

ASYMMETRICAL STEEL SHEET PILE AND
METHOD FOR MANUFACTURING THE SAME ✓

(Technical Field)

The present invention relates to steel sheet piles for
5 use in civil engineering and building construction, as well
as to processes for the production thereof including a hot
rolling step. More particularly, the invention is concerned
with steel sheet piles in which the joints on the right- and
left-hand sides are asymmetrical (such steel sheet piles
10 being hereinafter referred to as asymmetrical steel sheet
piles) as well as processes for their production.

The present invention also relates to corner steel
sheet piles which are used to make the corners of a steel
sheet pile wall, as well as to processes for their
15 production.

(Background Art)

Among many types of steel sheet piles which are
currently used, the most popular ones are U-shaped steel
sheet piles having a trapezoidal cross section. The
20 following description will be made with respect to U-shaped
steel sheet piles, although the present invention is not
restricted to such piles.

When conventional U-shaped steel sheet piles are used
to form a wall, there is a problem that alternate piles must
25 be arranged upside down, making wall construction time
consuming. Another problem is that they are not suitable
for construction in city areas where it is required to
construct a wall close to the adjacent land for the purpose
of efficient use of land, since the resulting wall has a
30 thickness larger than that of a wall constructed by small-
gauge H steels.

In order to solve these problems, the applicant
proposed a U-shaped steel sheet pile having unique
asymmetric joints at opposite ends in Japanese Patent
35 Application Laid-Open No. 5-140928(1993).

Figure 1 is a schematic cross-sectional view of an
asymmetric U-shaped steel sheet disclosed in that Japanese

patent application. As can be seen from this figure, steel sheet pile 1 has flange portions 2, a web portion 3, and asymmetrical joints 4, 5 at opposite ends having different shapes from each other.

5 Figure 2a schematically illustrates a wall, which serves as a retaining wall, for example, constructed by joining such asymmetrical steel sheet piles 1 close to the adjacent land (A.L.). Compared to a wall shown in Figure 2b which is formed by conventional symmetric steel sheet piles
10 6, the asymmetrical steel sheet piles achieve more efficient use of space, since the required working area (W.A.) shown by a dashed line in Figure 2a is smaller than that in Figure 2b. The working area (W.A.) indicates the minimum working area required to perform field installation of sheet piles
15 by means of a pile hammer. It should also be noted that the thickness (D_1) of the wall composed of the asymmetric sheet piles 1 shown in Figure 2a is much smaller than that (D_2) of the wall formed by the conventional symmetric sheet piles 6 shown in Figure 2b.

20 The above-described asymmetrical U-shaped steel sheet piles make it possible to pile them consecutively to form a wall since they are arranged in series in the same direction. The resulting wall has a section stiffness comparable to or higher than that of a wall of conventional
25 symmetric U-shaped steel sheet piles. However, there are unavoidable bulges 5a at the joint portions between adjoining sheet piles 1 of this type as shown in Figure 2a.

When a corner is to be formed in a retaining wall using conventional symmetric U-shaped steel sheet piles, a special
30 steel sheet pile having a different shape must be used to change the direction of the U-shaped sheet pile wall. Such a steel sheet pile for forming a corner will be referred to as a corner (steel) sheet pile.

Various shapes of corner steel sheet piles for use with
35 conventional U-shaped steel sheet piles are disclosed, for example, in Japanese Patent Publications Nos. 64-8139(1989), 2-60807(1990), and 6-9682(1994). Processes for producing corner steel sheet piles are disclosed in Japanese Patent

Publications Nos. 64-10281(1989) and 6-9682(1994).

When asymmetric steel sheet piles as described above are used to form a wall having a corner, it is also necessary to use a corner steel sheet pile adapted to such asymmetric sheet piles in the corner.

Figures 3a and 4a show examples of corner steel sheet piles which can be used along with conventional U-shaped steel sheet piles. The corner sheet pile shown in Figure 3a (which will be referred to as T-shaped) consists of a U-shaped sheet pile 7 and a half section of a sheet pile of the same U shape which is vertically cut in its web portion and welded to the first full sheet pile with the cut edge abutting on the backside 8 of the web portion of the first sheet pile. The corner sheet pile shown in Figure 4a (which will be referred to as W-shaped) is comprised of a U-shaped sheet pile 7 which is bent along the vertical center line of its web portion 9 and which may be reinforced by build up welding (overlaying) on the inside corner of the bend. Figures 3b and 4b schematically show the manner of joining the corner sheet piles of Figures 3a and 4a, respectively, with U-shaped sheet piles to form a corner.

However, a T-shaped corner sheet pile is roughly 1.5 times as heavy as an ordinary U-shaped sheet pile, and it is difficult to hold with a chuck of a vibro pile hammer, which is commonly used for steel sheet piles. It is also inconvenient for storage and shipping since its shape makes stacking impossible. A W-shaped corner sheet pile has a very small section modulus, even though the above-described build up welding is applied, the section modulus being insufficient to ensure that the resulting cornered wall is safe as a retaining wall. Like a T-shaped corner sheet pile, grasping a W-shaped corner sheet pile in the chuck of a pile hammer may be difficult.

Usually, an asymmetric U-shaped steel pile is manufactured by welding, but a hot rolling process can be employed to produce it. In the case of the hot rolling process, a conventional process for manufacturing symmetric U-shaped steel piles is repeated except that each of the

joints of an asymmetric U-shaped steel pile is formed little by little through a plurality of passes using a plurality of grooved rolls. The processes of forming the pile, therefore, takes place in a bilaterally symmetric manner, and grooves for its manufacture are designed to be bilaterally symmetric. This is the case for bending joint portions, too. In a final stage of rolling, therefore, joints are bent bilaterally simultaneously through passes of rolls having bilateral symmetric grooves.

10 Figures 5a and 5b are grooved rolls (K-2) before finishing and grooved rolls (K-1) for finishing, respectively, each of which comprises an upper roll (U. R.) and a lower roll (L. R.), and which are used for hot rolling a conventional type of bilaterally symmetrical U-shaped
15 steel pile. As shown in these figures, a rolling material, i.e., a U-shaped steel pile 11 comprises bilateral flange portions 10, a web portion 12, and bilateral joints 14. At the stage of Figure 5a the rolling material is shaped by hot rolling with respect to the thickness and height of joints,
20 and at the stage of Figure 5b the joints are bent to a finished shape by the grooved rolls (K-1).

Figure 6 shows the process of bending of joints by the grooved rolls (K-1) in more detail. The process can be divided into the following four steps. In Figure 6, only
25 one widthwise end of the rolling material, i.e., a U-shaped steel pile 11 comprising its flange portion 10, web portion 12, and joint 14 is shown.

In Figure 6, Step (I') shows the U-shaped steel pile just after leaving the grooved rolls (K-2), and in Step (I),
30 the U-shaped steel pile 11 is subjected to pre-deformation due to contact of the rolling material with a roll at its front edge, resulting in a decrease in the width of the steel pile. The term "width" means that of a full length of width of U-shaped steel pile.

35 In step (II), a collar 20 of the upper roll 18a contacts the outer surface of a joint 14, resulting in a decrease in width, and bending is started.

In Step (III), a lower roll 22 contacts the joint, and

in Step (IV) the upper and lower rolls 18, 22 finish bending of the joint 14. Step (IV') shows a finished sheet pile after leaving the rolls (K-1).

As shown in Figures 5 and 6, when a rolling material
5 and a rolled product have a bilaterally symmetric shape, the process of bending also goes on in a bilaterally symmetrical manner, and the position of the rolling material is bilaterally symmetric and is the same before and after being gripped by rolls.

10 In contrast, when a rolling material or rolled product is bilaterally asymmetric, and in particular when it has bilaterally asymmetric joints, deformation by bending does not occur bilaterally symmetrically in a section
15 perpendicular to the rolling direction. The position of the rolling material is bilaterally asymmetric and is different between before and after being gripped by rolls, causing a fluctuation in rolling position and incomplete bending of joints.

(Disclosure of Invention)

20 An object of the present invention is to provide an asymmetric steel sheet pile with joints having a bilaterally asymmetric shape in its section, and which can be used to form a wall by inserting the sheet piles into the ground in series, there being no bulges away from the wall at joints
25 between adjoining sheet piles.

Another object of the present invention is to provide a process for producing asymmetric steel sheet piles with joints having a bilaterally asymmetric shape in section by hot rolling, in which bending of the joints is carried out
30 without fluctuations in roll bending position and incomplete bending of joints.

Still another object of the present invention is to provide a corner steel sheet pile and a process for its production, the corner sheet pile being particularly
35 suitable for joining U-shaped sheet piles having asymmetric joints, and being capable of being grasped by the chuck of a pile hammer as well as being capable of being stacked during storage and shipping.

The inventors found that it is possible to join the opposing joints of sheet piles along a line extending from flat arm portions when one bilateral asymmetric joint is arranged downwardly and another one is arranged upwardly, and that the resulting sheet pile wall does not have bulges away from its innermost surface.

When an asymmetric steel sheet pile is produced by hot rolling, a problem does not occur during simultaneous rolling of joints until bending takes place, even if the shape of the joints is bilaterally asymmetric. However, during bending as a finishing step, when the bending is carried out simultaneously for the bilateral joints using grooved rolls, since the joints are bilaterally asymmetric, a fluctuation in the rolling position and incomplete bending are inevitable, resulting in a decreased yield.

As mentioned before, it is possible to solve such problems as those relating to rolling position by carrying out bending of bilaterally asymmetric joints little by little through multi-stage forming. However, it is less economical and impractical to carry out rolling little by little through a number of passes.

The inventors noted that even for such steel sheet piles having asymmetric joints it would be advantageous if the bilateral joints could be bent by a single pass using different grooved rolls. Thus, the present invention has been completed based on the findings that, instead of carrying out bending of bilateral joints simultaneously by a single pass, bending is carried out separately for each of the bilateral joints, and the before-mentioned problems can be solved effectively.

The inventors also designed many corner sheet piles for use in connecting the above-mentioned asymmetric sheet piles, and carried out test installation thereof. The inventors completed the present invention, therefore, based on the findings that it is possible to change the direction of a steel pile wall by 90° merely by bending inwardly either one of the joints, without using any specific corner sheet piles such as T-type sheet piles.



The present invention is summarized as follows:

- (1) An asymmetric steel sheet pile comprising a main member constituting a steel sheet pile body, two asymmetric joints, and arm portions each connected between the main member and the joint, characterized in that one of the joints faces outwardly and the other joint faces inwardly, the arm portions extend in parallel to the alignment line or the connection axis, and the arm portions and the asymmetric joints are aligned with a line of the innermost edge of the sheet pile wall.
- (2) A process for producing an asymmetric steel sheet pile, characterized in that after shaping by hot rolling of a steel sheet pile having asymmetric joints, the bilateral joints are bent one by one using different grooved rolls for each of the joints.
- (3) A process for producing an asymmetric steel sheet pile as set forth in (2) above wherein while one of the joints is subjected to finish bending, the other joint is kept within a groove of the grooved rolls and is free from bending.
- (4) An asymmetric steel sheet pile as set forth in (1) above which is further characterized in that one of the outward joint or the inward joint is bent toward the inside of the sheet pile and the resulting steel sheet pile is used as a corner sheet pile.
- (5) An asymmetric steel sheet pile as set forth in (4) above wherein the inner surface of a contact edge of the inward joint is parallel to the alignment line of the asymmetric steel sheet pile.
- (6) An asymmetric steel sheet pile as set forth in (4) above wherein the inner surface of a contact edge of the outward joint is perpendicular to the alignment line of the asymmetric steel sheet pile.
- (7) A process for producing an asymmetric corner steel sheet pile having an inwardly-facing joint and an outwardly-facing joint, characterized in that after shaping by hot rolling of an asymmetric steel sheet pile having bilateral asymmetric joints, either of the inwardly-facing joint or the outwardly-facing joint is bent toward the inside of the

THIS SHEET HAS BEEN
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sheet pile.

(8) A process for producing an asymmetric corner steel sheet pile having an inwardly-facing joint and an outwardly-facing joint, characterized in that after shaping by hot rolling of an asymmetric steel sheet pile having bilateral asymmetric joints, either of the inwardly-facing joint or the outwardly-facing joint is cut at the border between the joint and the arm portion, and the joint is turned toward the inside of the sheet pile, and the joint is fixed by welding to the arm portion.

(Brief Description of Drawings)

Figure 1 is a schematic sectional view of a prior art asymmetric U-shaped steel sheet pile.

Figure 2a is a schematic illustration of how a prior art asymmetric steel sheet pile is used, and Figure 2b shows how a prior art symmetric steel sheet pile is used.

Figure 3a is a schematic illustration of a conventional corner steel sheet pile, and Figure 3b shows how it is used.

Figure 4a is a schematic illustration of another conventional corner steel sheet pile, and Figure 4b shows how it is used.

Figure 5a is a schematic illustration of grooved rolls (K-2) which are used before finishing in the production of U-shaped steel sheet piles, and Figure 5b is a schematic illustration of a finishing grooved rolls (K-1).

Figure 6 is a schematic illustration of processes of bending joints using the grooved rolls (K-1).

Figure 7 is a schematic sectional view of an asymmetric U-shaped steel sheet pile of the present invention.

Figure 8 is a plan view of the connection of joints in accordance with an embodiment of the present invention shown in Figure 7.

Figure 9 is a plan view showing a flat portion is grasped by a chuck during construction of a sheet pile wall.

Figure 10a is a schematic illustration of grooved rolls (K-3') which are used before finishing in the production of a bilaterally asymmetric U-shaped steel sheet pile, and Figures 10b, and 10c are schematic illustrations of grooved

rolls (K-2' and K-1'), respectively.

Figure 11 is a schematic sectional view of a corner steel sheet pile of the present invention.

Figure 12 is a schematic sectional view of another corner sheet pile.

Figure 13a is an illustration of a working example of a corner sheet pile of the present invention, and Figure 13b is an enlarged view of a portion thereof.

Figure 14 is a view showing an example of producing a corner sheet pile of the present invention.

Figure 15 is a view showing another example of producing a corner sheet pile of the present invention.

Figures 16a and 16b show how the corner sheet piles of the present invention are stacked, in which Figure 16a shows the case of corner sheet piles having inward joints which are bent toward the inside, and Figure 16b shows the case of corner sheet piles having outward joints which are bent toward the inside.

Figures 17a - 17f are schematic illustrations of results of a simulation of deformation of a rolling material within grooved rolls (K-2') by means of the two-dimensional finite element method.

Figure 18 is an enlarged view showing each of the members of a joint.

Figure 19 is a view illustrating a working example using asymmetric sheet piles and corner sheet piles, both according to the present invention.

(Best mode for Carrying Out the Invention)

In conjunction with the accompanying drawings, the asymmetric steel sheet pile of the present invention and a process for its production will be described, and the corner sheet pile of the present invention and a process for its production will also be described.

Figure 7 is a general view showing an example of a U-shaped steel sheet pile 30 of the asymmetric type according to the present invention, Figure 8 shows the joint thereof, and Figure 9 shows a sheet pile wall 40 which is built by striking a series of asymmetric U-shaped sheet piles into

the ground.

As shown in Figure 7, the asymmetric U-shaped steel sheet pile 30 has a main member having a U-shape, and the main member comprises a web portion 32 and flange portions 34 to form a sheet pile body. Bilateral joints 36, 38 are arranged in an asymmetric manner, e.g., joint 36 is made inward and joint 38 is made outward, so that while the convex portions, i.e., the U-shaped sides are arranged on the same side, the joints can be combined along a line extended from the line connecting the opposite arm portions 37, i.e., they can be combined on the sheet pile wall.

Namely, arm portions 37 are provided extending in parallel to the alignment line (shown by a three-dot chain line in Figure 7), and the joint portion where the joints 36, 38 are combined is positioned together with the arm portion 37 along the same line as the innermost edge 35 of the sheet pile wall 40 (shown by a one-dot chain line in Figure 7).

In this embodiment of the present invention, one joint 38 faces outward and the other joint 36 faces inward with respect to the innermost edge which corresponds to the front edge of excavation. The joints can be combined with each other, as shown in Figure 8, in such a way that there is no protrusion from the inner side of the wall surface of the sheet pile wall 40. It is to be noted that the outward joint 38 comprises a ridge portion 39 to prevent the joints from rotating.

According to the present invention, when the asymmetric U-shaped sheet pile 30 is sunk into the ground by a hydraulic press or by a vibro pile hammer, it is possible to grasp the arm portion 37 with a chuck as shown in Figure 9. Since the arm portion 37 is positioned in parallel to the alignment line and on the same line as the line on which the joints are positioned, i.e., the connection axis (shown by a two-dot chain line in Figure 7), and the joint portion, which would be the center of rotation if the sheet pile were to rotate during striking into the ground, is located on the same level as the arm portion 37, it is possible to prevent

the steel sheet pile 30 from rotating when striking forces are applied to the chuck 44.

Furthermore, if an obstacle such as conglomerate is met underground, as shown in Figure 9, an asymmetric U-shaped steel sheet pile 30 of the present invention has an arm portion 37 which can exhibit resistance (as shown by black arrows in Figure 9) against a force (shown by a white arrow in Figure 9) tending to rotate the pile, rotation or twisting of the U-shaped sheet pile underground can be prevented.

In Figure 10a through Figure 10c some examples of grooved rolls for use in producing a bilateral asymmetric U-shaped sheet pile of the present invention are shown, i.e., grooved rolls (K-3') which are used before finish bending, and grooved rolls (K-2' and K-1') for joint bending.

A process for hot bending the joints in accordance with the present invention will be described on the basis of Figures 10.

As shown in Figure 10a, an asymmetric sheet pile 30 which is prepared by a conventional method of hot rolling with grooved rolls is introduced to grooved rolls K-3' having an upper roll (U.R.) and a lower roll (L. R.) so as to adjust its joint thickness and joint height. After the grooved rolls K-3' are employed, as shown in Figure 10b, bending of the left-hand side joint, for example, is carried out using grooved rolls K-2' comprising an upper roll (U.R.) and a lower roll (L. R.). At this stage of bending, the shape of the sheet pile 30 in section perpendicular to the rolling direction is bent in a bilaterally asymmetric manner, and its positions before and during roll bending are different from each other with respect to its bilateral shapes. According to the present invention, however, since the right-hand side joint is not subjected to bending, forced deformation can be suppressed near the roll bottom dead center, resulting in a stable rolling position, especially on the exit side. Thus, the left-hand side joint is bent successfully, and the shape of the right-hand side joint when just leaving the grooved rolls (K-3') can be

maintained.

Next, as shown in Figure 10c, the right-hand side joint is subjected to bending in the grooved rolls (K-1') while the shape of the groove on the left-hand side is designed to be the same as that of the grooved rolls (K-2'). The rolling position is stable for the same reason as mentioned before, and, as a whole, bilateral joints each having a good shape can be obtained.

According to another embodiment of the present invention, while one joint is being subjected to bending, the other joint may be formed to some extent, i.e., to an intermediate degree of bending. This degree of bending will be referred to as "intermediate bending".

Taking Figure 6 as an example, the term "intermediate bending" means bending carried out in step (II), namely until the tip of the joint is bent upright. Such a degree of bending does not adversely affect the rolling position. In addition, taking Figure 10a through Figure 10c as an example, the intermediate bending corresponds to that carried out by the grooved rolls (K-2') shown in Figure 10b in which bending proceeds to a degree where instability of rolling position remains within a tolerance.

Thus, according to the present invention, the bilateral joints are subjected to bending under conditions that a substantial degree of bending is not applied simultaneously to both joints.

As an example of the asymmetric steel sheet pile which is subjected to hot bending in accordance with the present invention, a U-shaped steel sheet pile having asymmetric bilateral joints has been described, but it will be apparent to those skilled in the art that other steel sheet piles such as Z-shaped, I-shaped, tube-type Z-shaped, and tube-type I-shaped steel sheet piles, and cylindrical steel sheet piles can be bent on their bilateral joints at the finish bending stage during hot rolling in accordance with the present invention.

The present invention will be described with respect to a corner steel sheet pile and a process for producing it.

Figure 11 and Figure 12 illustrate a corner sheet pile 54 of the present invention, which comprises an inward joint 50 and an outward joint 52. Figure 11 is a schematic view of a corner sheet pile 54 in which the inward joint 50 is
5 combined with an arm by welding with an inward inclination at an angle of 45° . Figure 12 is a schematic view of a corner sheet pile 54 in which the outward joint 52 is combined with an arm by welding with an inward inclination at an angle of 45° . In each of the drawings a welded portion
10 56 is indicated in black.

A starting asymmetric U-shaped sheet pile for forming the corner sheet pile 54 of the present invention is indicated by reference figure 30 in Figure 7, which comprises one inward joint 36 (facing downwardly) and an
15 outward joint 38 (facing upwardly) with these joints being connected with the neighboring ones in series while arranging the U-shaped portions in the same direction. As shown in Figure 7 as well as in Figure 11 and Figure 12, either one of the joints 36, 38 of sheet pile 30 is bent
20 inwardly (downwardly) at an angle of 45° at a border line 55 between a flat arm portion 37 and the joint. In Figure 7, the border line 55 is indicated by a dotted line, and this portion also corresponds to a weld portion in case the corner sheet pile is manufactured by welding.

25 Figure 13a illustrates how the corner sheet piles of the present invention, i.e., a corner sheet pile having an inward joint bent inwardly and a corner sheet pile having an outward joint bent inwardly are installed with the corresponding joints of sheet piles being combined. Figure
30 13b is an enlarged view of a portion of Figure 13a.

Since, as shown in Figure 11, the inward joint 50 is bent inwardly at an angle of 45° , an inner surface 51a of a contact edge 51 of the inward joint 50 is positioned in parallel to the alignment line (indicated by a two-dot chain
35 line in Figure 11) as well as the connection axis (indicated by a one-dot chain line in Figure 11) of steel sheet pile 54.

In addition, since, as shown in Figure 12, the outward

joint 52 is bent inwardly at an angle of 45°, an inner surface 53a of a contact edge 53 of the outward joint 52 is positioned perpendicularly to the alignment line (indicated by a two-dot chain line in Figure 12) as well as the connection axis (indicated by a one-dot chain line in Figure 12) of steel sheet pile 54.

As shown in Figures 13a and 13b, the combination of the above-mentioned two types of corner steel sheet piles in which respective bent joints are inserted into each other can make the respective alignment lines or connecting lines cross at an angle of 90°, resulting in a wall structure available as a corner portion of a sheet pile wall.

The present invention has been explained with reference to the case in which the inward or outward joint is bent inwardly by welding. Namely, an asymmetric U-shaped steel sheet pile having an inward joint and an outward joint such as shown in Figure 7 can be produced by hot rolling, and either one of the resulting joints is cut at a border line (indicated by the dashed line in Figure 7). The removed joint is turned inwardly, and the resulting joint is welded to the arm portion at the border line where the joint was previously cut. As is apparent, according to the present invention it is possible to efficiently produce corner sheet piles with a high production yield. This is because there is no waste portion of a starting U-shaped sheet pile, in contrast to a method of production of conventional T-shaped corner sheet piles by welding.

Furthermore, according to the present invention, it is possible to produce a corner sheet pile merely by bending inwardly either one of the joints of a U-shaped sheet pile having bilateral asymmetrical joints, and such bending can be achieved by hot rolling, or hot or warm forming.

Figure 14 shows an example in which an outward joint is bent inwardly by hot rolling to produce a corner sheet pile of the present invention. In Figure 14, grooved rolls comprise an upper roll 60 and a lower roll 62, and a rolling material such as pre-shaped sheet pile, e.g., an asymmetric U-shaped steel sheet pile 30 shown in Figure 7, is used.

While the upper and lower surfaces of the sheet pile 30 are constrained by the upper and lower rolls 60, 62, an outward joint 38, for example, is pressed downward so as to achieve bending by a single pass. Thus, bending of joint 38 is
5 carried out by inserting the rolling material into the grooved rolls.

Figure 15 shows an example in which an inward joint is bent inwardly by hot or warm forming to produce a corner sheet pile of the present invention. As a rolling material,
10 an asymmetric U-shaped steel sheet pile 30 shown in Figure 7 is used. Roller guides 64 are positioned at the opposite sides of the steel sheet pile 30. While the upper and lower surfaces of the sheet pile 30 are constrained by the upper and lower rollers 66, 68, and the side of the outward joint
15 38 is constrained by a roller 70 provided by on the left-hand side, an inward joint 36, for example, is pressed downward by the upper roller 66 provided on the right-hand side so as to achieve bending by a single pass. From the viewpoint of facilitating forming, it is preferable for the
20 forming roller guide 64 to be positioned near and downstream of a rolling machine for hot finishing asymmetric sheet piles 30.

The corner sheet piles of the present invention can be installed underground in the same manner as the asymmetric
25 U-shaped sheet pile of the present invention shown in Figure 7. In addition, it is possible for the chuck of a pile hammer to grasp a steel sheet pile by a web portion or arm portion. In this respect, therefore, the present invention is free from the troubles encountered by conventional T-
30 shaped or W-shaped corner sheet piles that are impossible for the chuck of a pile hammer to grasp in a usual manner.

A bend angle of the sheet pile wall, i.e., an angle between the lines of alignment of two series of sheet piles which cross each other, is 90° in most cases, but it may be
35 possible to employ an angle other than 90° , depending on the construction site. In this respect, according to the present invention, a corner sheet pile can be produced by bending either one of the joints with a roller guide

provided near or downstream of a finish rolling machine, and by adjusting the bending angle to an appropriate angle other than 90° , a corner sheet pile can be obtained which can be used at a corner having an angle other than 90° .

5 Figures 16a and 16b shows how the corner sheet piles 54 of the present invention are stacked. Figure 16a shows the case in which inward joints are bent inwardly, and Figure 16b shows the case in which outward joints are bent inwardly. As is apparent from these illustrations, joint
10 portions do not interfere with each other upon stacking, and it is possible to stack a number of sheet piles without resulting in instability of the stack.

Working examples of the present invention will be described with reference to an asymmetric steel sheet pile
15 and a process for producing a corner steel sheet pile.
(Example 1)

In order to confirm the effectiveness of the present invention, a simulation based on the two-dimensional finite element method (2D-FEM) and a rolling test using a real
20 rolling machine were carried out.

Figures 17 show results of analysis of a process of forming a rolling material within grooved rolls K-2' (see Figure 10), which was carried out by means of 2D-FEM.

According to the results shown in Figure 17a to Figure
25 17f, in the process of rolling with the grooved rolls K-2', the joint on the side free from bending (the right-hand side in Figures 17) is constrained between the grooved rolls together with a flange portion 34 and an arm portion 37, and those portions keep their original shapes. Results are
30 summarized quantitatively in Table 1 below, in which results obtained when the bilateral asymmetric joints were rolled simultaneously are also shown for comparison. The dimensions "Height (H)", "Thickness (T)", and "Gap (G)" in Table 1 are illustrated in Figure 18.

35 It is apparent from these results that it is advantageous for the asymmetric joints to be bent one by one in order to obtain well-shaped joints over the whole length of the sheet pile.

Furthermore, the present invention is effective in respect to prevention of galling during rolling of joints.

Table 1

5	<u>Deviation in dimensions of joint in the longitudinal direction (mm)</u>			Occurrence of sticking (%)
	<u>Height (H)</u>	<u>Thickness (T)</u>	<u>Gap (G)</u>	
Present				
Invention	$\sigma=0.5$	$\sigma=0.8$	$\sigma=1.1$	5.0
Comparative	$\sigma=1.2$	$\sigma=0.8$	$\sigma=2.7$	80.0

10 A hot rolling test with an actual rolling machine was carried out in accordance with the present invention, and the resulting data showed that sheet piles having good bilateral joints as shown in Figure 7 were obtained at a high yield.

15 (Example 2)

Asymmetric steel sheet piles and corner sheet piles of the present invention were produced by hot rolling and forming carried out in a manner as described in conjunction with Figures 10 and Figure 15. The resulting asymmetric U-
20 shaped steel sheet piles shown in Figure 7 and corner steel sheet piles shown in Figure 11 and Figure 12 were installed underground in combination to build a wall structure of a basement for a house.

A continuous cast slab with a thickness of 250 mm and a
25 width of 700 mm was heated to 1280°C in a heating furnace, and the heated slab was then passed to three mills, i.e., a breakdown mill (rough rolling mill), an intermediate mill, and then a finish rolling mill, each comprising double horizontal rolls, to finish hot rolling. The rolls of each
30 roll mill had 4 grooves, 3 grooves, and 3 grooves, respectively. Thus, a rolling material was subjected to reverse rolling through these three rolling mills to finish asymmetric U-shaped sheet piles, as shown in Figure 7.

On the other hand, as shown in Figure 15, the corner
35 sheet pile was produced by using a roller guide and forming roller to bend outward joints at angle of 45° inwardly to

produce corner sheet piles of type A (see Fig. 12), and to bend inward joints at an angle of 45° inwardly to produce corner sheet piles of type B (see Fig. 11).

Hot rolled sheet piles were also produced in the same production chance (lot) by expanding the gaps between the roller guides and between rollers.

Thus prepared sheet piles, i.e., four corner sheet piles of type A, four corner sheet piles of type B, and 30 asymmetric U-shaped steel sheet piles which constituted main wall portions were installed underground to build a retaining wall of a pit for use as a basement for a house. Figure 19 shows the resulting structure of steel sheet piles, in which the corner sheet pile of type A is indicated merely by the symbol "A", and that of type B is by the symbol "B". The other sheet piles are asymmetric steel sheet piles as shown in Figure 7.

As is apparent from Figure 19, six sheet piles extending in the vertical direction in the figure (two out of the six are corner sheet piles) and thirteen sheet piles extending in the lateral direction in the figure (two out of the thirteen are corner sheet piles) were successfully installed underground without any troubles.
(Industrial Applicability)

According to the present invention, asymmetric U-shaped steel sheet piles which can be arranged such that the joints and flat arm portions are positioned on the same plane corresponding to the innermost edge of a sheet pile wall can be obtained. These asymmetric U-shaped steel sheet piles having bilateral asymmetric joints can be produced by hot rolling which is free from instability of rolling position and imperfect bending of joints, resulting in sheet piles having well-shaped joints.

Furthermore, the asymmetric sheet piles and corner sheet piles of the present invention are free from troubles encountered when being grasped by a chuck during installation, and troubles encountered during transportation and storage. In addition, the sheet piles and corner sheet piles of the present invention can be installed underground

in series with adjoining piles facing in the same direction. Thus, the present invention is effective for improving ease of construction with minimum manpower, and is also effective for reducing construction costs. In particular, the corner
5 sheet pile can be produced from the asymmetric U-shaped steel sheet pile of the present invention merely by cutting off part of the sheet pile and then fixing the part back to the sheet pile by welding. This means that the corner sheet piles of the present invention can be produced without
10 modification of manufacturing facilities to a large extent, but merely by modifying the rolling roll structure to some extent or by adding a roller guide. Thus, the present invention is quite valuable from an industrial viewpoint.



Claims

1. An asymmetric steel sheet pile comprising a main member constituting a steel sheet pile body, two asymmetric joints, and arm portions each connected between the main member and the joint, characterized in that one of the joints faces outwardly and the other joint faces inwardly, the arm portions extend in parallel to the alignment line or the connecting axis, and the arm portions and the asymmetric joints are aligned with a line of the innermost edge of the sheet pile wall.
2. A process for producing an asymmetric steel sheet pile, characterized in that after shaping by hot rolling of a steel sheet pile having bilateral asymmetric joints, the bilateral joints are bent one by one using different grooved rolls for each of the joints.
3. A process for producing an asymmetric steel sheet pile as set forth in Claim 2 wherein while one of the joints is subjected to finish bending, the other joint is kept within a groove of the grooved rolls while being free from bending.
4. An asymmetric steel sheet pile as set forth in Claim 1 which is further characterized in that one of the outward joint and the inward joint is bent inwardly with respect to the sheet pile and the resulting steel sheet pile is used as a corner sheet pile.
5. An asymmetric steel sheet pile as set forth in Claim 4 wherein the inner surface of a contact edge of the inward joint is parallel to the alignment line of the asymmetric steel sheet pile.
6. An asymmetric steel sheet pile as set forth in Claim 4 wherein the inner surface of a contact edge of the outward joint is perpendicular to the alignment line of the asymmetric steel sheet pile.
7. A process for producing an asymmetric corner steel sheet pile having an inward joint and an outward joint, characterized in that after shaping by hot rolling of an asymmetric steel sheet pile having bilateral asymmetric joints, either of the inward joint or the outward joint is bent toward the inside of the sheet pile.

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8. A process for producing an asymmetric corner steel sheet pile having an inward joint and an outward joint, characterized in that after shaping by hot rolling of an asymmetric steel sheet pile having bilateral asymmetric
- 5 joints, either of the inward joint or the outward joint is cut off at the border between the joint and the arm portion, and the joint is turned toward the inside of the sheet pile, and the joint is fixed to the arm portion by welding.

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