + 48 < \theta \leq 80 \quad (30,000 \leq I < 80,000)$$

$$70 < \theta \leq 80 \quad (80,000 \leq I < 200,000)$$

5. The Z-type steel sheet pile according to any one of claims 1 to 4, wherein the relationship between a height (H) and a web plate thickness (tw) of the Z-type steel sheet pile is set so as to satisfy a following formula.

$$H/tw \leq 60.0$$