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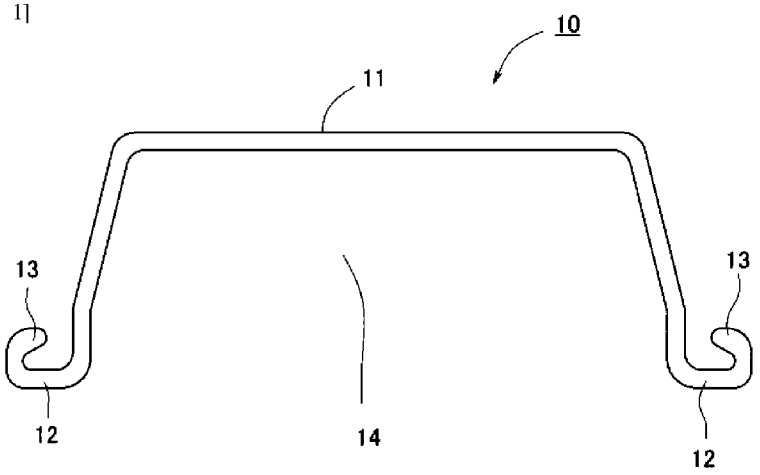
(54) Title: UNDERGROUND WALL, ITS CONSTRUCTION METHOD, AND FORMWORK PANELS USED THEREIN

[Figure 1]



(57) Abstract: To provide an underground wall having an embedded retaining wall, that can be constructed more inexpensively and that is less susceptible to deterioration over time, and a method for constructing the same; sheet piles (10a, 10b) are linked by means of engaging portions (13a, 13b) such that projecting portions (11a, 11b) face alternately in opposite directions to form a retaining wall, and a formwork panel (30) comprising a synthetic resin foam is fitted between the sheet piles (10b, 10b) having the projecting portions (11b) facing the underground structure side, thereby blocking an opening portion of a recessed portion (14) of the sheet pile (10a) having the projecting portion (11a) facing the opposite side to the underground structure, and concrete is poured in contact with the projecting portions (11b) of the sheet piles (10b) and the formwork panel 30 to form a concrete wall (40).

WO 2025/019253 A1

[DESCRIPTION]

[Title of invention]

Underground wall, its construction method, and formwork panels used therein.

[Technical field]

[0001] The present invention relates to an underground wall constructed around an underground structure, a construction method thereof, and a formwork panel used for the underground wall.

[Background art]

[0002] Conventionally, when constructing an underground structure, a retaining wall is formed by inserting sheet piles in positions surrounding an area in which the underground structure is to be constructed, thereby providing support against earth pressure from the surroundings, and then the inside ground surrounded by the retaining wall is excavated and concrete is poured inside of the retaining wall (on the underground structure side) to form a concrete wall, thereby constructing an underground wall (see patent literature article 1).

[Citation List]

[Patent Literature]

[0003] [PTL 1] Japanese Unexamined Patent Publication No. 2010-270442

[Summary of the Invention]

[Technical Problem]

[0004] Sheet piles have a substantially hat-shaped width direction cross section and are provided with a projecting portion, and the retaining wall is formed by alternately arranging sheet piles with the projecting portion facing the underground structure side, and sheet piles facing the opposite side to the underground structure, and linking the width direction end portions thereof together. Therefore, in the retaining wall, a recessed portion having a depth that is approximately twice the height of the projecting portion of the sheet pile opens on the underground structure side, and when forming a concrete wall adjacent to the retaining wall, in order to prevent concrete from penetrating into the recessed portion and increasing the amount of concrete poured, an outer formwork is attached to the entire retaining wall, covering the recessed portion, and crosspieces and struts are arranged between the outer

formwork and a bottom portion the recessed portion such that the outer formwork can withstand the pressure of the concrete.

[0005] The sheet piles that constitute the retaining wall are often extracted and removed after the underground wall has been constructed, but the extraction work requires heavy equipment and a certain amount of space. Furthermore, if the sheet piles are extracted, cavities are created in the ground, and there is a risk that this may cause subsidence of the surrounding ground and may affect adjacent structures. For this reason, when constructing an underground wall, it has been necessary to determine in advance the parts from which the sheet piles will be extracted and the parts in which the sheet piles will remain embedded without being extracted.

[0006] If the sheet piles are not extracted, the outer formwork, crosspieces and struts used when pouring the concrete also remain embedded. These members are made from wood, and since prices have risen in recent years, an inability to recover the members has a significant impact on the construction costs of underground walls. In addition, there is a risk that the wooden outer formwork, crosspieces and struts may deteriorate over time through corrosion and the like, and there is also a risk of gaps forming between the retaining wall and the concrete wall, reducing the strength of the underground wall.

[0007] The present invention takes account of such problems, and the objective thereof is to provide an underground wall having an embedded retaining wall, that can be constructed more inexpensively and that is less susceptible to deterioration over time, and a method for constructing the same.

[Solution to Problem]

[0008] A first aspect of the present invention provides an underground wall surrounding the periphery of an underground structure, the underground wall characterized by comprising:

a retaining wall formed by causing a plurality of sheet piles, each having a projecting portion, to engage with one another at width direction end portions, and causing the sheet piles to penetrate into the ground, such that the projecting portions face alternately in opposite directions in a horizontal direction;

a synthetic resin foam body that is fitted between two sheet piles having the projecting portions facing the underground structure side, and that closes an opening portion of the sheet pile having the protruding portion facing the opposite side to the underground structure side; and

a concrete wall arranged in contact with the sheet piles having the protruding portions facing the underground structure side.

[0009] A second aspect of the present invention provides a construction method for the underground wall of the abovementioned aspect of the present invention, the method including

a step for forming a retaining wall by causing a plurality of sheet piles, each having a projecting portion, to engage with one another at width direction end portions, and causing the sheet piles to penetrate into the ground, such that the projecting portions face alternately in opposite directions in a horizontal direction,

a step for excavating the ground between the retaining wall and the underground structure,

a step for fitting a formwork panel between two sheet piles having the projecting portions facing the underground structure side, to close the opening portion of the sheet pile having the protruding portion facing the opposite side to the underground structure side,

a step for disposing an inner formwork at a predetermined distance on the underground structure side of the retaining wall, and

a step for pouring concrete between the retaining wall and the inner formwork,

wherein the formwork panel comprises at least a synthetic resin foam.

[0010] A third aspect of the present invention provides a formwork panel for use in the underground wall of the abovementioned aspect of the present invention, characterized in that

in the retaining wall formed by causing the plurality of sheet piles, each having a projecting portion, to engage with one another at width direction end portions, such that the projecting portions face alternately in opposite directions in the horizontal direction, the formwork panel has a cross-sectional shape that can be fitted between two sheet piles having the projecting portions facing the underground structure side, and comprises at least a synthetic resin foam.

[Advantageous Effects of Invention]

[0011] In the present invention, by using a synthetic resin foam as the formwork on the retaining wall side when pouring concrete, the cost of the concrete formwork and costs associated with the formwork

installation work can be significantly reduced. In addition, synthetic resin foam is less susceptible to deterioration over time due to corrosion and the like after having been embedded, so there is no risk of gaps occurring over time between the retaining wall and the concrete wall, and the strength of the underground wall is maintained for an extended period of time.

[Brief Description of Drawings]

[0012]

[Figure 1] is a schematic cross sectional view, in the width direction, of a sheet pile used in the present invention.

[Figure 2] is a schematic cross sectional view, in the horizontal direction, of a retaining wall consisting of the sheet piles of Figure 1.

[Figure 3] is a schematic cross sectional view, in the horizontal direction, of an embodiment of an underground wall of the present invention.

[Figure 4] is a schematic cross sectional view, in the horizontal direction, illustrating a method for constructing the underground wall of Figure 1.

[Figure 5] is a schematic cross sectional view, in the horizontal direction, illustrating a method for constructing the underground wall of Figure 1.

[Figure 6] is a schematic cross sectional view, in the horizontal direction, for explaining the shape and dimensions of a retaining wall and a formwork panel according to the present invention.

[Figure 7] is a schematic cross sectional view, in the horizontal direction, of a configuration example of an underground wall having a thermal insulation layer.

[Figure 8] is a schematic cross sectional view, in the width direction, illustrating application examples of formwork panels of the present invention.

[Figure 9] is a schematic cross sectional view, in the horizontal direction, illustrating a state in which an application example of the formwork panel of the present invention has been fitted into a retaining wall.

[Figure 10] is a schematic cross sectional view, in the vertical direction, of a central portion, in the width direction, of application examples of formwork panels of the present invention having a strut portion or a recessed portion.

[Figure 11] is a schematic cross sectional view, in the vertical direction, of a central portion in the width direction of formwork panels, illustrating methods for connecting a plurality of formwork panels in the vertical direction.

[Figure 12] is a schematic cross sectional view, in the horizontal direction, illustrating a conventional method for constructing an underground wall.

[Description of Embodiments]

[0013] The underground wall of the present invention is a structure that surrounds the periphery of an underground structure to prevent earth pressure from the surrounding ground from being transmitted to the underground structure, and that also prevents the penetration of groundwater. The underground wall of the present invention is characterized by comprising a retaining wall and a concrete wall adjacent to the retaining wall on the underground structure side, wherein the retaining wall consists of a plurality of sheet piles, and recessed portions are blocked using a synthetic resin foam. The present invention will now be described in detail.

[0014] The sheet piles used in the present invention are elongate members that penetrate into the ground and that are used for earth retention, and in the present invention, sheet piles made of steel plate, known as steel sheet piles, are preferably used. Figure 1 schematically illustrates an embodiment thereof. Figure 1 is a schematic cross sectional view, in a width direction, of a sheet pile 10 which, as illustrated in Figure 1, is a member that is long in a direction perpendicular to the page in Figure 1, and that includes a projecting portion 11 and flange portions 12, 12 connected to both ends of an opening portion of a recessed portion 14 inside the projecting portion 11, the width direction cross section exhibiting substantially a hat shape, and end portions of the flange portions 12 being rolled up toward the projecting portion 11 side to form engaging portions 13.

[0015] Figure 2 is a schematic cross sectional view, in the horizontal direction, of a retaining wall 20 formed by linking three sheet piles 10 of Figure 1, where the side indicated by the arrow is the underground structure side. In Figure 2, the sheet pile of which the opening portion of the recessed portion 14 of Figure 1 faces the underground structure side is denoted by 10a, and the sheet piles of which the protruding portion 11 faces the underground structure side are denoted by 10b, and by alternately linking the sheet piles 10a and 10b by way of engaging portions 13a, 13b, a retaining wall 20 having recesses and protrusions in the horizontal direction is formed. Reference numeral 21 in the drawing denotes a gap between the left and right sheet piles 10b, 10b that are linked to the sheet pile 10a, and together with the recess 14 of the sheet pile 10a, constitutes a recessed portion of the retaining wall 20 that opens toward the underground structure side.

[0016] Figure 3 is a schematic cross sectional view, in the horizontal direction, illustrating the structure of an embodiment of an underground wall 50 of the present invention, in which a concrete wall 40 is formed on the underground structure side (the side indicated by the arrow) of the retaining wall 20 consisting of the sheet piles 10 of Figure 1. In Figure 3, reference numeral 30 denotes a formwork panel of the present invention, discussed hereinafter.

[0017] As illustrated in Figure 2, the sheet piles 10a, 10b are inserted into the ground while linked such that the projecting portions 11a, 11b alternately face in opposite directions in the horizontal direction, to form the retaining wall 20. Next, the ground between the retaining wall 20 and an area in which the underground structure is to be constructed is excavated, exposing the underground structure side of the retaining wall 20, except for a lower portion thereof. Concrete is subsequently poured onto the underground structure side of the retaining wall 20 to form the concrete wall 40, thereby completing the underground wall 50. The underground structure is constructed within the area surrounded by the underground wall 50.

[0018] Here, a conventional method for constructing an underground wall will be described with reference to Figure 12. Figure 12 is a schematic cross sectional view in the horizontal direction, where the side indicated by the arrow is the underground structure side. First, as illustrated in Figure 12(a), an outer formwork 61 is attached to the underground structure side of the retaining wall 20 of Figure 2 to close the opening of the recessed portion (14, 21) of the retaining wall 20. At this time, in order to cope with the concrete pressure, crosspieces 62 extending along the outer formwork 61 are attached to the recessed portion (14, 21) side of the outer formwork 61, and struts 63 are attached in a plurality of positions in a direction perpendicular to the page, between the crosspieces 62 and a rear surface of the protruding portion 11a of the sheet pile 10a. The outer formwork 61 is attached to the entire surface of the retaining wall 20, in contact with the surface of the projecting portion 11b of the sheet pile 10b on the underground structure side thereof. In addition, an inner formwork 64 is disposed a predetermined distance from the outer formwork 61 on the underground structure side thereof.

[0019] Next, as illustrated in Figure 12(b), concrete is poured between the outer formwork 61 and the inner formwork 64 to form the concrete wall 40. The inner formwork 64 is removed after the concrete wall 40 has been formed.

[0020] In the present invention, a formwork panel 30 is used instead of the outer formwork 61 illustrated in Figure 12. A method for constructing an underground wall according to the present invention will be described with reference to Figure 4 and Figure 5. Figure 4 and Figure 5 are schematic cross sectional views in the horizontal direction, where the side indicated by the arrow is the underground structure side. Further, in the drawings, members that are the same as those in Figure 1 to Figure 3 are denoted using the same reference numerals.

[0021] A formwork panel 30 having a cross-sectional shape corresponding to the cross-sectional shape of the gap 21 between the sheet piles 10b, 10b in the recessed portion (14, 21) of the retaining wall 20 of Figure 2 is prepared (Figure 4 (a)). Then, the formwork panel 30 is pushed and fitted between the sheet piles 10b, 10b, thereby closing the opening portion of the recessed portion 14 of the sheet pile 10a (Figure 4 (b)). The inner formwork 64 is placed a predetermined distance from the underground structure side surface of the projecting portions 11b of the sheet piles 10b (Figure 5 (a)). Concrete is poured between the inner formwork 64 and the formwork panel 30 and the projecting portions 11b of the sheet piles 10b to form the concrete wall 40 (Figure 5(b)). If the inner formwork 64 is removed after the concrete wall 40 has been formed, the underground wall body 50 of Figure 3, in which the retaining wall 20, the formwork panel 30, and the concrete wall 40 are integrated, is obtained.

[0022] In the present invention, the formwork panel 30 comprises at least a synthetic resin foam, and can therefore be easily attached to the retaining wall 20 by being fitted between the sheet piles 10b, 10b. Consequently, workability is significantly improved in comparison with the conventional method illustrated in Figure 12, in which the outer formwork 61, the crosspieces 62, and the struts 63 are attached. Furthermore, the formwork panel 30 is lightweight, easy to handle, and has good workability. In addition, since the formwork panel 30 is made from a synthetic resin, it is less susceptible to deterioration over time, and there is no risk of gaps forming between the formwork panel 30 and the concrete wall 40, which would reduce the strength of the underground wall 50.

[0023] Next, the formwork panel 30 of the present invention will be described. Figure 6 is a schematic cross sectional view in the horizontal direction (the width direction of the sheet piles 10a and 10b and the formwork panel 30) of the retaining wall 20 and the formwork panel 30 before the formwork panel 30 has been attached to the retaining wall 20. The side indicated by arrow A is the underground

structure side. It should be noted that in the following description, for convenience, the sheet pile will be referred to as either the sheet pile 10a or 10b, but the sheet piles 10a and 10b have the same shape and dimensions.

[0024] The projecting portion 11a of the sheet pile 10a has a substantially trapezoidal shape, the length thereof in the width direction gradually increasing toward the flange portions 12a, 12a. Consequently, the cross-sectional shape, in the horizontal direction, of the gap 21 between the sheet piles 10b, 10b also has a substantially trapezoidal shape. Since the formwork panel 30 abuts the underground structure side surfaces of the flange portions 12a of the sheet pile 10a and is fitted between the sheet piles 10b, 10b, the cross-sectional shape thereof in the width direction is a substantially trapezoidal shape corresponding to the gap 21. When the distance between the sheet piles 10b, 10b on an extension plane of the underground structure side surface of the flange portions 12a of the sheet pile 10a is L11, the distance between the projecting portions 11b, 11b of the sheet piles 10b, 10b on an extension plane of the underground structure side surface of the projecting portions 11b of the sheet pile 10b is L12, the distance from the underground structure side surfaces of the flange portions 12a of the sheet pile 10a to the underground structure side surface of the projecting portions 11b of the sheet piles 10b is D11, the width direction length of the surface of the formwork panel 30 on the opposite side to the underground structure is L21, the width direction length of the surface thereof on the underground structure side is L22, and the distance from the surface of the formwork panel 30 on the opposite side to the underground structure to the surface on the underground structure side thereof is D21, the following relationships are preferably satisfied.

[0025]

$$L11=L21$$

$$L12=L22$$

$$D11=D21$$

The above relationships may include a certain amount of error, and provided that the elasticity of the synthetic resin foam can be utilized to allow the formwork panel 30 to fit between the sheet piles 10b and 10b, the lengths L21 and L22 of the formwork panel 30 may be slightly larger than L11 and L12.

[0026] The formwork panel 30 is a member for preventing penetration of concrete into the recessed portion (14, 21) of the retaining wall 20, but since the thickness of the concrete wall 40 is determined

from the side closer to the underground structure, among the surface of the formwork panel 30 on the underground structure side and the surface of the projecting portions 11b of the sheet piles 10b on the underground structure side, in order to minimize the amount of concrete poured, it is desirable for the error between D11 and D21 to be small so that the surface of the formwork panel 30 on the underground structure side and the surfaces of the projecting portions 11b of the sheet piles 10b on the underground structure side form a continuous surface.

[0027] Further, if the underground wall 50 is to have a heat insulating function, a heat insulating layer can easily be constructed by adding the required thickness of the heat insulating layer to D11 to obtain D21, and disposing a heat insulating panel comprising a synthetic resin foam the same as or different from that of the formwork panel 30 on the underground structure side of the projecting portions 11b of the sheet piles 10b. Figure 7 is a schematic cross sectional view, in the horizontal direction, of a configuration example of the underground wall 50 having such a thermal insulation layer. In Figure 7, reference numeral 70 denotes the heat insulating panel, which is continuous with the formwork panel 30 and constitutes a heat insulating layer.

[0028] Figure 8 illustrates application examples of the shape of the formwork panel 30. Figure 8 is a schematic cross sectional view of the formwork panel 30 in the width direction. It is preferable that the formwork panel 30 does not readily become detached from between the sheet piles 10b, 10b after fitting, and from this viewpoint, it is preferable to provide projecting portions on the side surfaces that come into contact with the side surfaces of the sheet piles 10b (the side surfaces of the projecting portions 11b). In Figure 8(a) and (b), recesses and protrusions 31 are provided on the side surfaces. By making the width direction length at the projecting portions greater than or equal to the horizontal direction length of the corresponding gap 21, the projecting portions are squashed by the elastic force of the synthetic resin foam during fitting, and after fitting, stress remaining in the squashed parts causes the side surfaces to press against the side surfaces of the sheet piles 10b, making the formwork panel 30 less liable to become detached from between the sheet piles 10b, 10b. It should be noted that if the width direction length at the projecting portions is too great compared with the horizontal length of the corresponding gap 21, it becomes difficult to fit the formwork panel 30, and there is a possibility that gaps may form after fitting, between the side surface other than the projecting portions and the side surface of the sheet pile 10b, and it is therefore preferable that the length of the formwork panel 30 at

the projecting portions be approximately 5 mm to 10 mm greater than the horizontal direction length of the corresponding gap 21.

[0029] Further, from the viewpoint of making it easier to fit the formwork panel 30 between the sheet piles 10b, 10b of the retaining wall 20, slits 32 may be provided on the underground structure side of the formwork panel 30, as illustrated in Figure 8(c). Further, as illustrated in Figure 8(d) and (e), by providing a recessed portion 33 on the side of the formwork panel 30 on the opposite side to the underground structure, both ends of the formwork panel 30 in the width direction on the opposite side to the underground structure can be more easily flexed inward, making it easier to fit between the sheet piles 10b, 10b. It is also possible to combine the shapes illustrated in Figure 8(a) and (b) with the shapes illustrated in Figure 8 (c) to (e).

[0030] Further, as illustrated in Figure 9, the formwork panel 30 may be provided with a strut portion 34 on the opposite side to the underground structure. Figure 9 is a schematic cross sectional view in the width direction of the formwork panel 30, and Figure 9 illustrates a state in which the formwork panel is 30 fitted between the sheet piles 10b, 10b of the retaining wall 20. The strut portion 34 may be attached to the formwork panel 30 described hereinabove using adhesive or the like, or may be integrally molded. Further, Figure 10 is a schematic cross sectional view, in the vertical direction, of a central portion, in the width direction, of the formwork panel 30 including the strut portion 34, wherein the strut portion 34 may be provided along the entire formwork panel 30 in the vertical direction, as illustrated in Figure 10(a), may be provided partially, as illustrated in Figure 10(b), or may be provided with a recess 34a in a central portion, as illustrated in Figure 10(c). Furthermore, the shapes in Figure 8 may be combined with the shapes in Figure 9 and Figure 10(a) to (c). Further, it is also possible to adopt a form in which the side opposite to the underground structure is flat in both upper and lower end portions, as illustrated in Figure 6, and has a recessed portion 33 in a region separated from both the upper and lower end portions, as illustrated in Figure 10(d), (e). Figure 8(d) and (e) correspond to schematic cross sectional views, in the width direction, of central portions, in the vertical direction, of Figure 10(d) and (e).

[0031] If the vertical length of the formwork panel 30 of the present invention is not sufficient for the vertical length of the retaining wall 20, a plurality of formwork panels 30 may be arranged vertically and linked to one another. Figure 11 illustrates forms of linking. Figure 11 is a schematic cross sectional view,

in the vertical direction, of a central portion, in the width direction, of formwork panels 30, and in Figure 11(a) two formwork panels 30, 30 are stacked vertically, with sealing tape 35 applied to the linking points. Figure 11(b) illustrates a linking method known as a spline joint, in which grooves 36, 36 are formed in a lower surface of the upper formwork panel 30 and an upper surface of the lower formwork panel 30, and a separately prepared spline 37 is fitted into the grooves 36, 36 to link the panels. The spline 37 may be made from the same material as the formwork panel 30 or from a different material, for example wood or steel, and since the formwork panel 30 of the present invention is a synthetic resin foam, a non-foamed material of the same synthetic resin may also be used.

[0032] Figure 11(c) is a linking method known as shiplap, in which corresponding steps are formed in the surfaces of the upper and lower formwork panels 30 that come into contact with one other. Further, as illustrated in Figure 11(d), linking may be effected by providing a recessed portion 38 on one side and a projecting portion 39 on the other side, and Figure 11(d) illustrates an example in which the side surfaces of the recessed portion 38 and the projecting portion 39 are tapered. In the configurations of Figure 11(b) to (d), the same sealing tape 35 as in Figure 11(a) may be applied to the linking portions.

[0033] The formwork panel 30 of the present invention comprises at least a synthetic resin foam, and preferably comprises only a synthetic resin foam. As the resin material, polystyrene foam, polyurethane foam, polyphenol foam, and polyester foam are used, and as the polyester foam, polyethylene terephthalate foam is preferable. Polystyrene foam is preferably used, and either an extruded foam molding or a bead foam molding may be used, an extruded foam molding being preferable. Further, in order to adjust the strength, as described below, a non-foamed synthetic resin film may be attached to the surface of the synthetic resin foam, and in this case, the non-foamed synthetic resin film is attached to at least the surface on the sheet pile 10a side, but may also be attached to both the sheet pile 10a side and the underground structure side. Further, as the synthetic resin film, polyester films such as polyethylene terephthalate film, polyolefin films such as polyethylene film and polypropylene film, or said films laminated with polystyrene, polyvinyl acetate, a copolymer of polyethylene and polyvinyl acetate, linear low-density polyethylene, or the like, as an adhesive layer for thermally laminating the films to the synthetic resin foam, are preferably used.

[0034] Further, the formwork panel 30 of the present invention should have a strength capable of withstanding the pressure of concrete, and preferably has a bending stiffness of 20,000 $N \cdot cm^2$ (0.002

kPa·m^4) and more preferably at least 30,000 N·cm^2 (0.003 kPa·m^4) per 1 cm of length (the direction perpendicular to the page in Figure 6). Further, in order to increase the bending stiffness per 1 cm of length of the form panel 30, it is effective to increase the density of the synthetic resin foam, but a high density synthetic resin foam with which the bending stiffness of the form panel 30 exceeds 10,000,000 N·cm^2 (1 kPa·m^4) not only increases the weight but also has a reduced dimensional accuracy when processed into a formwork panel, and therefore the bending stiffness of the formwork panel 30 is preferably at most equal to 10,000,000 N·cm^2 (1 kPa·m^4), and more preferably at most equal to 5,000,000 N·cm^2 (0.5 kPa·m^4).

[0035] The formwork panel 30 will differ depending on the dimensions of the sheet piles to be used, but the preferred dimensions of the sheet piles with which the formwork panel of the present invention is to be used are a width of 400 mm for one sheet pile in the retaining wall 20, and a height (in the direction indicated by arrow C in Figure 6) of approximately 100 mm to 170 mm. Consequently, the dimensions of the formwork panel 30 of the present invention are a width L22, illustrated in Figure 6, of just under 500 mm, a thickness D21 of 75 mm to 140 mm, and a length of approximately 2,000 mm.

[0036] The bending stiffness per 1 cm of the length of the formwork panel 30 is obtained by cutting a length suitable for measurement from the formwork panel 30 to prepare a test piece, measuring the apparent flexural modulus E (kPa) of the test piece by means of a test, and calculating the bending stiffness using the following formula, on the basis of the apparent flexural modulus E and the dimensions of the test piece used in the measurement. It should be noted that the "width" of the test piece in the test of JIS K 7221-2 is the "length" of the test piece cut from the formwork panel 30 of the present invention, and in the test, the shorter side (length: L21) of the trapezoid of the formwork panel 30 illustrated in Figure 6 is placed on the fulcrum B side, and the longer side (length: L22) is placed on the pressure wedge A side. Consequently, the "thickness" of the test piece in the test of JIS K 7221-2 is the "thickness" of the test piece cut from the formwork panel 30 of the present invention, that is, the thickness (D21 in Figure 6) of the formwork panel 30.

Bending stiffness per 1 cm length = apparent flexural modulus E × second moment of area I/b

Second moment of area I = $bd^3/12$

b: Length of test piece (L21 in Figure 6)

d: Thickness of formwork panel 30 (D21 in Figure 6)

[0037] It should be noted that if the formwork panel 30 comprises only a synthetic resin foam, it is possible to cut out a thin test piece to measure E described hereinabove, but if the formwork panel 30 comprises a synthetic resin foam with a synthetic resin film attached to the surface thereof, the thickness of the test piece should remain the same as the thickness of the formwork panel 30. Further, if the thickness of the formwork panel 30 varies depending on the location, as illustrated in Figure 8(d), (e) and Figure 10, the thickness of the formwork panel 30 is taken as the thickness of the thinnest part, and E described hereinabove is measured by cutting test pieces having a uniform thickness such that the thickness of each test piece corresponds to the thickness of the corresponding location.

[0038] If the bending stiffness of the synthetic resin foam per 1 cm of length is 20,000 $N \cdot cm^2$ or more, the synthetic resin foam can be used alone as is as the formwork panel 30, and if the bending stiffness of the synthetic resin foam is less than 20,000 $N \cdot cm^2$, it is preferable to attach a synthetic resin film thereto, as described above, to increase the bending stiffness of the formwork panel 30.

[0039] Further, if the formwork panel 30 of the present invention is too hard, it will be difficult to be fitted between the sheet piles 10b, 10b, and therefore, the compressive strength in the side surface direction of the formwork panel (the direction in which a compressive force is received when being fitted between the sheet piles, that is, the direction indicated by arrow B in Figure 6) measured according to JIS K 7220 is preferably less than 20 N/cm^2 (200 kPa), and more preferably less than 16 N/cm^2 (160 kPa). Further, if the compressive strength of the formwork panel 30 is less than 5 N/cm^2 (50 kPa), the formwork panel will not be able to withstand changes in gas pressure within the bubbles, caused by temperature fluctuations, or forces exerted by a hand or fingertips during transportation or construction, and will deform easily, and therefore the compressive strength of the formwork panel 30 is preferably at least equal to 5 N/cm^2 (50 kPa), and more preferably at least equal to 9 N/cm^2 (90 KPa). The formwork panel of the present invention preferably has a combination of the shapes, dimensions, bending stiffness, and compressive strengths cited hereinabove as the preferred embodiments.

[Reference signs list]

[0040]

10, 10a, 10b: sheet pile, 11, 11a, 11b: projecting portion, 12, 12a, 12b: flange portion, 13, 13a, 13b: engaging portion, 14: recessed portion, 20: retaining wall, 21: gap, 30: formwork panel, 32: recesses and

protrusions, 33: recessed portion, 34: strut portion, 34a: recessed portion, 35: sealing tape, 36: groove, 37: spline, 38: recessed portion, 39: recessed portion, 40: concrete wall, 50: underground wall, 61: outer formwork, 62: crosspiece, 63: strut, 64: inner formwork, 70: heat insulating layer

[CLAIMS]

[Claim 1] An underground wall surrounding an underground structure, the underground wall comprising:

a retaining wall formed by causing a plurality of sheet piles, each having a projecting portion, to engage with one another at width direction end portions, and causing the sheet piles to penetrate into the ground, such that the projecting portions face alternately in opposite directions in a horizontal direction;

a synthetic resin foam body that is fitted between two sheet piles having the projecting portions facing the underground structure side, and that closes an opening portion of the sheet pile having the protruding portion facing the opposite side to the underground structure side; and

a concrete wall arranged in contact with the sheet piles having the protruding portions facing the underground structure side.

[Claim 2] A construction method for the underground wall as claimed in claim 1, the method including

a step for forming a retaining wall by causing a plurality of sheet piles, each having a projecting portion, to engage with one another at width direction end portions, and causing the sheet piles to penetrate into the ground, such that the projecting portions face alternately in opposite directions in a horizontal direction,

a step for excavating the ground between the retaining wall and the underground structure,

a step for fitting a formwork panel between two sheet piles having the projecting portions facing the underground structure side, to close the opening portion of the sheet pile having the protruding portion facing the opposite side to the underground structure side,

a step for disposing an inner formwork at a predetermined distance on the underground structure side of the retaining wall, and

a step for pouring concrete between the retaining wall and the inner formwork,

wherein the formwork panel comprises at least a synthetic resin foam.

[Claim 3] A formwork panel for use in the underground wall as claimed in claim 1, wherein

in the retaining wall formed by causing the plurality of sheet piles, each having a projecting portion, to engage with one another at width direction end portions, such that the projecting portions face alternately in opposite directions in the horizontal direction, the formwork panel

has a cross-sectional shape that can be fitted between two sheet piles having the projecting portions facing the underground structure side, and comprises at least a synthetic resin foam.

[Claim 4] The formwork panel as claimed in claim 3, wherein the bending stiffness per 1 cm of the length of the formwork panel is at least equal to 20,000 $N \cdot cm^2$ and at most equal to 10,000,000 $N \cdot cm^2$.

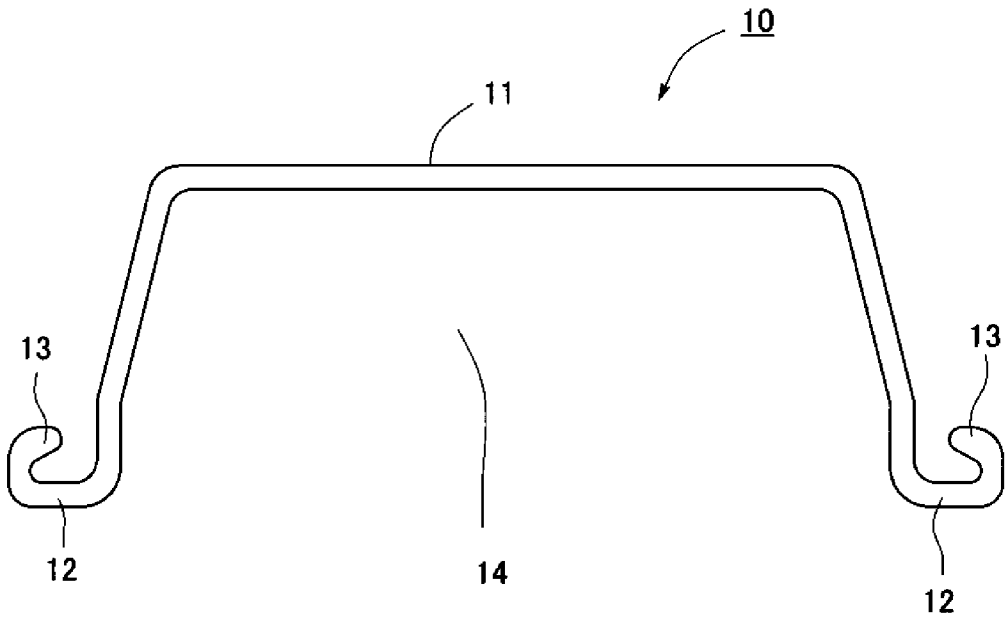
[Claim 5] The formwork panel as claimed in claim 3, wherein the compressive strength in a side surface direction of the formwork panel is at least equal to 5 N/cm^2 and less than 20 N/cm^2.

[Claim 6] The formwork panel as claimed in claim 3, wherein the synthetic resin foam is a polystyrene extruded foam molding.

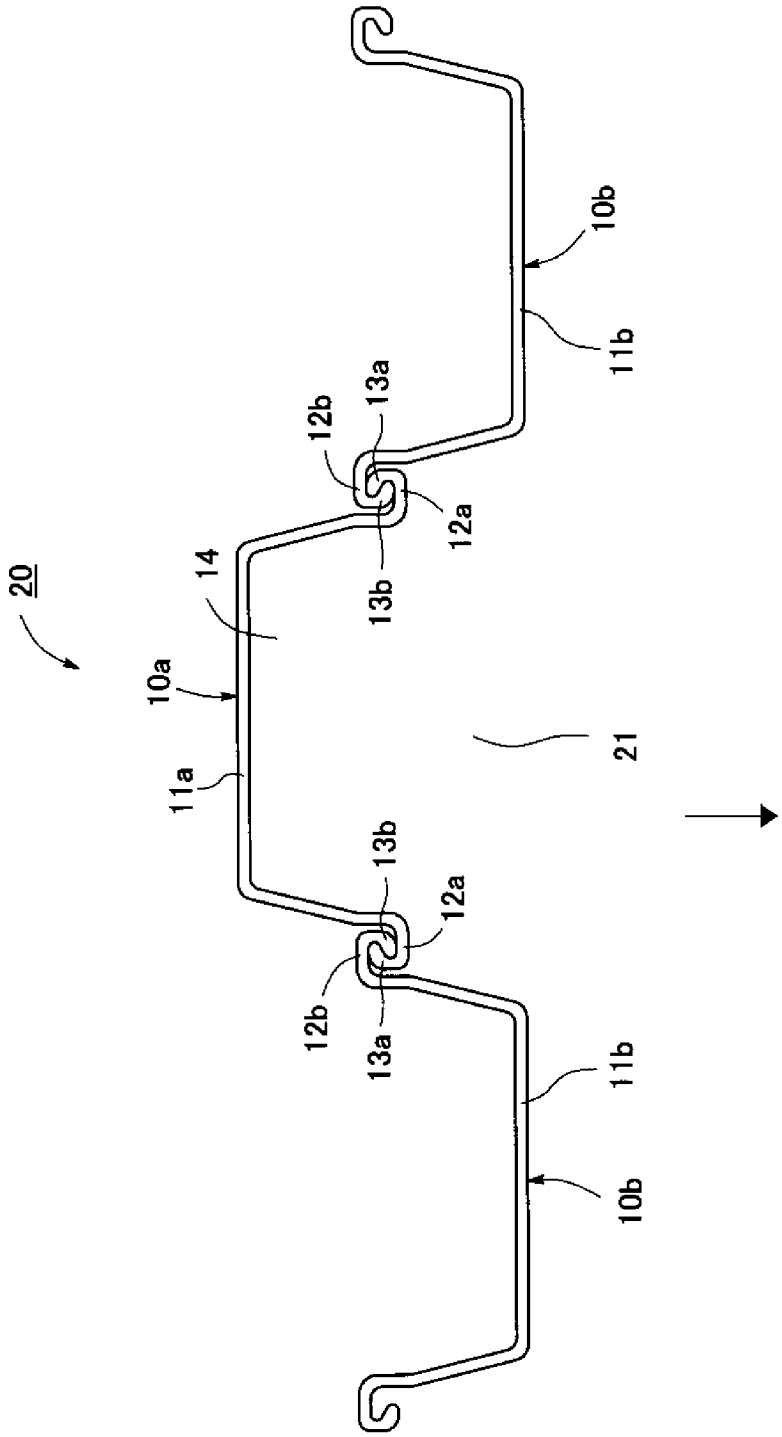
[Claim 7] The formwork panel as claimed in any one of claims 3 to 6, wherein the synthetic resin foam has a projecting portion on a side surface that comes into contact with the sheet pile.

[DRAWINGS]

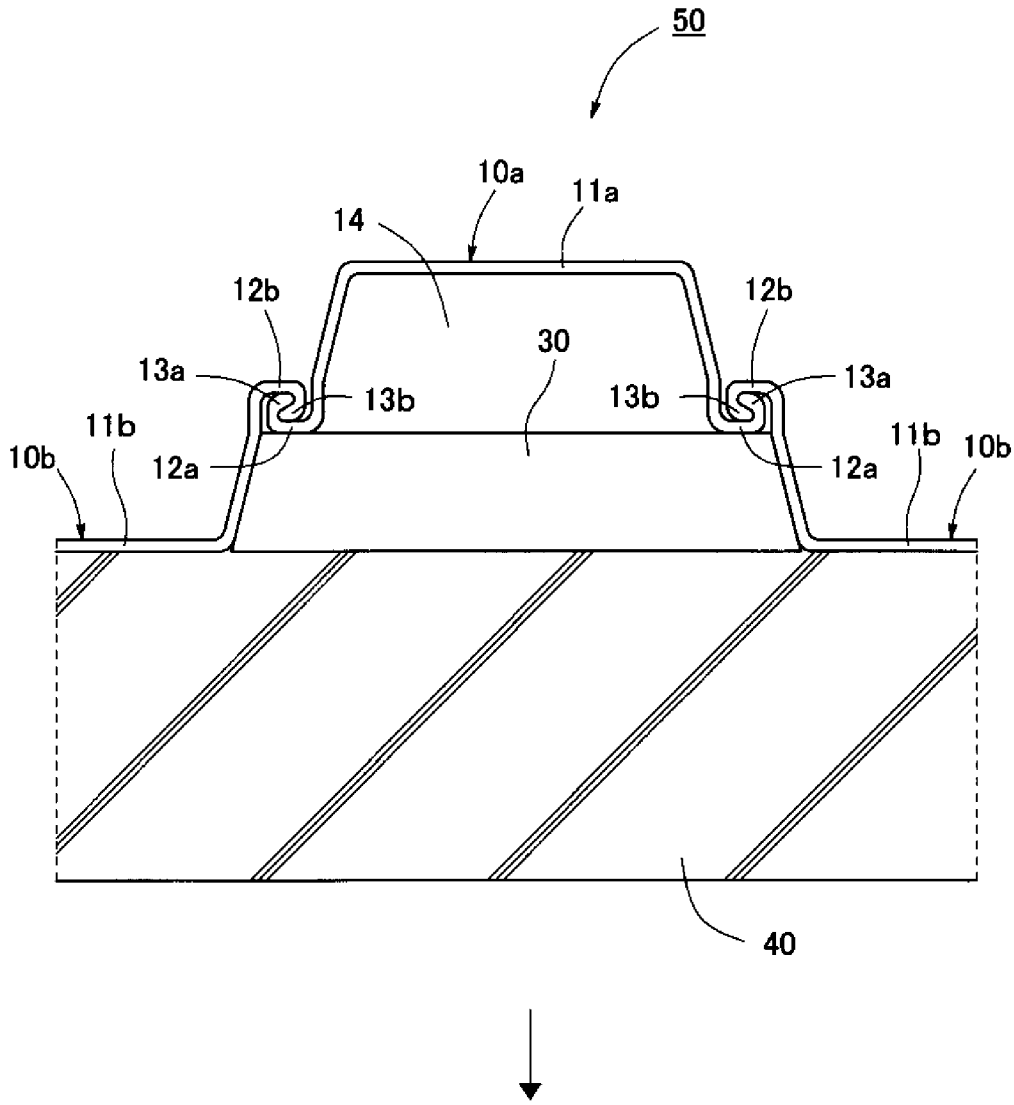
[Figure 1]



[Figure 2]



[Figure 3]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11a
14
12b
12b
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13a
11b
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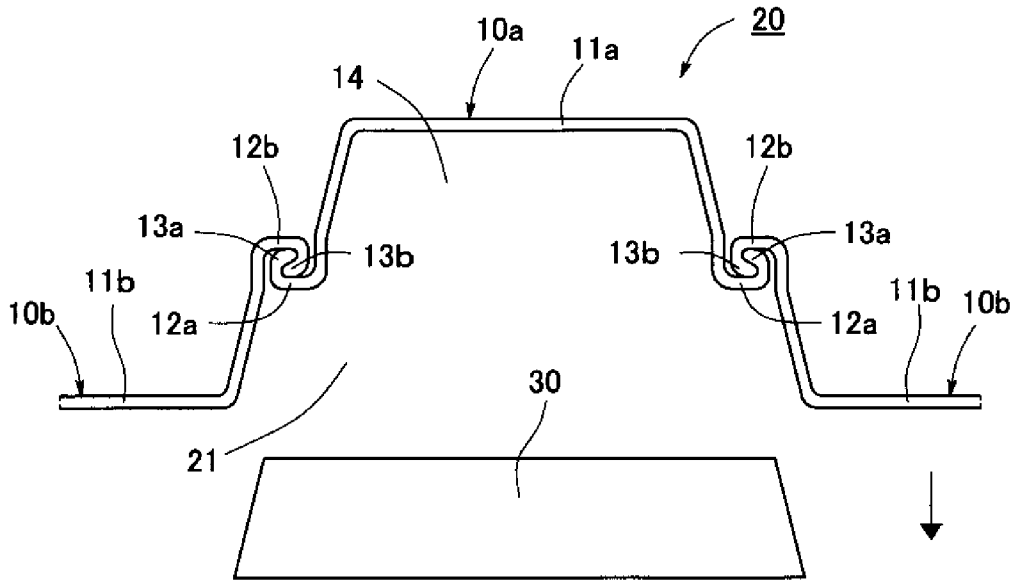
10b
40

[Figure 4]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11a
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11b
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12a
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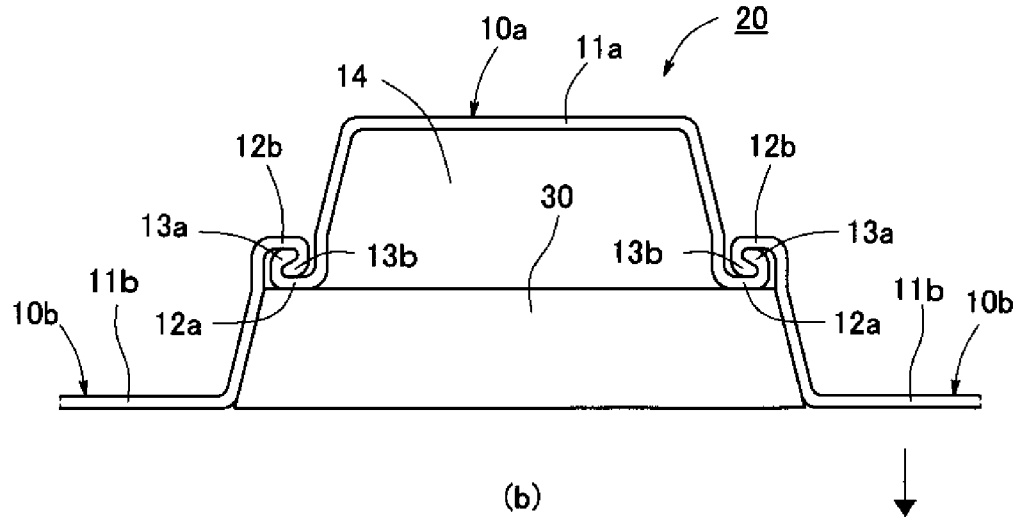
10b
30
21

(a)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14
12b
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13b
13b
13a
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10b
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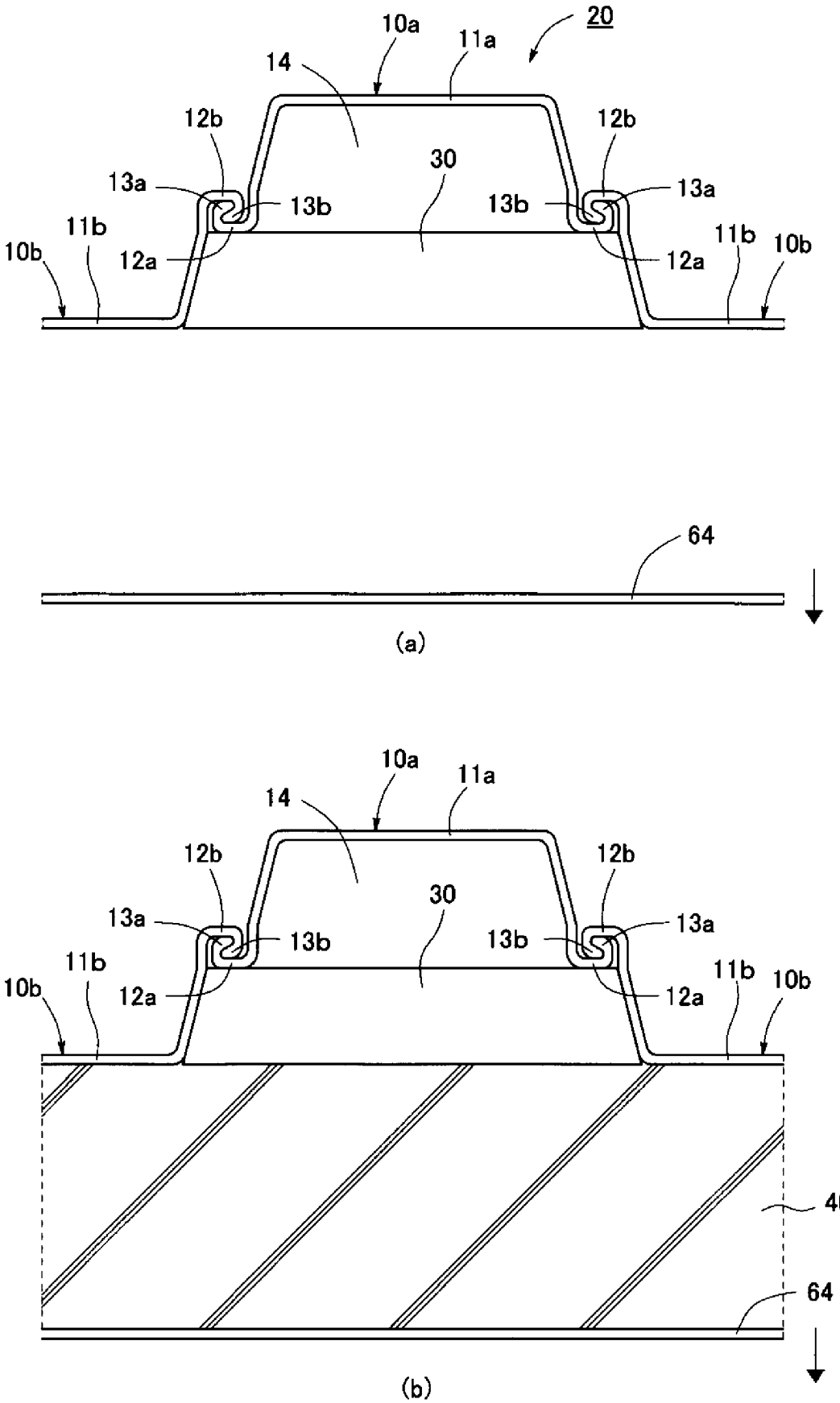
12a
11b
10b

(b)

[Figure 5]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14
12b
12b
30
13a
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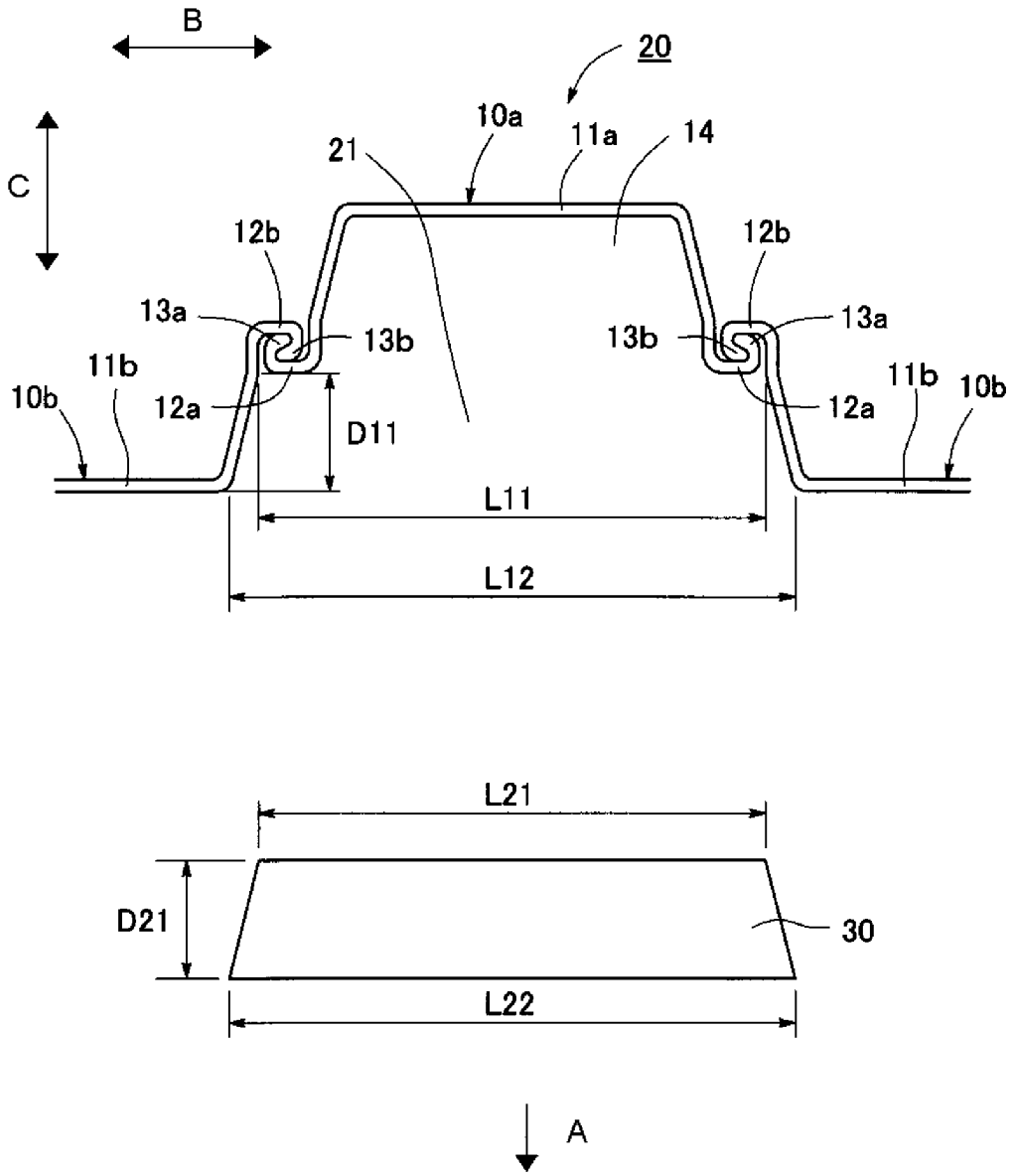
12a
64
(a)
10a
11a
14
12b
12b
30
13a
13b
13b
13a
11b
11b
10b
10b
12a
12a
40
64
(b)

[Figure 6]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C
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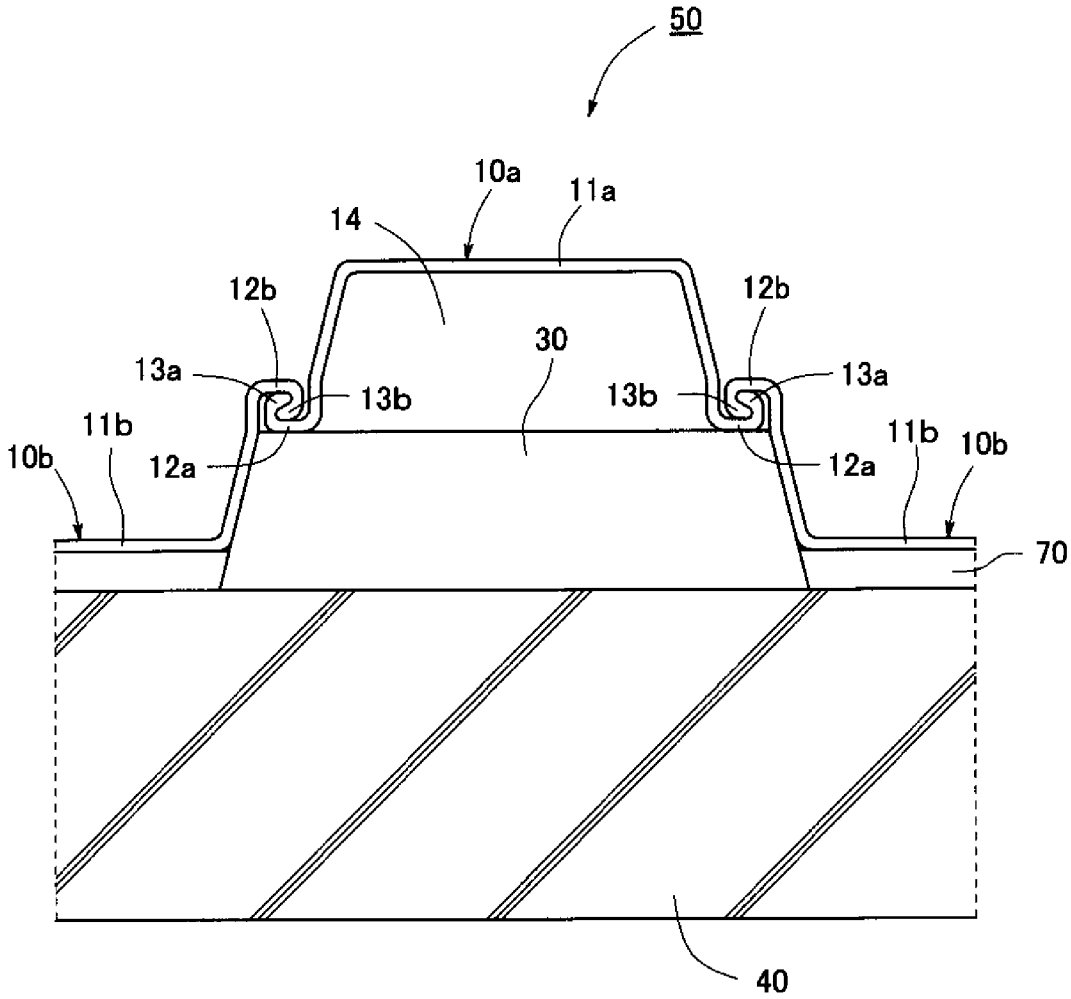
11b
10b
D11
L11
L12
L21
D21
30
L22
A

[Figure 7]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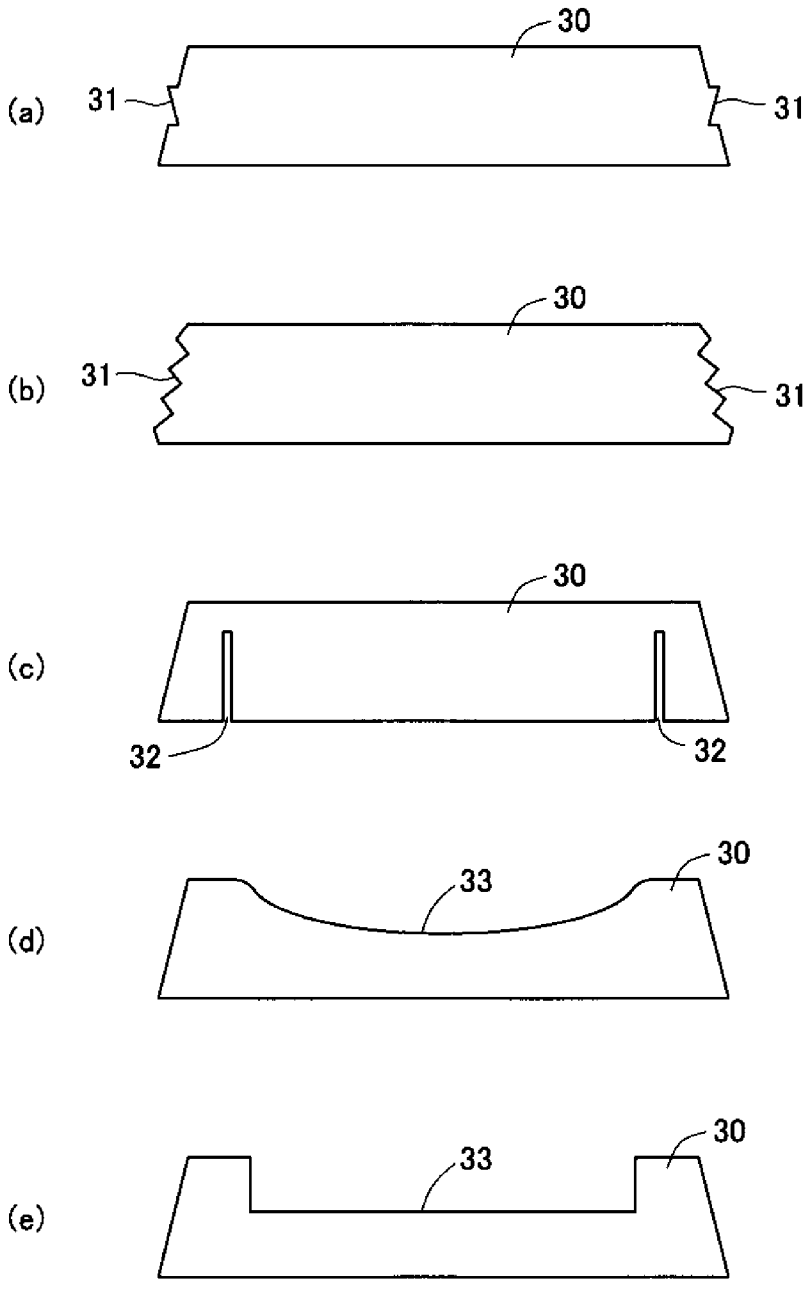
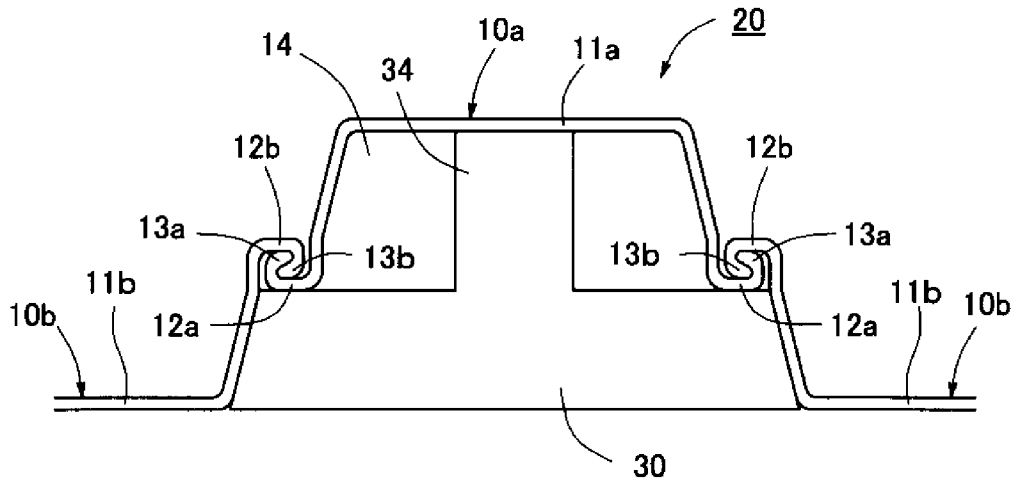
40

[Figure 8]



[Figure 9]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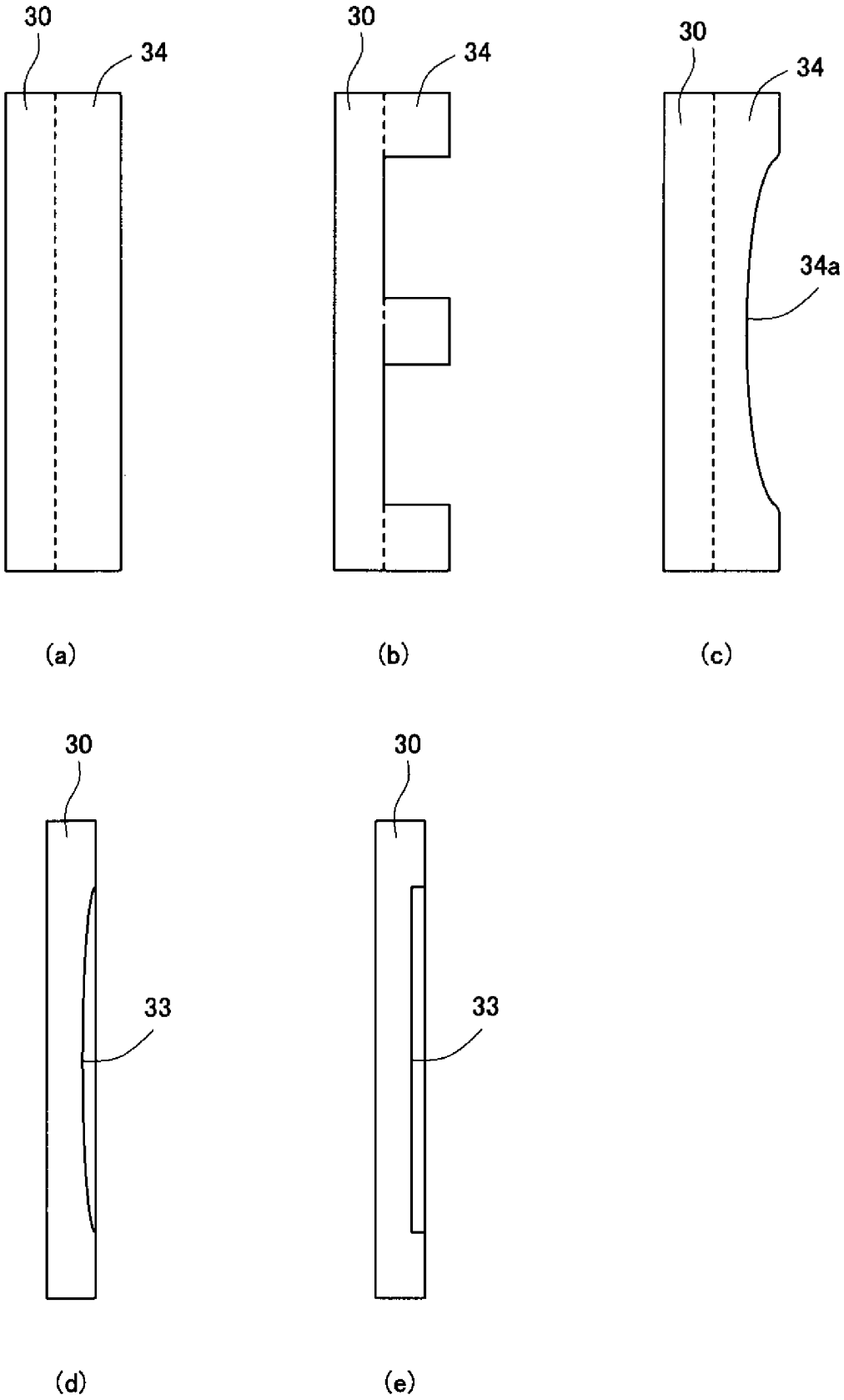
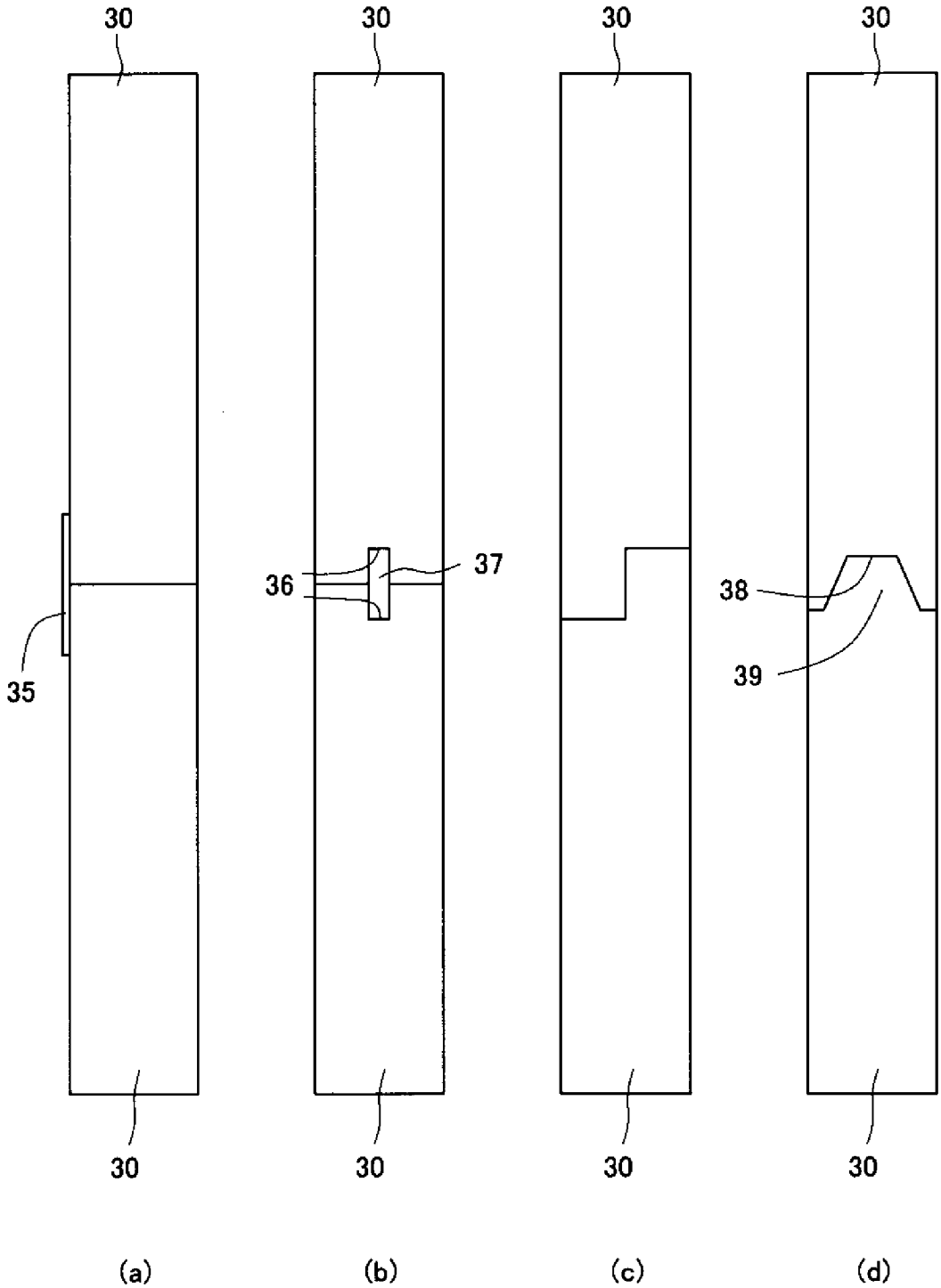
11b
10b
30

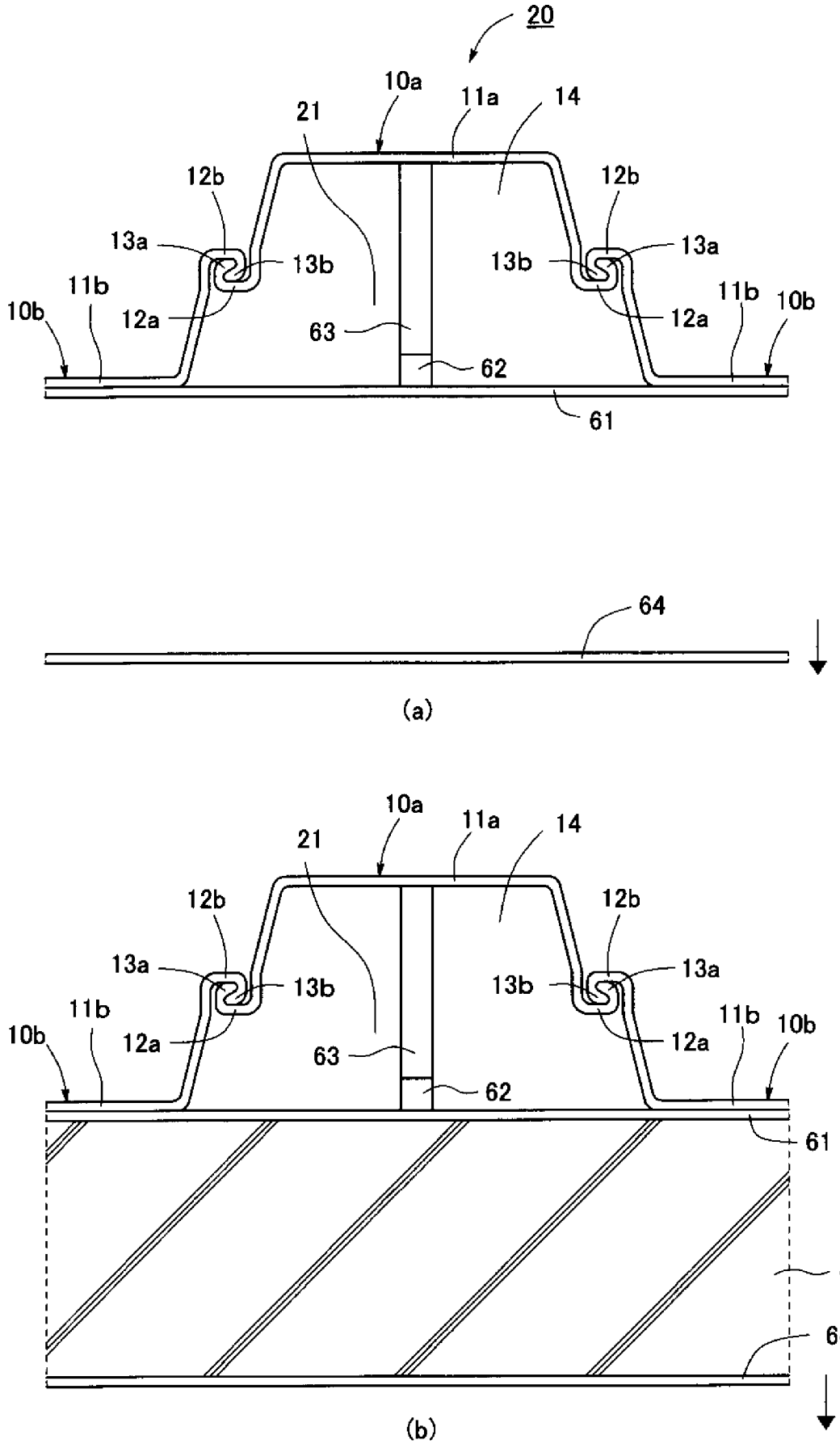
[Figure 10]



[Figure 11]



[Figure 12]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11b
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12a
63
62
61
40
64
(b)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2024/037527

A. CLASSIFICATION OF SUBJECT MATTER

E02D 5/08(2006.01)i; **E02D 29/045**(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E02D 5/08(2006.01); A01G 1/00(2006.01); E02B 3/06(2006.01); E02D 5/04(2006.01); E02D 5/06(2006.01); E04B 1/00(2006.01); E04G 9/06(2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: concrete, wall, sheet pile, formwork, and resin

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	AU 2022-218610 A1 (MESO SYSTEMS PTY LTD.) 16 March 2023 (2023-03-16) paragraphs [0032]-[0038] and figures 7-8	1-7
Y	BEWI, 'SHEET PILE INFILL', November 2022, Retrieved from the Internet [URL: https://bewi.com/wp-content/uploads/2023/02/Sheet-Pile-Infill.pdf]. pages 1-2	1-7
A	KR 10-1220898 B1 (GEOTECHNICAL KOREA ENG, CO., LTD.) 11 January 2013 (2013-01-11) paragraphs [0024]-[0047] and figures 2-8	1-7
A	JP 2001-295242 A (NIPPON STEEL CORP. et al.) 26 October 2001 (2001-10-26) paragraphs [0026]-[0039] and figures 1-6	1-7
A	JP 11-323912 A (SUMITOMO METAL IND LTD.) 26 November 1999 (1999-11-26) paragraphs [0028]-[0038] and figures 1-5	1-7

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 October 2024	**26 October 2024**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office **189 Cheongsa-ro, Seo-gu, Daejeon** **35208, Republic of Korea**	**LEE, Eon Su**
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US2024/037527

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
AU 2022-218610 A1	16 March 2023	None	
KR 10-1220898 B1	11 January 2013	None	
JP 2001-295242 A	26 October 2001	None	
JP 11-323912 A	26 November 1999	None	