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(54) REUSABLE METAL SHEET PILE

WIEDERVERWENDBARE SPUNDWAND AUS METAL

PALPLANCHE MÉTALLIQUE RÉUTILISABLE

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Description

[0001] The present invention relates to a metal sheet pile, in particular a metal sheet pile for the construction of temporary structures.

[0002] It is well known to use metal sheet piles for the construction of earth retaining structure, such as river embankments, quay walls of ports, retaining walls, cut-off walls, basements, underground carparks, abutments for bridges or earthquake strengthening structures, where a differential surface level is to be established. These structures can be either temporary or permanent.

[0003] More particularly, the metal sheet piles are driven in the ground, alone or in pairs so that the interlock located on one of their lateral extremities slot into the interlock of a metal sheet pile previously driven in the ground. Once the metal sheet piles have been assembled, the assembly must resist the mechanical constraints imposed by the ground. The metal sheet piles are thus designed to have both a good drivability and a good resistance to declutching.

[0004] In the specific case of temporary structures, when the metal sheet piles are removed and reused, the interlock gets damaged which jeopardizes the tightness and weaken the resistance of the structure.

[0005] The document CN201386275Y discloses a metal sheet pile comprising in cross-section a central web bordered by outwardly inclined flanges, the extremities of which are inclined at an angle α of at least 97° with respect to the neutral axis of the metal sheet pile and are extended by an interlock comprising: a bottom part, convexly extending outward from the extremity of the inclined flange, comprising an internal side and an external side separated by a radial thickness, the internal side extending along a first portion of circle whose center lies in a plane perpendicular to the plane as defined above by the neutral axis and 1.1 the external side extending along a second portion of circle whose center lies in plane perpendicular to the plane as defined above by the neutral axis and whose radius of curvature is at least equal the radius of curvature of the internal side plus the radial thickness separating said internal and external sides.

[0006] The aim of the present invention is therefore to remedy the drawbacks of the metal sheet piles of the prior art by providing a sheet pile whose drivability and reusability have been improved while maintaining a good resistance to declutching.

[0007] For this purpose, a first subject of the present invention consists of a metal sheet pile comprising in cross-section a central web bordered by outwardly inclined flanges, the extremities of which are inclined at an angle α of at least 97° with respect to the neutral axis P_1 of the metal sheet pile and are extended by an interlock comprising consecutively:

- A bottom part, convexly extending outward from the extremity of the inclined flange, comprising an internal side and an external side separated by a radial thickness T_1, the internal side extending along a first portion of circle whose center lies in a plane P_2 perpendicular to plane P_1 and whose radius of curvature R_1 satisfies inequation (i) :

$$1.5 \leq R_1/T_1 \leq 5 \text{ (i)}$$

  and the external side extending along a second portion of circle whose center lies in plane P_2 and whose radius of curvature R2 is at least equal to R1+T1,
- A finger of substantially triangular cross-section, extending upward from the bottom part, pointing towards the inclined flange, having a projected width W_1 on plane P_1, the fingertip being separated from the inclined flange by distance W_2, W_1 and W_2 satisfying the inequation (ii):

$$1.2 \leq W_1/W_2 \leq 1.7 \text{ (ii)}.$$

[0008] The metal sheet pile according to the invention may also have the optional features listed below, considered individually or in combination:

- angle α is comprised between 97° and 101°,
- the ratio between the radius of curvature R_1 and the radial thickness T_1 is comprised between 1.5 and 2.5,
- the perpendicular bisector of the first portion of circle is within plane P_2,
- the first portion of circle has an angle of aperture γ comprised between 20° and 137°,
- the perpendicular bisector of the first portion of circle and the perpendicular bisector of the second portion of circle are identical,
- R_2 is equal to R_1+T_1,
- the finger comprises a lateral side and a top side, the vertex of which is rounded with a radius of curvature R_3 equal to the radius of curvature R_1 of the internal side of the bottom part,
- the ratio between the projected width W_1 of the finger and the distance W_2 is comprised between 1.45 and 1.55,
- at least one of the inclined flanges comprise two sides which converge in the direction of the interlock with a

convergence rate comprised between 1 and 3%,

- at least one of the inclined flanges comprises a shoulder located at the junction between the central web and the at least one of the inclined flanges,
- the connections between the central web and the inclined flanges delimit concave corners which are substantially flattened by a material surcharge.

[0009] A second subject of the invention consists of an earth retaining structure comprising at least two metal sheet piles according to the invention interlocked to one another.

[0010] Other characteristics and advantages of the invention will be described in greater detail in the following description.

[0011] The invention will be better understood by reading the following description, which is provided purely for purposes of explanation and is in no way intended to be restrictive, with reference to:

- Figure 1, which is a cross-section of the metal sheet pile according to one variant of the invention,
- Figure 2, which is a cross-section of the metal sheet pile according to another variant of the invention,
- Figure 3, which is a partial cross-section of the metal sheet pile according to the variant illustrated on Figure 1,
- Figure 4, which is a partial cross-section of the interlocking of two adjacent metal sheet piles according to one variant of the invention,
- Figure 5, which is a cross-section of the interlock of a metal sheet pile according to one variant of the invention,
- Figure 6, which is a cross-section of the interlock of a metal sheet pile according to one variant of the invention,
- Figure 7, which is an illustration of the rotational capacity of the metal sheet pile according to one variant of the invention,
- Figure 8, which is a cross-section of the interlock of a metal sheet pile according to another variant of the invention,
- Figure 9, which is an illustration of the resistance to declutching of the metal sheet pile according to one variant of the invention,
- Figure 10, which is an illustration of the resistance to declutching of the metal sheet pile according to another variant of the invention.

[0012] It should be noted that the terms "above", "outward", "outwardly", "convexly", "concave" ... as used in this application refer to the positions and orientations of the different constituent elements of the metal sheet pile when the y-y axis of the sheet pile is horizontal.

[0013] With reference to Figure 1, the metal sheet pile 1 according to the invention first comprises, in cross-section perpendicular to its length, a central web 2 and a first inclined flange 3 and a second inclined flange 4 both extending outwardly from the lateral edges of the central web.

[0014] The metal sheet pile is preferably made of steel and obtained by hot rolling.

[0015] The central web is preferably substantially flat and lies in a plane. It is preferably of constant thickness across the cross-section.

[0016] The two inclined flanges extend either on the same side of the central web so as to form a U-shaped sheet pile (as illustrated on Figure 1) or on two different sides so as to form a Z-shaped sheet pile (as illustrated on Figure 2). The angle β between the central web and one inclined flange is generally comprised between 110° and 150°. The sheet pile is preferably a U-shaped sheet pile. Preferably, inclined flanges 3 and 4 are symmetrical.

[0017] According to one variant of the invention, the inclined flange is of constant thickness across the cross-section. According to the variant illustrated on Figure 3, its thickness decreases towards the extremity of the sheet pile, i.e. towards the interlock. In other words, the inclined flange has a conical cross-section. More preferably, the two sides of the flange converge in the direction of the interlock with a convergence rate comprised between 1 and 3%. The convergence rate is defined as the difference between the thicknesses at two points of the wing divided by the distance between these two points. The conicity of the inclined flange(s) improves the drivability of the metal sheet pile while optimizing its weight.

[0018] According to one variant of the invention illustrated on Figure 3, the inclined flange(s) 3, 4 can comprise a shoulder 5 located at the junction between the central web 2 and the inclined flange(s). By "shoulder", it is meant a material extension projecting with respect to the imaginary plane which prolongs the external face of the inclined flange towards the central web. The shoulder increases the resistance modulus and thus the reusability of the metal sheet pile.

[0019] Alternatively, or in addition to shoulder 5, the central web can comprise an extension (not illustrated) projecting with respect to the imaginary plane which prolongs the external face of the central web towards the inclined flange.

[0020] Similarly, the bending radius at the junction between the central web 2 and the inclined flange(s) 3, 4 can be increased so as to thicken the connection of the central web and the inclined flange(s) from the inside. In other words, the concave corners 6 delimited by the two flange/web connections are substantially flattened by a material surcharge. This increases the mechanical resistance of the metal sheet pile and, thus, improves its reusability.

[0021] The extremity of the inclined flanges, defined as the end of the inclined flanges located on the opposite side of the

central web, are inclined at an angle α of at least 97° with respect to the neutral axis P_1 of the metal sheet pile. The neutral axis is defined as the axis along which there are no stresses or strains. The neutral axis is always parallel to the y-y axis of the sheet pile as defined in EN1993-5:2007. In the case of a U-shaped sheet pile, the interlocks are on the neutral axis; in other words, the central web is parallel to the neutral axis. In the case of a Z-shaped sheet pile, the neutral axis is parallel to the inclined flanges and cross the central web in its middle. Thanks to this inclination, and in combination with the shape of the interlock (described later on), the rotational capacity of the sheet pile is improved. This improved rotational capacity strongly limits the risk of deforming the interlock when the sheet pile is driven in the ground and/or removed before reuse. More preferably, angle α is comprised between 97° and 101° in order to have the best compromise between rotational capacity and resistance to declutching.

[0022] According to one variant of the invention, the flange is straight in that case. According to another preferred variant illustrated on Figure 3, the extremity of the inclined flange is bent so that angles α and β differ. Thanks to this bent at the extremity of the inclined flange, angle β can be adjusted to optimize the tension modulus of the sheet pile while angle α is adjusted differently to optimize the rotational capacity of the sheet pile. According to the variant illustrated on Figure 2, one of the extremities of the inclined flanges is inclined with respect to the neutral axis in the form of a protrusion thickening the extremity in direction of the neutral axis. The other extremity is bent so that the interlocking is possible.

[0023] With reference to Figure 1, the metal sheet pile 1 according to the invention further comprises a first interlock 8 and a second interlock 9 extending from the extremity of respectively the first inclined flange 3 and the second inclined flange 4. Interlocks 8 and 9 are designed so that interlock 8 of a first metal sheet pile can slot into interlock 9 of a second metal sheet pile, as illustrated on Figure 4.

[0024] With reference to Figures 5 and 6, each of the two interlocks 8, 9 comprises a bottom part 10 convexly extending outward from the extremity of the inclined flange and a finger 11 of substantially triangular cross-section, extending upward from the bottom part. The extremity of the inclined flange, the bottom part and the finger delimit a chamber 12. As illustrated on Figure 4, the finger of a first metal sheet pile can slot into the chamber of a second metal sheet pile so as to connect the two sheet piles.

[0025] The bottom part 10 comprises an internal side 13 and an external side 14 separated by a radial thickness T_1. By internal side, it is meant the side facing the chamber 12 and which extends from the external face of the inclined flange. The external side is thus the side at the opposite from the chamber and which extends from the internal face of the inclined flange.

[0026] The internal side 13 extends along a first portion of circle 15 whose center lies in a plane P_2 perpendicular to plane P_1 and whose radius of curvature R_1 satisfies inequation (i) :

$$1.5 \leq R_1/T_1 \leq 5 \qquad \text{(i)}$$

[0027] As the thickness of the bottom part can vary along its cross-section, the radial thickness T_1 is defined as the thickness measured along the perpendicular bisector of the first portion of circle 15.

[0028] As the bottom part extends convexly from the extremity of the inclined flange, the center of the circle corresponding to the first portion of circle 15 is located above the bottom part.

[0029] Thanks to the rounded bottom part, and in particular to the ratio between the radius of curvature R_1 and the radial thickness T_1, the chamber 12 presents a rounded shape which improves the rotational capacity of the sheet pile. This is illustrated on Figure 7 where the illustrated variant allows rotating the interlock by 19° both clockwise and counter-clockwise. In combination with the inclination of the extremity of the inclined flange, the rounded bottom part thus strongly limits the risk of deforming the interlock when the sheet pile is driven in the ground and/or removed before reuse.

[0030] More preferably the ratio between the radius of curvature R_1 and the radial thickness T_1 is comprised between 1.5 and 2.5. This was found to be the best compromise between rotational capacity and resistance to declutching.

[0031] Preferably, the perpendicular bisector of the first portion of circle 15 is within plane P_2. This symmetry favors the interlocking of two adjacent sheet piles.

[0032] Preferably, the first portion of circle 15 has an angle of aperture γ comprised between 30° and 140°, depending on the radius of curvature R_1. This favors a smooth transition between the bottom part and, on one side, the finger and, on the other side, the inclined flange. More preferably, the radius of curvature R_1 and the angle of aperture γ satisfy the inequation (iii):

$$100116\ (R_1)^{-2.499} \leq \gamma \leq 3044\ (R_1)^{-1.122} \qquad \text{(iii)}$$

[0033] The external side 14 extends along a second portion of circle 16 whose center lies in plane P_2 and whose radius of curvature R_2 is at least equal to R_1+T1.

[0034] Preferably, the perpendicular bisector of the first portion of circle 15 and the perpendicular bisector of the second portion of circle 16 are identical. This ensures a symmetrical distribution of the material on both sides of the perpendicular

bisector of the first portion of circle 15. This favors a homogeneous behavior of the interlock.

[0035] According to one variant of the invention, the second portion of circle 16 and the first portion of circle are concentric. In that case, R_2 is equal to R_1+T1.

[0036] According to another variant of the invention illustrated on Figure 8, R_2 is greater than R_1+T1. In other words, this means that the bottom part 10 is thicker on its extremities than along the perpendicular bisector of the first portion of circle 15. This material surcharge on the extremities reinforces the mechanical resistance of the interlock and, in particular, its resistance to declutching.

[0037] With reference to Figures 5 and 6, the finger 11 is of substantially triangular cross-section, extending upward from the bottom part, pointing towards the inclined flange. Preferably, the cross-section of finger 11 is substantially a rectangular triangle, whose hypotenuse 17 is facing the chamber 12, whose lateral side 18 is parallel to plane P_2 and whose top side 19 is parallel to plane P_1. More preferably, the vertex between the lateral side and the top side is rounded. Even more preferably, the radius of curvature R_3 of the rounded vertex is equal to the radius of curvature R_1 of the internal side 13 of the bottom part 10. This favors the interlocking of two interlocks and improves the rotational capacity of the sheet pile.

[0038] Preferably, the vertex between the top side and the hypotenuse is rounded too to favors the interlocking of two interlocks.

[0039] The finger 11 has a projected width W_1 which is defined as the distance along a plane parallel to P_1 between the fingertip 20 and the plane P_3, perpendicular to P_1, which contains the lateral side 18.

[0040] The finger 11 is separated from the extremity of the inclined flange by the distance W_2, which is defined as the distance along a plane parallel to P_1 between the fingertip 20 and the inclined flange.

[0041] The finger 11 is positioned so that W1 and W2 satisfy the inequation (ii):

$$1.2 \leq W_1/W_2 \leq 1.7 \qquad \text{(ii)}$$

[0042] Thanks to this ratio between the projected width W_1 of the finger and the distance W_2, the two interlocks 8, 9 can more easily interlock and rotate while maintaining a good resistance to declutching. Thanks to this ratio, and in combination with the rounded shape of the bottom part 10 and the inclination of the extremity of the inclined flange, the rotational capacity of the sheet pile is improved. This improved rotational capacity strongly limits the risk of deforming the interlock when the sheet pile is driven in the ground and/or removed before reuse.

[0043] Preferably, the ratio between the projected width W_1 of the finger and the distance W_2 is comprised between 1.45 and 1.55. This was found to be the best compromise between rotational capacity and resistance to declutching.

[0044] Numerical simulations with the Qform metal forming simulation software have been performed on the metal sheet piles according to the invention. The performed simulation is similar to a tensile test where a continuous axial displacement is imposed in the tool direction and the force on the clamp is measured. The results are presented in Figure 9 where X is the time in seconds and Y is the force in MN. They show that, when R_2 is equal to R_1+T_1, the interlock resists a load of 0.085 MN before declutching, which is similar to the performances obtained with the metal sheet pile from the prior art. The results presented in Figure 10 show that increasing the radius of curvature R_2 compared to R_1 (as illustrated on Figure 8) further improves the resistance to declutching.

Claims

1. Metal sheet pile (1) comprising in cross-section a central web (2) bordered by outwardly inclined flanges (3, 4), the extremities of which are inclined at an angle α of at least 97° with respect to the neutral axis P_1 of the metal sheet pile and are extended by an interlock (8, 9) comprising consecutively:

   - A bottom part (10), convexly extending outward from the extremity of the inclined flange, comprising an internal side (13) and an external side (14) separated by a radial thickness T_1, the internal side extending along a first portion of circle (15) whose center lies in a plane P_2 perpendicular to plane P_1 and whose radius of curvature R_1 satisfies inequation (i) :

   $$1.5 \leq R_1/T_1 \leq 5 \text{ (i)}$$

   and the external side extending along a second portion of circle (16) whose center lies in plane P_2 and whose radius of curvature R2 is at least equal to R1+T1,
   - A finger (11) of substantially triangular cross-section, extending upward from the bottom part, pointing towards the inclined flange, having a projected width W_1 on plane P_1, the fingertip (20) being separated from the inclined flange by distance W_2, W_1 and W_2 satisfying the inequation (ii):

$$1.2 \leq W_1/W_2 \leq 1.7 \text{ (ii)}.$$

2. Metal sheet pile according to claim 1 wherein angle α is comprised between 97° and 101°.

3. Metal sheet pile according to any one of claims 1 or 2 wherein the ratio between the radius of curvature R_1 and the radial thickness T_1 is comprised between 1.5 and 2.5.

4. Metal sheet pile according to any one of the preceding claims wherein the perpendicular bisector of the first portion of circle (15) is within plane P_2.

5. Metal sheet pile according to any one of the preceding claims wherein the first portion of circle (15) has an angle of aperture γ comprised between 20° and 137°.

6. Metal sheet pile according to any one of the preceding claims wherein the perpendicular bisector of the first portion of circle (15) and the perpendicular bisector of the second portion of circle (16) are identical.

7. Metal sheet pile according to any one of the preceding claims wherein R_2 is equal to R_1+T_1.

8. Metal sheet pile according to any one of the preceding claims wherein the finger (11) comprises a lateral side (18) and a top side (19), the vertex of which is rounded with a radius of curvature R_3 equal to the radius of curvature R_1 of the internal side (13) of the bottom part (10).

9. Metal sheet pile according to any one of the preceding claims wherein the ratio between the projected width W_1 of the finger and the distance W_2 is comprised between 1.45 and 1.55.

10. Metal sheet pile according to any one of the preceding claims wherein at least one of the inclined flanges (3, 4) comprises two sides which converge in the direction of the interlock with a convergence rate comprised between 1 and 3%.

11. Metal sheet pile according to any one of the preceding claims wherein at least one of the inclined flanges (3, 4) comprises a shoulder located at the junction between the central web (2) and the at least one of the inclined flanges (3, 4).

12. Metal sheet pile according to any one of the preceding claims wherein the connections between the central web and the inclined flanges delimit concave corners (6) which are substantially flattened by a material surcharge.

13. Earth retaining structure comprising at least two metal sheet piles according to any one of claims 1 to 12 interlocked to one another.

Patentansprüche

1. Metallene Spundwand (1), die im Querschnitt einen Mittelsteg (2) aufweist, der von nach außen geneigten Flanschen (3, 4) begrenzt wird, deren Enden in einem Winkel α von mindestens 97° gegenüber der neutralen Achse P_1 der metallenen Spundwand geneigt sind und durch ein Schloss (8, 9) verlängert werden, das aus aufeinanderfolgenden Teilen besteht:

   - Ein Bodenteil (10), das sich vom Ende des geneigten Flansches konvex nach außen erstreckt, mit einer Innenseite (13) und einer Außenseite (14), die durch eine radiale Dicke T_1 getrennt sind, wobei sich die Innenseite entlang eines ersten Kreisabschnitts (15) erstreckt, dessen Mittelpunkt in einer Ebene P_2 senkrecht zur Ebene P_1 liegt und dessen Krümmungsradius R_1 die Ungleichung (i) erfüllt:

$$1.5 \leq R_1/T_1 \leq 5\text{(i)}$$

   und die Außenseite sich entlang eines zweiten Kreisabschnitts (16) erstreckt, dessen Mittelpunkt in der Ebene P_2 liegt und dessen Krümmungsradius R2 mindestens gleich R1+T1 ist,
   - Ein Finger (11) mit im wesentlichen dreieckigem Querschnitt, der sich vom Bodenteil nach oben erstreckt, in

Richtung des geneigten Flansches zeigt und eine vorstehende Breite W_1 auf der Ebene P_1 hat, wobei die Fingerspitze (20) von dem geneigten Flansch durch einen Abstand W_2 getrennt ist, wobei W_1 und W_2 die Ungleichung (ii) erfüllen:

$$1.2 \leq W_1/W_2 \leq 1.7 \text{ (ii)}.$$

2. Metallene Spundwand nach Anspruch 1, wobei der Winkel α zwischen 97° und 101° liegt.

3. Metallene Spundwand nach einem der Ansprüche 1 oder 2, wobei das Verhältnis zwischen dem Krümmungsradius R_1 und der radialen Dicke T_1 zwischen 1,5 und 2,5 liegt.

4. Metallene Spundwand nach einem der vorhergehenden Ansprüche, wobei die Mittelsenkrechte des ersten Kreisabschnitts (15) in der Ebene P_2 liegt.

5. Metallene Spundwand nach einem der vorhergehenden Ansprüche, wobei der erste Kreisabschnitt (15) einen Öffnungswinkel γ zwischen 20° und 137° aufweist.

6. Metallene Spundwand nach einem der vorhergehenden Ansprüche, wobei die Mittelsenkrechte des ersten Kreisabschnitts (15) und die Mittelsenkrechte des zweiten Kreisabschnitts (16) identisch sind.

7. Metallene Spundwand nach einem der vorhergehenden Ansprüche, wobei R_2 gleich R_1+T_1 ist.

8. Metallene Spundwand nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** der Finger (11) eine Seitenfläche (18) und eine Oberseite (19) aufweist, deren Scheitelpunkt mit einem Krümmungsradius R_3 abgerundet ist, der gleich dem Krümmungsradius R_1 der Innenseite (13) des Bodenteils (10) ist.

9. Metallene Spundwand nach einem der vorhergehenden Ansprüche, wobei das Verhältnis zwischen der vorstehenden Breite W_1 des Fingers und dem Abstand W_2 zwischen 1,45 und 1,55 liegt.

10. Metallene Spundwand nach einem der vorhergehenden Ansprüche, wobei mindestens einer der geneigten Flansche (3, 4) zwei Seiten aufweist, die in Richtung des Schlosses mit einer Konvergenzrate zwischen 1 und 3 % konvergieren.

11. Metallene Spundwand nach einem der vorhergehenden Ansprüche, wobei mindestens einer der geneigten Flansche (3, 4) eine Schulter aufweist, die an der Verbindung zwischen dem Mittelsteg (2) und mindestens einem der geneigten Flansche (3, 4) angeordnet ist.

12. Metallene Spundwand nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die Verbindungen zwischen dem Mittelsteg und den geneigten Flanschen konkave Ecken (6) begrenzen, die durch einen Materialzuschlag im Wesentlichen abgeflacht sind.

13. Erdstützbauwerk, bestehend aus mindestens zwei miteinander verriegelten metallenen Spundwänden nach einem der Ansprüche 1 bis 12.

Revendications

1. Palplanche métallique (1) comprenant en section transversale une âme centrale (2) bordée par des brides inclinées vers l'extérieur (3, 4), dont les extrémités sont inclinées à un angle α d'au moins 97° par rapport à l'axe neutre P_1 de la palplanche métallique et sont prolongées par un verrouillage mutuel (8, 9) comprenant consécutivement :

- Une partie inférieure (10), s'étendant de manière convexe vers l'extérieur à partir de l'extrémité de la bride inclinée, comprenant un côté interne (13) et un côté externe (14) séparés par une épaisseur radiale T_1, le côté interne s'étendant le long d'une première portion de cercle (15) dont le centre se trouve dans un plan P_2 perpendiculaire au plan P_1 et dont le rayon de courbure R_1 satisfait l'inéquation (i) :

$$1,5 \leq R_1/T_1 \leq 5 \text{ (i)}$$

et le côté extérieur s'étendant le long d'une seconde partie de cercle (16) dont le centre se trouve dans le plan P_2 et dont le rayon de courbure R2 est au moins égal à R1+T1,
- Un doigt (11) de section transversale sensiblement triangulaire, s'étendant vers le haut à partir de la partie inférieure, orienté vers la bride inclinée, ayant une largeur projetée W_1 sur le plan P_1, l'extrémité du doigt (20) étant séparée de la bride inclinée par une distance W_2, W_1 et W_2 satisfaisant l'inéquation (ii) :

$$1{,}2 \leq W_1/W_2 \leq 1{,}7 \text{ (ii)}.$$

2. Palplanche métallique selon la revendication 1, dans laquelle l'angle α est compris entre 97° et 101°.

3. Palplanche métallique selon l'une quelconque des revendications 1 ou 2, dans laquelle le rapport entre le rayon de courbure R_1 et l'épaisseur radiale T_1 est compris entre 1,5 et 2,5.

4. Palplanche métallique selon l'une quelconque des revendications précédentes, dans laquelle la bissectrice perpendiculaire de la première partie de cercle (15) se trouve dans le plan P_2.

5. Palplanche métallique selon l'une quelconque des revendications précédentes, dans laquelle la première partie de cercle (15) présente un angle d'ouverture γ compris entre 20° et 137°.

6. Palplanche métallique selon l'une quelconque des revendications précédentes, dans laquelle la bissectrice perpendiculaire de la première partie de cercle (15) et la bissectrice perpendiculaire de la seconde partie de cercle (16) sont identiques.

7. Palplanche métallique selon l'une quelconque des revendications précédentes, dans laquelle R_2 est égal à R_1+T_1.

8. Palplanche métallique selon l'une quelconque des revendications précédentes, dans laquelle le doigt (11) comprend un côté latéral (18) et un côté supérieur (19) dont le sommet est arrondi avec un rayon de courbure R_3 égal au rayon de courbure R_1 du côté interne (13) de la partie inférieure (10).

9. Palplanche métallique selon l'une quelconque des revendications précédentes, dans laquelle le rapport entre la largeur projetée W_1 du doigt et la distance $\backslash N_2$ est compris entre 1,45 et 1,55.

10. Palplanche métallique selon l'une quelconque des revendications précédentes, dans laquelle au moins l'une des brides inclinées (3, 4) comporte deux côtés qui convergent dans la direction du verrouillage mutuel avec un taux de convergence compris entre 1 et 3 %.

11. Palplanche métallique selon l'une quelconque des revendications précédentes, dans laquelle au moins l'une des brides inclinées (3, 4) comporte un épaulement situé à la jonction entre l'âme centrale (2) et au moins une des brides inclinées (3, 4).

12. Palplanche métallique selon l'une quelconque des revendications précédentes, dans laquelle les raccords entre l'âme centrale et les brides inclinées délimitent des coins concaves (6) qui sont sensiblement aplatis par une surcharge de matériau.

13. Structure de retenue des terres comprenant au moins deux palplanches métalliques selon l'une quelconque des revendications 1 à 12, verrouillées l'une à l'autre.

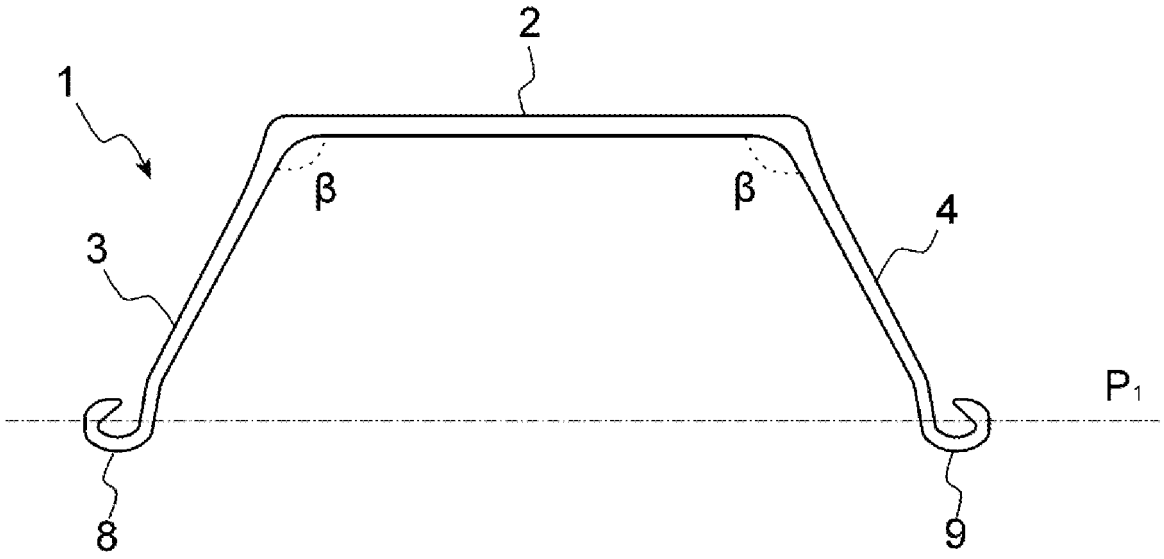

Figure 1

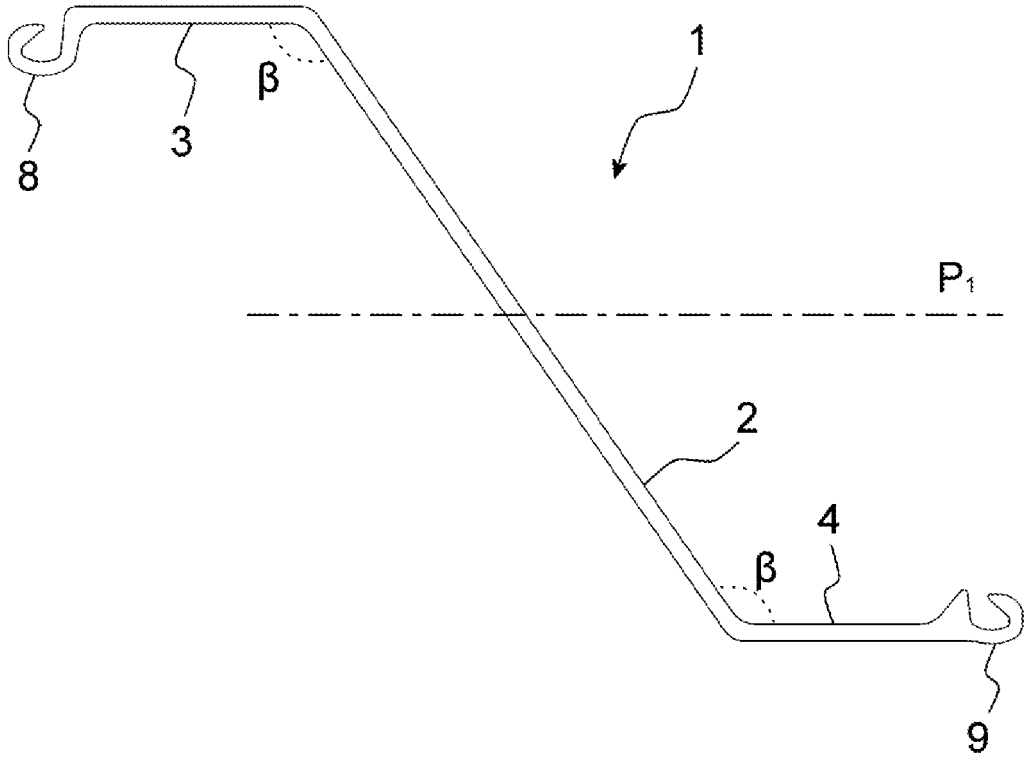

Figure 2

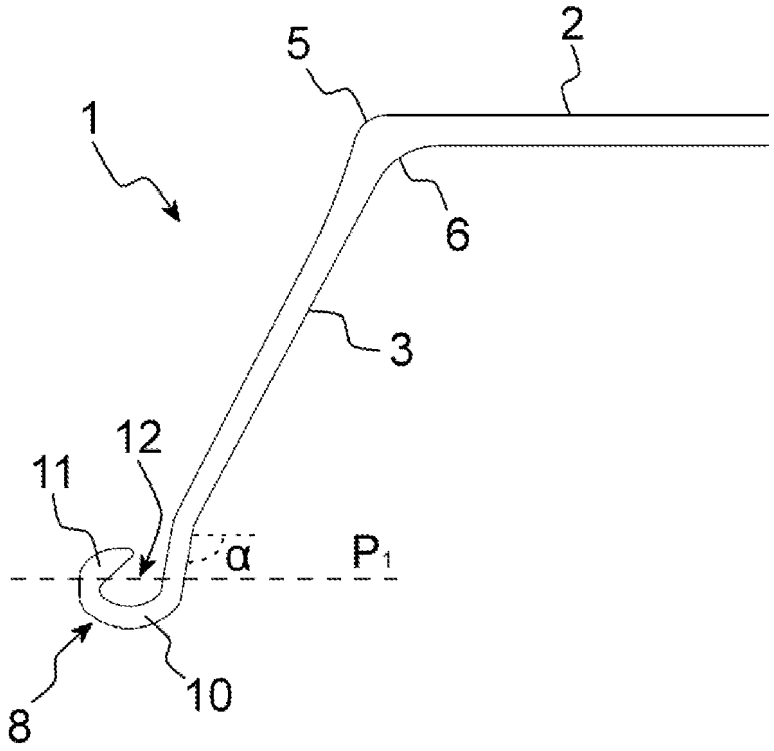

Figure 3

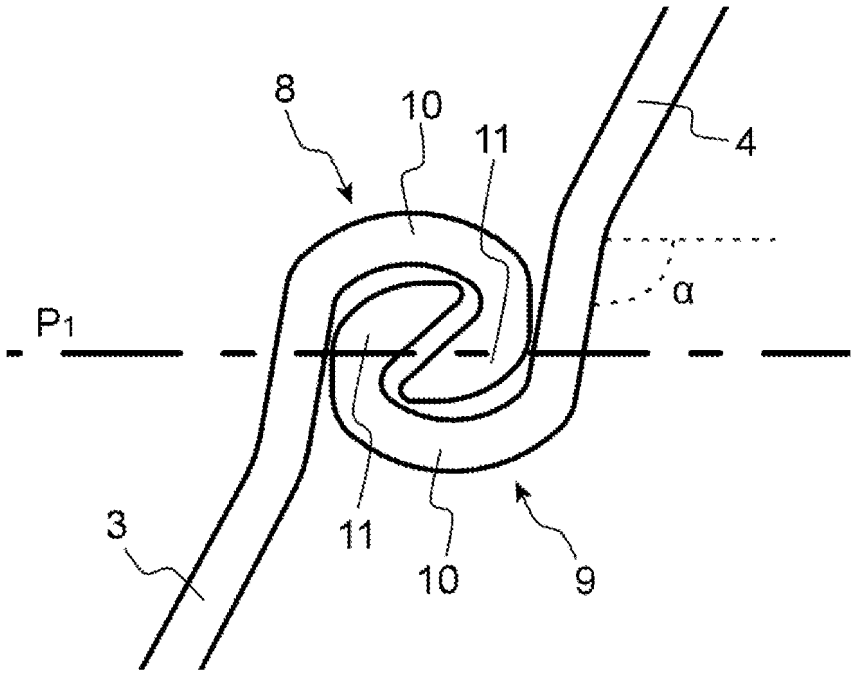

Figure 4

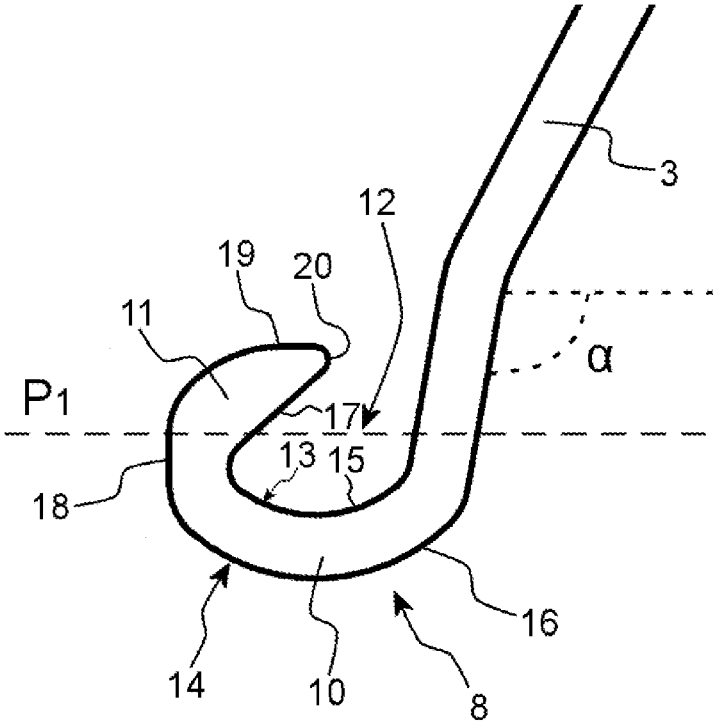

Figure 5

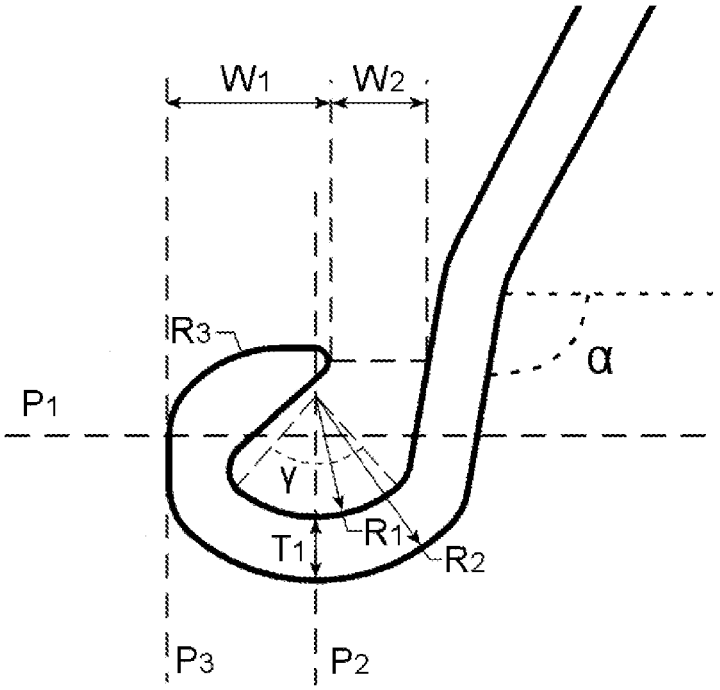

Figure 6

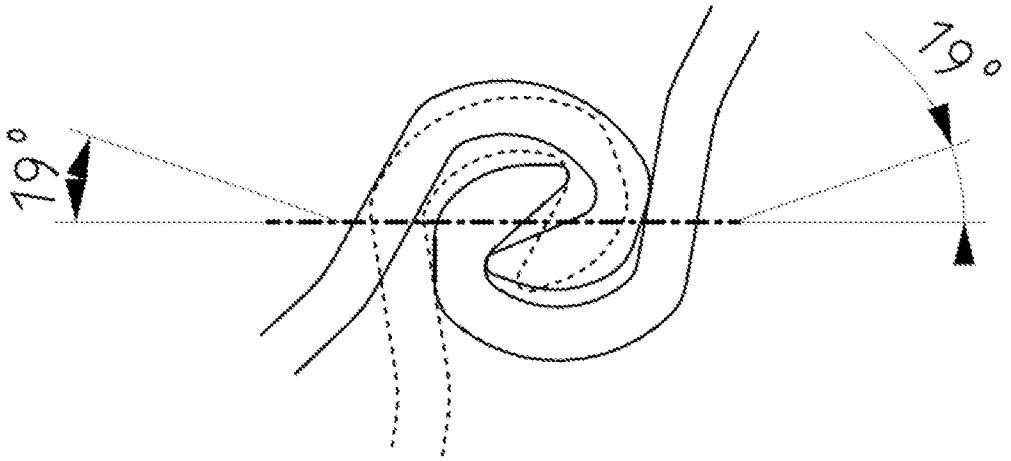

Figure 7

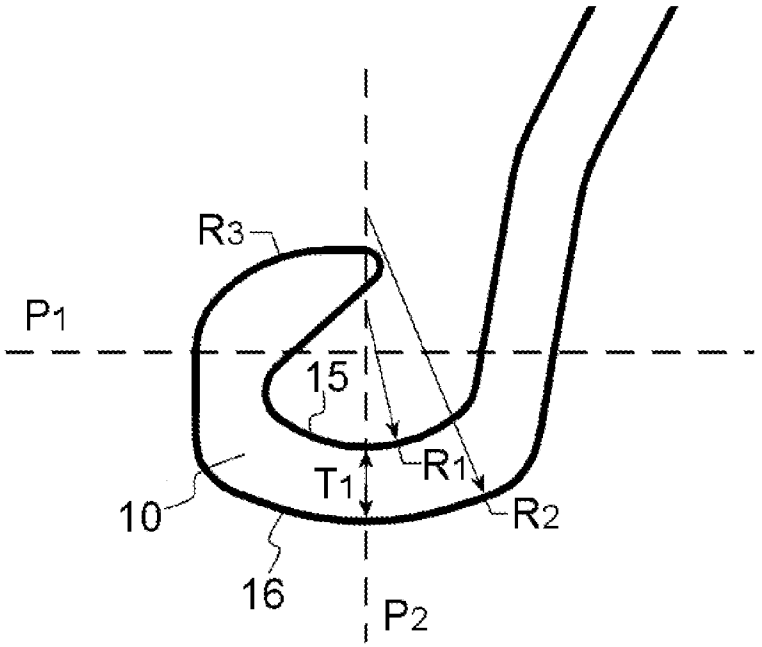

Figure 8

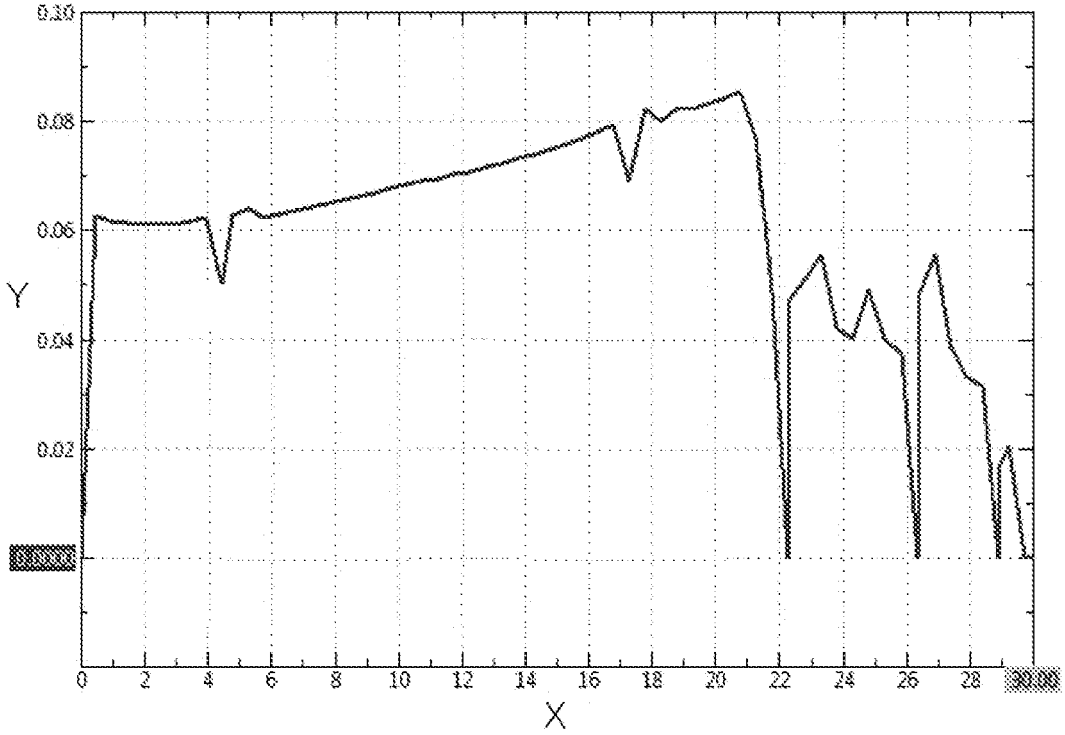

Figure 9

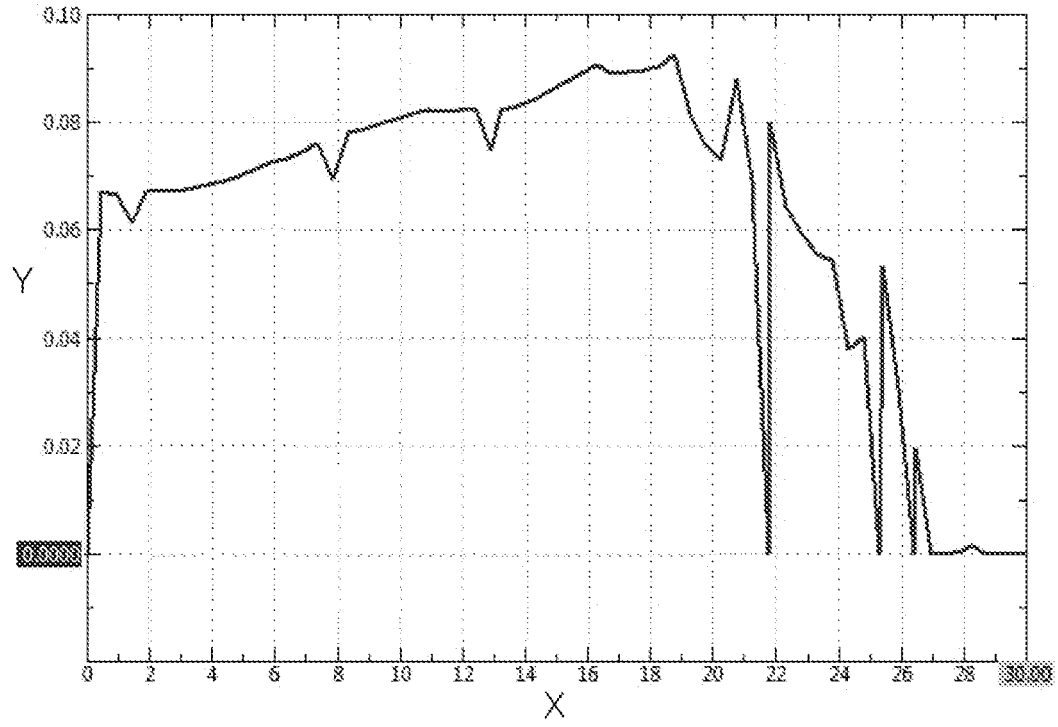

Figure 10

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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