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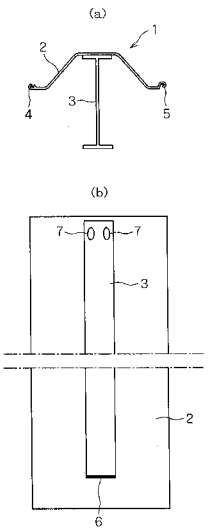
(54) **COMPOSITE STEEL SHEET PILE AND STEEL SHEET PILE WALL USING THE COMPOSITE STEEL SHEET PILE**

(57) A composite steel sheet pile and a steel sheet pile wall which comprise a steel sheet pile and a rigidity increasing steel material which are not fully integrated with each other but are combined with each other as superposed beams in such a manner that the deflection behaviors of the steel sheet pile and the rigidity increasing steel material almost coincide with each other. The configuration eliminates labor and cost required for welding, shape measurement, correction work, processing management etc., and allows the composite steel sheet pile and the steel sheet pile wall to be stored and transported with high efficiency. An H-shaped steel member 3 is disposed inside the web section of a steel sheet pile 2, and the upper end and the lower end of the H-shaped steel member 3 are joined to the web section of the steel sheet pile 2. Steel sheet piles 2 are connected together by engagement between joints 4, 5 provided at both ends of each steel sheet pile 2 in the width direction thereof, the connection being made in such a manner that protrusions and recesses in a cross-section of the steel sheet piles 2 face the same direction. One end of an H-shaped steel member 3 is secured by welding 6 etc. to a steel sheet pile 2, and the other end is joined to the steel sheet pile 2 using a combination of a joining bolt and a bolt hole having a size greater than a bolt hole having a size appropriate for the diameter of the bolt, and as a result, the H-shaped steel member 3 and the steel sheet pile 2 are permitted to be displaced from each other in the top-bottom direction. The H-shaped steel member 3 and the steel sheet pile 2 can be joined together in a construction site, and this allows the H-shaped steel member 3 and the steel sheet pile 2 to be transported separately to the site, joined together in the site and driven into the ground in the integrated form.

FIG.1



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Description

TECHNICAL FIELD

[0001] This invention relates to a composite steel sheet pile which comprises a steel sheet pile and a shape steel material such as an H-shaped steel member extending in the longitudinal direction of the steel sheet pile, the shape steel material being disposed on one side of the steel sheet pile, and also to a structure of a steel sheet pile wall which is constructed using the composite steel sheet pile, and it is useful in applications to retaining walls, impermeable walls and the like (inclusive of walls such as underground continuous walls).

BACKGROUND ARTS

[0002] Heretofore, there is one known arrangement which is such that an H-shaped steel member or like shape steel material is mounted as a rigidity increasing steel material to one side of a steel sheet pile such as a U-shaped steel sheet pile, a straight-shaped steel sheet pile and a hat-shaped steel sheet pile that form a retaining wall, an impermeable wall or the like.

[0003] Regarding this type of prior arts, the Patent document 1, for instance, describes one arrangement which is such that a steel sheet pile 52 is provided on one of both sides thereof with a worked jig 54, into which a shape steel material 53 such as an H-shaped steel member is adapted to be fitted as a rigidity increasing steel material, as shown in FIGS. 17(a) and 17(b).
In this case, the steel sheet pile 52 and the rigidity increasing steel material 53 are adapted to be separately driven into the ground in a construction site into the integrated form.

[0004] Further, the Patent document 2 describes an underground continuous wall steel material 61 which is composed of a steel sheet pile 62 provided at both ends thereof with joints and an H-shaped or T-shaped steel member as a rigidity increasing steel material 63, wherein the web section of the steel sheet pile 62 and the flange section of the H-shaped or T-shaped steel member as the rigidity increasing steel material 63 are longitudinally overlapped with each other, only one end of the overlapped section in the longitudinal direction thereof being placed under restraint, as shown in FIGS. 18(a) and 18(b).

[0005] In this case, it is also stated that by reason of the structure that is to restrain only one end of the overlapped section in the longitudinal direction thereof by coping, welding 66, bolts 67 or drill screw threads, there are the advantages that the need for steel sheet pile correction is avoided in applications of any of restraining means other than welding, or more suppressed deformation of the steel sheet pile can be provided than before even in welding applications as the restraining means, and also that the underground continuous wall steel material need not be manufactured in a factory in all cases, resulting in that the steel sheet pile and the rigidity increasing steel material such as the H-shaped steel member can be individually transported to a construction site or its neighbor site and afterwards assembled together therein.

[0006] Moreover, the Patent document 3 describes an underground continuous wall-structure steel member 71 which has an H-shaped steel member 73 whose flange section on one side thereof is secured to the inside of the web section of a hat-shaped steel sheet pile 72 manufactured by hot rolling, wherein the width of the secured one of the flange sections in the H-shaped steel member 73 is not more than the web section width of the hat-shaped steel sheet pile 72.

[0007] In addition, it is also stated that the web section of the hat-shaped steel sheet pile 72 and the flange section of the H-shaped steel member 73 are adapted to be secured together using any of securingmeans selected from a group consisting of welding, bonding, bolting, riveting, screwing and tacking.

LITERATURES ON THE PRIOR ARTS

PATENT DOCUMENTS

[0008]

Patent document 1: Japanese Laid-open Patent Publication No. 2008-267069
Patent document 2: Japanese Laid-open Patent Publication No. 2005-299202
Patent document 3: Japanese Laid-open Patent Publication No. 2008-175029

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0009] In the invention described in the Patent document 1, the steel sheet pile and the rigidity increasing steel material such as the H-shaped steel member 53 need to be separately driven into the ground, and in accordance with that, the problem of the reduced efficiency in execution of construction works arises.

[0010] Further, by reason of the structure that is to fit the flange of the H-shaped steel member or the like into the jig provided on one side of the steel sheet pile, the deflection behaviors of the steel sheet pile and the rigidity increasing steel material such as the H-shaped steel member should coincide with each other. Thus, its application is limited to the structure which is such that the steel sheet pile side (refer to the upper side in FIG. 17) thereof receives an earth pressure.

[0011] In the invention described in the Patent document 2, the steel sheet pile and the H-shaped or T-shaped steel member as the rigidity increasing steel material are secured together only in one end of the overlapped section in the longitudinal direction thereof, and thus, it may well be that the disconnection of the steel sheet pile and the H-shaped or T-shaped steel member from each other will occur in the ground. In addition, it is also stated in the Patent document 2 that the bottom of the overlapped section would be given temporal securing in the case of the firm ground. However, the steel sheet pile and the H-shaped or T-shaped steel member, if secured together in both ends of the overlapped section, bring about restraint of their longitudinal deformations, resulting in the danger of buckling.

[0012] In the invention described in the Patent document 3, the width of the H-shaped steel member needs to be smaller than the web width of the steel sheet pile if the H-shaped steel member is disposed inside the web section of the steel sheet pile, and accordingly, the size limitation is imposed on the H-shaped steel member. Or, there is a need to use a special-sized H-shaped steel member whose flanges at both ends thereof have different lengths as shown in FIG. 19(b).

[0013] In particular, various types of steel sheet piles and/or H-shaped steel members or the like are available in the standardized forms in most cases. For that reason, special-sized steel sheet piles and/or H-shaped steel members require additional processing or the like, and thus, will be difficult of their applications from the viewpoint of cost.

[0014] No matter whether the rigidity increasing steel material such as the H-shaped steel member is mounted to the inside or the outside of the web section of the steel sheet pile, it gives the same cross-section performance in either case. Thus, with consideration of a composite steel sheet pile as superposed beams, it will be appreciated that mounting the rigidity increasing steel material to the inside of the web section of the steel sheet pile rather than the outside thereof is of advantage to the attainment of a smaller wall thickness which leads to space saving. However, if an H-shaped steel member having a width greater than the web width of the steel sheet pile is mounted, it may well be that the steel sheet pile deformation in such a direction that the steel sheet pile is forced open will occur at the time of mounting.

[0015] An object of the present invention is to solve the problems in the above prior arts, more specifically, to provide a composite steel sheet pile and a steel sheet pile wall which comprise a steel sheet pile and a rigidity increasing steel material which are not fully integrated with each other but are combined with each other as superposed beams in such a manner that the deflection behaviors of the steel sheet pile and the rigidity increasing steel material almost coincide with each other in order to give the configuration which eliminates labor and cost required for welding, shape measurement, correction work, processing management and the like, and allows the composite steel sheet pile and the steel sheet pile wall to be stored and transported with high efficiency.

MEANS FOR SOLVING THE PROBLEMS

[0016] A composite steel sheet pile according to the present invention comprises a steel sheet pile and a rigidity increasing shape steel material extending in the longitudinal direction of the steel sheet pile, the shape steel material being disposed on one side of the steel sheet pile, wherein the shape steel material is joined to the steel sheet pile in more than one joining point of the shape steel material in the longitudinal direction thereof in such a manner that at least to one joining point thereof is applied a structure that is to permit the steel sheet pile and the shape steel material to be longitudinally displaced from each other in order that the deflection behaviors of the steel sheet pile and the shape steel material may almost coincide with each other.

[0017] As to the point to join the shape steel material and the steel sheet pile together, more than one point including both ends of the shape steel material in the longitudinal direction thereof is desirably required to bring the steel sheet pile and the shape steel material into close contact with each other wholly as much as possible. However, it is to be understood that the present invention does not necessarily apply joining point limitation to both ends of the shape steel material in the longitudinal direction thereof, and may also include cases where except for one of the joining points, the others involve no end, or where any more than one joining point involves no end but the middle of the shape sheet material in the longitudinal direction thereof.

[0018] The composite steel sheet pile of the present invention having the above configuration is accordingly such that

the steel sheet pile and the shape steel material are combined with each other as superposed beams, and this permits the steel sheet pile and the shape steel material to be longitudinally displaced from each other and avoids substantially the shearing force transmission between the steel sheet pile and the shape steel material, resulting in that the deflection behaviors of the steel sheet pile and the shape steel material almost coincide with each other.

[0019] The steel sheet pile is not necessarily limited to a U-shaped steel sheet pile, a straight-shaped steel sheet pile, a hat-shaped steel sheet pile and the like. However, considering the relation to the wall thickness of a retaining wall and the like constructed by connecting the composite steel sheet piles together, the hat-shaped steel sheet pile as described later is desirably employed.

[0020] As for the rigidity increasing shape steel material, while an H-shaped steel member considered as a highly efficient material from the viewpoint of the relation to the cross-section rigidity and/or the cost is in general use, it need not be limited to the H-shaped steel member in all cases.

[0021] It is noted that the rigidity increasing shape steel material is not necessarily provided as long as the full length of the steel sheet pile in the longitudinal direction thereof, and it would be possible also to employ a shape steel material having a length smaller than a steel sheet pile length according to the requirements for design or the like. Alternatively, it would be possible also to arrange more than one short shape steel material discontinuously in the longitudinal direction of the steel sheet pile.

[0022] For the reason that the shape steel material is joined to the steel sheet pile in both ends of the shape steel material in the longitudinal direction thereof, it will be appreciated that the shape steel material can be driven into the ground in such a manner that it is integrated with the steel sheet pile as the composite steel sheet pile. In a case where only both ends of the shape steel material are adapted to be joined to the steel sheet pile, applying at least to one end thereof a combination of a joining bolt and a bolt hole having a size greater than a bolt hole having a size appropriate for the bolt diameter in order to permit the steel sheet pile and the shape steel material to be longitudinally displacedfrom each other can avoid substantially the shearing force transmission between the steel sheet pile and the shape steel material, and thus allows the deflection behaviors of the steel sheet pile and the shape steel material to almost coincide with each other. Accordingly, no buckling will occur, unlike a case where both ends of the shape steel material are fully secured to the steel sheet pile.

[0023] In a case where the shape steel material is joined to the steel sheet pile in both ends plus the middle of the shape steel material in the longitudinal direction thereof, it would be possible also to secure the joined part of the middle thereof to the steel sheet pile in order to apply both ends thereof to permit the displacement. Alternatively, it would be possible also to secure one end of the shape steel material to the steel sheet pile in order to apply the other end and the middle thereof to permit the displacement.

[0024] Further, it would be possible also to join the steel sheet pile and the shape steel material together by tension-type bolted connection using more than one longitudinally spaced bolt in order that the deflection behaviors of the steel sheet pile and the shape steel material may almost coincide with each other.

[0025] The bolts must be sufficient in number tomeet the requirement under which the deflection behaviors of the steel sheet pile and the shape steel material are allowed to almost coincide with each other in cases where the rigidity increasing shape steel material side of the composite steel sheet pile receives an earth pressure. In H-shaped steel member applications as the rigidity increasing shape steel material, the bolts will be usually arranged in one or more than one row at predetermined intervals in such position as to be at each of the opposite sides of the flange with the web between.

[0026] Even if the rigidity increasing shape steel material side of the composite steel sheet pile receives an earth pressure, the tension-type bolted connection using the required number of bolts can avoid increasing the deformation of only the steel sheet pile which is smaller in flexural rigidity than the rigidity increasing shape steel material, and thus allows the deflection behaviors of the steel sheet pile and the rigidity increasing shape steel material to coincide with each other.

[0027] For joining the steel sheet pile and the shape steel material together by the tension-type bolted connection using more than one longitudinally spaced bolt in order that the deflection behaviors of the steel sheet pile and the shape steel material may almost coincide with each other, a tensile force × resulting from summing up the tensile forces of more than one longitudinally spaced bolt in applications of the tension-type bolted connection to join the steel sheet pile and the shape steel material together may be to meet the requirement given by the following expression (1) .

$$X \geqq \{ (l - a) \cdot I_1 - a \cdot I_2 \} \cdot p / (I_1 + I_2) \quad \ldots (1)$$

Where l represents the width of the steel sheet pile, a represents the width of the shape steel material, I_1 represents the moment of inertia of area of the steel sheet pile, I_2 represents the moment of inertia of area of the shape steel material, and p represents an earth pressure acting on the shape steel material side of the composite steel sheet pile.

[0028] As described later, the above expression (1) is to indicate the requirement under which the deflection behaviors of the steel sheet pile and the shape steel material as the rigidity increasing steel material are allowed to almost coincide with each other by the tension-type bolted connection.

[0029] Further, in such a composite steel sheet pile, the structure applied to the joining point, or the structure that is to permit the steel sheet pile and the shape steel material to be longitudinally displaced from each other may be of a type given by a combination of a joining bolt and an elongate bolt hole provided at least in one of the steel sheet pile and the shape steel material or a bolt hole having a size greater than a bolt hole having a size appropriate for the bolt diameter.

[0030] Applying the combination of a joining bolt and a bolt hole having a size greater than a bolt hole having a size appropriate for the bolt diameter to permit the steel sheet pile and the shape steel material to be longitudinally displaced from each other can avoid the excessive shearing force application to the bolts and at the same time, allows the deflection behaviors of the steel sheet pile and the shape steel material as the rigidity increasing steel material to almost coincide with each other.

[0031] Further, in such a composite steel sheet pile, the steel sheet pile may include hat-shaped steel sheet piles which are connected together by engagement between joints provided at both ends of each steel sheet pile in the width direction thereof, the connection beingmade in such a manner that protrusions and recesses in a cross-section perpendicular to the longitudinal direction face the same direction.

[0032] The hat-shaped steel sheet piles are adapted to be connected together by engagement between joints provided at both ends of each hat-shaped steel sheet pile in the width direction thereof, the connection being made in such a manner that protrusions and recesses in a cross-section perpendicular to the longitudinal direction face the same direction. Further, the composite steel sheet pile of the present invention is originally such that the steel sheet pile and the shape steel material are not fully integrated with each other from the physical point of view, and thus, there would not be much influence on the cross-section rigidity by a difference in the mounting surface or mounting position of the shape steel material to the steel sheet pile. Therefore, mounting the shape steel material to the recess section of the hat-shaped steel sheet pile can provide a compact-sized composite steel sheet pile which thus may hold down a steel sheet pile wall to a smaller wall thickness, and is also suitable to be driven into the ground in state where the shape steel material and the steel sheet pile are in the combined form.

[0033] Moreover, in the composite steel sheet pile of the present invention, it would be possible also to join the steel sheet pile and the shape steel material together through a steel material as a spacer interposed between the steel sheet pile and the shape steel material.

[0034] In hat-shaped or U-shaped steel sheet pile applications as the steel sheet pile, the width of the H-shaped steel member needs to be smaller than the web width of the steel sheet pile if the shape steel material is disposed inside the recess section of the hat-shaped or U-shaped steel sheet pile, and accordingly, the size limitation is imposed on the H-shaped steel member.

[0035] The recess section of the hat-shaped or U-shaped steel sheet pile has usually an outwardly (or toward the opening side) widening spacing. Thus, in this case, if the steel material as the spacer is interposed between the steel sheet pile and the shape steel material, the size limitation on the H-shaped steel member is relaxed.

[0036] The steel material as the spacer may be a steel sheet, or alternatively, in cases of the need for a wider spacer spacing, it would be possible also to use other steel materials such as channel steels and square steels. However, in either case, the required minimum spacer spacing is determined depending on the size relation between the steel sheet pile and the shape steel material. Alternatively, it would be possible also to arrange more than one steel sheet in layers for spacer spacing adjustment, for instance.

It is noted that means of mounting the spacer is not particularly limited to bolting, welding, drill screw threads and the like.

[0037] A steel sheet pile wall of the present invention comprises more than one steel sheet pile, the steel sheet piles being connected together through joints provided at both ends of each steel sheet pile, wherein the steel sheet piles employ, at least in part, the composite steel sheet pile having any of the above configurations.

[0038] All the steel sheet piles are not necessarily limited to the composite steel sheet pile, and it would be possible also to provide, according to the required strength of the steel sheet pile wall, the appropriately mixed arrangement composed of the composite steel sheet piles of the present invention and the usual type of steel sheet piles with no shape steel member mounted.

[0039] Further, in the steel sheet pile wall of the present invention, it is desired that the steel sheet piles that form the composite steel sheet piles are arranged on the earth pressure receiving side or the high earth pressure developing side thereof.

[0040] Usually, the steel sheet piles that form the composite steel sheet piles are more easily subjected to flexural deformation than the shape steel materials. Thus, in cases where the steel sheet piles receive an earth pressure, the configuration of the composite steel sheet pile of the present invention, if provided for the steel sheet pile wall, allows the deflection behavior of the shape steel material to follow that of the steel sheet pile. However, in the contrary case, it may well be that the flexural deformation of the steel sheet pile will be so increased that the deflection behaviors of

the steel sheet pile and the shape steel material fail to coincide with each other.

EFFECTS OF THE INVENTION

[0041] The composite steel sheet pile of the present invention is such that the steel sheet pile and the rigidity increasing shape steel material are not integrated with each other but are combined with each other as superposed beam, and thus, provides the advantage that the deflection behaviors of the steel sheet pile and the rigidity increasing shape steel material are allowed to almost coincide with each other, resulting in that no buckling will occur, as compared with the prior art which is such that the steel sheet pile and the rigidity increasing shape steel material are integrated with each other.

[0042] Although being inferior in cross-section rigidity to the structure which is such that the rigidity increasing shape steel material is secured over the full length thereof by welding, the composite steel sheet pile of the present invention permits less labor and less cost for welding, shape measurement, correction work and processing management.

[0043] The steel sheet pile and the rigidity increasing shape steel material or the spacer can be transported separately to a construction site, and combined together in the site, followed by being driven into the ground in the integrated form, and this allows the steel sheet pile and the rigidity increasing shape steel material or the spacer to be stored and transported with high efficiency. Moreover, the steel sheet pile and the rigidity increasing shape steel material need not be separately driven into the ground, thereby eliminating the problem of the reduced efficiency in execution of construction works, unlike the invention described in the Patent document 1.

[0044] In hat-shaped or U-shaped steel sheet pile applications as the steel sheet pile, the width of the H-shaped steel member needs to be smaller than the web width of the steel sheet pile if the shape sheet material is disposed inside the recess section of the steel sheet pile, and accordingly, the size limitation is imposed on the H-shaped steel member. In contrast with the above, the result of interposition of the steel material as the spacer is that the size limitation on the H-shaped steel member is relaxed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0045]

[FIG. 1] FIG. 1 shows one embodiment of a composite steel sheet pile of the present invention, with FIGS. 1(a) and 1(b) being a plan view and an elevation view respectively showing the same.

[FIG. 2] FIG. 2 gives an explanation on deflection behaviors, with FIGS. 2(a) and 2(b) being explanatory views respectively showing deflection behaviors in the case of a composite steel sheet pile in the prior art and in the case of a composite steel sheet pile of the present invention.

[FIG. 3] FIGS. 3(a) and 3(b) are elevation views respectively showing modifications to the embodiment shown in FIG. 1.

[FIG. 4] FIG. 4 is a plan view showing one embodiment of a steel sheet pile wall of the present invention.

[FIG. 5] FIG. 5 is a plan view showing another embodiment of the steel sheet pile wall of the present invention.

[FIG. 6] FIG. 6 shows another embodiment of the composite steel sheet pile of the present invention, with FIGS. 6 (a), 6(b) and 6(c) being a plan view and an elevation view respectively showing the same and an elevation view showing a modification thereto.

[FIG. 7] FIG. 7 shows a relation between a steel sheet pile wall using a composite steel sheet pile of the present invention and an earth pressure, with FIGS. 7(a) and 7(b) being plan views respectively showing the same in cases where an earth pressure acts on the steel sheet pile side of the steel sheet pile wall and in cases where an earth pressure acts on the rigidity increasing shape steel material side of the steel sheet pile wall.

[FIG. 8] FIG. 8 is an explanatory view applied to derive the requirement in the case of joining by tension-type bolted connection.

[FIG. 9] FIG. 9 is a plan view showing a further embodiment of the steel sheet pile wall of the present invention.

[FIG. 10] FIG. 10 shows one embodiment of a composite steel sheet pile with a steel material interposed as a spacer, with FIG. 10 (a) and 10(b) being a plan view and an elevation view respectively showing the same.

[FIG. 11] FIGS. 11(a) and 11(b) are plan views respectively showing modifications of the spacer to the embodiment shown in FIG. 10.

[FIG. 12] FIG. 12 shows a further embodiment of the composite steel sheet pile of the present invention, with FIGS. 12(a) and 12(b) being a plan view and an elevation view respectively showing the same.

[FIG. 13] FIGS. 13(a) and 13(b) are elevation views respectively showing modifications to the embodiment shown in FIG. 12.

[FIG. 14] FIG. 14 is a plan view showing a still further embodiment of the steel sheet pile wall of the present invention.

[FIG. 15] FIG. 15 is a plan view showing a yet further embodiment of the steel sheet pile wall of the present invention.

[FIG. 16] FIG. 16 is a plan view showing a still further embodiment of the composite steel sheet pile of the present

invention.

[FIG. 17] FIGS. 17(a) and 17(b) are plan views respectively showing the outline of the invention described in the Patent document 1.

[FIG. 18] FIGS. 18(a) and 18(b) are perspective views respectively showing the outline of the invention described in the Patent document 2.

[FIG. 19] FIGS. 19(a) and 19(b) are plan views respectively showing the outline of the invention described in the Patent document 3.

MODE FOR EMBODYING THE INVENTION

[0046] Specific embodiments of the present invention will be now described. It is to be understood that the present invention is not limited to the following embodiments thereof.

[0047] FIG. 1 shows one embodiment of a composite steel sheet pile 1 of the present invention, with FIGS. 1(a) and 1(b) being a plan view and an elevation view respectively showing the same.

[0048] An H-shaped steel member 3 as a rigidity increasing steel material is disposed inside the web section of a hat-shaped steel sheet pile 2 as a steel sheet pile, and the upper end and the lower end of the H-shaped steel member are joined to the web section of the hat-shaped steel sheet pile 2.

[0049] Hat-shaped steel sheet piles 2 are adapted to be connected together by engagement between joints 4 and 5 provided at both ends of each hat-shaped steel sheet pile in the width direction thereof, the connection beingmade in such a manner that protrusions and recesses in a cross-section of the hat-shaped steel sheet piles face the same direction.

[0050] According to this embodiment, the lower end of the H-shaped steel member is secured to the hat-shaped steel sheet pile by welding 6, and the upper end thereof is joined to the hat-shaped steel sheet pile by bolted connection. The bolted connection of the upper end thereof is made in such a manner that at least either a bolt hole of the hat-shaped steel sheet pile 2 or that of the H-shaped steel member 3 is given in the form of a bolt hole 7 having a size greater than a bolt hole having a size appropriate for the bolt diameter in order to permit the H-shaped steel member and the hat-shaped steel sheet pile to be displaced from each other in the top-bottom direction in FIG. 1(b).

[0051] It is noted that the hat-shaped steel sheet pile 2 and the H-shaped steel member 3 can be joined together in a construction site, and this allows the hat-shaped steel sheet pile and the H-shaped steel member having been transported separately to the site to be joined together in the site, followed by being driven into the ground in the integrated form.

[0052] FIG. 2 gives an explanation on deflection behaviors in a comparison between deflection behaviors in the case of a composite steel sheet pile in the prior art (see FIG. 2(a)) and in the case of a composite steel sheet pile of the present invention (see FIG. 2(b)).

[0053] In the case of a composite steel sheet pile 41 in the prior art as shown in FIG. 2(a), a steel sheet pile 42 and a rigidity increasing steel material 43 are secured together over the full length by welding or the like into the integrated form. Thus, the difference in deflection behavior arises between the steel sheet pile 42 and the rigidity increasing steel material 43, resulting in that the buckling will occur as the case may be.

[0054] In contrast with the above, a composite steel sheet pile 31 of the present invention as shown in FIG. 2(b) is adapted to permit a steel sheet pile 32 and a rigidity increasing steel material 33 to be longitudinally displaced from each other, so that the deflection behaviors of the steel sheet pile and the rigidity increasing steel material are allowed to almost coincide with each other as against an earth pressure or the like acting on the steel sheet pile 32-side of the composite steel sheet pile.

FIGS. 3(a) and 3(b) show respectively modifications to the embodiment shown in FIG. 1.

[0055] According to one modification shown in FIG. 3(a), H-shaped steel members 3 as the rigidity increasing steel material are arranged discontinuously in the longitudinal direction of a steel sheet pile, in which case, the lower end of each H-shaped steel member 3 is secured by welding to the steel sheet pile, and the upper end thereof is joined to the steel sheet pile using a combination of a joining bolt and an elongate bolt hole 7 in order to permit the steel sheet pile 2 to be longitudinally displaced in the occurrence of flexural deformation caused by an earth pressure or the like.

[0056] According to the other modification shown in FIG. 3(b), an H-shaped steel member 3 as the rigidity increasing steel material is joined to a steel sheet pile 2 in both the upper end and the lower end plus the middle of the H-shaped steel member, in which case, the joined part of the middle thereof is secured to the steel sheet pile using a bolt corresponding to a common-sized bolt hole 8, and the joined part of each of the upper end and the lower end thereof is given in the form a bolt hole 7 having a size greater than a bolt hole having a size appropriate for the bolt diameter in order to permit the H-shaped steel member and the steel sheet pile to be displaced from each other in the top-bottom direction.

[0057] FIG. 4 shows one embodiment of a steel sheet pile wall of the present invention, in which case, a steel sheet pile wall A is constructed by the manner in which the composite steel sheet piles 1 of the embodiment shown in FIG. 1, for instance, are successively connected together through joints provided at both ends of each hat-shaped steel sheet pile 2 in the width direction thereof, while being driven into the ground.

[0058] FIG. 5 shows another embodiment of the steel sheet pile wall of the present invention, in which case, there is

shown a steel sheet pile wall which is constructed in such a manner that the usual type of hat-shaped steel sheet pile 2 itself is partly combined with the composite steel sheet piles, instead of being constructed using only the composite steel sheet piles like the steel sheet pile wall A shown in FIG. 4.

In either case of the embodiments shown in FIGS. 4 and 5, the steel sheet pile wall is constructed on condition that a high earth pressure acts on the hat-shaped steel sheet pile 2-side thereof.

[0059] FIG. 6 shows another embodiment of the composite steel sheet pile 1 of the present invention, with FIGS. 6 (a), 6(b) and 6(c) being a plan view and an elevation view respectively showing the same and an elevation view of a modification thereto.

[0060] An H-shaped steel member 3 as the rigidity increasing steel material is disposed inside the web section of a hat-shaped steel sheet pile 2 as the steel sheet pile, and the flange section on one side of the H-shaped steel member 3 is joined to the web section of the hat-shaped steel sheet pile 2 by tension-type bolted connection using longitudinally predeterminedly spaced bolts 9.

[0061] Hat-shaped steel sheet piles 2 are adapted to be connected together by engagement between joints 4 and 5 provided at both ends of each hat-shaped steel sheet pile in the width direction thereof, the connection being made in such a manner that protrusions and recesses in a cross-section of the hat-shaped steel sheet piles face the same direction.

[0062] As to the bolt hole for tension-type bolted connection, at least either a bolt hole of the hat-shaped steel sheet pile 2 or that of the H-shaped steel member 3 is given in the form of a bolt hole 7 having a size greater than a bolt hole having a size appropriate for the bolt diameter in order to permit the hat-shaped steel sheet pile and the H-shaped steel member to be displaced from each other in the top-bottom direction in FIGS. 6(b) and 6(c).

[0063] It is noted that the hat-shaped steel sheet pile 2 and the H-shaped steel member 3 can be joined together in a construction site, and this allows the hat-shaped steel sheet pile and the H-shaped steel member having been transported separately to the site can be joined together in the site, followed by being driven into the ground in the integrated form.

[0064] While in the embodiment shown in FIG. 6(a), the H-shaped steel member 3 as the rigidity increasing steel material extends continuously in the longitudinal direction of the steel sheet pile 2, the modification shown in FIG. 6(b) is such that more than one H-shaped steel member 3 is arranged discontinuously in the longitudinal direction of the steel sheet pile 2, and the flange section of each H-shaped steel member 3 is adapted to be joined by tension-type bolted connection using the predeterminedly spaced bolts 9.

FIG. 7 shows a relation between the steel sheet pile wall using the composite steel sheet pile of the present invention and an earth pressure.

[0065] In cases where the steel sheet pile 2-side of the steel sheet pile wall receives an earth pressure as shown in FIG. 7(a), the deflection behaviors of the steel sheet pile 2 and the rigidity increasing H-shaped steel member 3 are allowed to almost coincide with each other without the need to make tension-type bolted connection in order to allow the above deflection behaviors to coincide with each other. However, if the H-shaped steel member 3-side of the steel sheet pile wall receives an earth pressure as shown in FIG. 7(b), the deformation of the steel sheet pile 2 will be so increased in applications of joining in the usual manner that the above deflection behaviors fail to coincide with each other, in which case, no consideration as superposed beams will be given.

[0066] In contrast with the above, joining by tension-type bolted connection allows the deflection behaviors of the steel sheet pile and the H-shaped steel member to coincide with each other even if the H-shaped steel member 3-side of the steel sheet pile wall receives an earth pressure.

[0067] How to derive the above expression (1) indicative of the requirement under which the deflection behaviors of the H-shaped steel member and the steel sheet pile are allowed to coincide with each other by tension-type bolted connection will be next described with reference to FIG. 8.

$$X \geqq \{ (l - a) \cdot I_1 - a \cdot I_2 \} \cdot p / (I_1 + I_2) \quad \ldots (1)$$

[0068] The composite steel sheet pile can be expressed as shown in FIG. 8(b) by assuming that it is divided into an upper section and a lower section when the H-shaped steel member 3-side thereof receives an earth pressure as shown in FIG. 8(a).

[0069] In FIG. 8, let 1 represent the width of the steel sheet pile, a represent the width of the shape steel member, and I_1 represent the moment of inertia of area of the steel sheet pile, I_2 represent the moment of inertia of area of the shape steel member and p represent an earth pressure acting on the shape steel member side of the composite steel sheet pile, respectively.

Suppose that the sum total of bolt tensile forces is denoted by $\times$, the steel sheet pile displacement is denoted by δ_1, and the H-shaped steel member displacement is denoted by δ_2.

Where:

[0070]

[Mathematical Expression 1]

$$\delta_1 \propto \frac{ap+X}{EI_1} \qquad \delta_2 \propto \frac{(l-a)p-X}{EI_2}$$

[0071] In this case, for reason that the H-shaped steel member having high rigidity is subjected to tension by the steel sheet pile, their deformations need to become equal. Thus, suppose $\delta_1 \geqq \delta_2$, this gives:

[Mathematical Expression 2]

$$\frac{ap+X}{EI_1} \geq \frac{(l-a)p-X}{EI_2}$$

[0072] Accordingly, the requirement under which the steel sheet pile and the H-shaped steel member are allowed to coincide with each other by tension-type bolted connection in cases where the H-shaped steel member side of the composite steel sheet pile receives an earth pressure will be expressed as follows.

[Mathematical Expression 3]

$$X \geq \frac{(l-a)I_1 - aI_2}{I_1 + I_2} p$$

[0073] One instance of a numerical simulation will be now given as follows, provided that a connection force α is used for the right-hand side of the expression (1).

[0074] As for the subject of the numerical simulation, consideration will be given to a composite steel sheet pile which comprises a hat-shaped steel sheet pile 900 (see Internet < URL: http:// www./mlit. go.jp/kisha/kisha06/13/131016_.html > [Circumstances of Enforcement on "Structural Reform of Public Undertaking Cost" by Ministry of Land, Infrastructure, Transport and Tourism in 2005], [referenced on March 17, 2009], for instance) which is of a large cross-section and small thickness structure with an effective width of 900 mm and provides higher executability of construction works and H-600×200 which is available as H-shaped steel members of small width type.

[0075] Considering an active earth pressure of the sandy ground with an N-value of 15, the coefficient of active earth pressure will be as follows.

$$\text{Kacos}\ \delta = 0.2911$$

If taking the case of a wall height of 5.0 m (a residual water level is assumed to be one half as high as the wall height), the sum of a residual water pressure and an active earth pressure at the frontal ground side will be as follows.

$$p = pa + pw = (w + \gamma h_1 + \gamma' h_2) \times \text{kacos}\,\delta + \gamma wh$$
$$= (10+18\times2.5+9\times2.5)\times0.2911+10\times2.5 = 47.56\ \text{kN/m}^2$$

In the case of H-600×200, α=0.6. Thus, this gives:

$$\times=0.6\times47.56 = 28.536 \text{ kN/m}$$

In the case of M-22 bolt,

$$A = 380.13 \text{ mm}^2$$

In the case of the allowable stress intensity of 140N/mm^2, the force adaptable to be assigned per bolt is assumed to be 53.22 kN. Thus, this gives:

$$53.22/28.536=1.86 \text{ m}$$

That is, it will be found that the result of calculation is that one bolt needs to be at each interval of 1.8m.

[0076] FIG. 9 shows a further embodiment of the steel sheet pile wall of FIG. 7(b), in which case, there is shown a steel sheet pile wall A which is constructed in such a manner that the usual type of hat-shaped steel sheet pile 2 itself is partly combined with the composite steel sheet piles, instead of being constructed using only the composite steel sheet piles 1 like the steel sheet pile wall A as shown in FIG. 7(b).
The steel sheet pile wall in the embodiment shown in FIG. 9 is also constructed on condition that a high earth pressure acts on the H-shaped steel member 3-side thereof.

[0077] FIG. 10 shows one embodiment of a composite steel sheet pile with a steel material interposed as a spacer 11, with FIGS. 10 (a) and 10(b) being a plan view and an elevation view respectively showing the same.

[0078] Hat-shaped steel sheet piles 2 as the steel sheet piles and/or H-shaped steel members 3 are mass-produced in the standardized forms. Thus, if an attempt is made to adapt such standardized hat-shaped steel sheet piles and/or H-shaped steel members to meet the requirements for design of the steel sheet pile wall, the flange of each H-shaped steel member 3 having an appropriate cross-section in view of design will sometimes fail to be seated into the web section of the hat-shaped steel sheet pile 2 from the dimensional point of view.

[0079] The embodiment shown in FIG. 10 is such that a hat-shaped steel sheet pile 900 (see Internet <URL: http://www. mlit. go.jp/kisha/kisha06/13/131016_.html>, [Circumstances of Enforcement on "Structural Reform of Public Undertaking Cost" by Ministry of Land, Infrastructure, transport and Tourism in 2005], [referenced on March 17, 2009], for instance) which is of a large cross-section and small thickness structure with an effective width of 900 mm and provides higher executability of construction works and H-700×300 which is available as H-shaped steel members of middle width type are joined together through a spacer 11 made of a steel sheet having a thickness of 20 mm. In this embodiment, the result of interposition of the spacer 11 is that the flange of the H-shaped steel member 3 can be seated into the web section of the hat-shaped steel sheet pile 2.

[0080] Hat-shaped steel sheet piles 2 are adapted to be connected together by engagement between joints 4 and 5 provided at both ends of each steel sheet pile in the width direction thereof, the connection being made in such a manner that protrusions and recesses in a cross-section of the steel sheet piles face the same direction.

[0081] In this case, the hat-shaped steel sheet pile 2, the spacer 11 and the H-shaped steel member 3 may be also secured together by bolted connection, welding or the like. Alternatively, applying the structure that is to permit the steel sheet pile 2 and the H-shaped steel member 3 or the spacer 11 to be longitudinally displaced from each other may result in that the deflection behaviors of the steel sheet pile 2 and the H-shaped steel member 3 will almost coincide with each other, like an embodiment shown in FIG. 12 as described later.

[0082] FIG. 11 shows modifications of the spacer to the embodiment shown in FIG. 10, with FIGS. 11(a) and 11(b) being views respectively showing one modification where a steel material used for a spacer 12 has a square cross-section, and another modification where two channel-shaped cross-section steel materials are used as spacers 13.

[0083] FIG. 12 shows a still further embodiment of the composite steel sheet pile 1 of the present invention, with FIGS. 12(a) and 12(b) being a plan view and an elevation view respectively showing the same.

[0084] An H-shaped steel member 3 as the rigidity increasing steel material is disposed inside the web section of a hat-shaped steel sheet pile 2 as the steel sheet pile through a spacer 11 made of a steel sheet, and the upper end and the lower end of the H-shaped steel member are joined to the steel sheet pile.

[0085] According to this embodiment, the lower end of the H-shaped steel member is secured to the steel sheet pile by welding 6, and the upper end thereof is joined to the steel sheet pile by bolted connection. The bolted connection of the upper end thereof is made in such a manner that at least either a bolt hole of the hat-shaped steel sheet pile 2 or that of the H-shaped steel member 3 is given in the form of a bolt hole 7 having a size greater than a bolt hole having

a size appropriate for the bolt diameter in order to permit the hat-shaped steel sheet pile and the H-shaped steel member to be displaced from each other in the top-bottom direction in FIG. 12(b).

[0086] It is noted that the hat-shaped steel sheet pile 2, the H-shaped steel member 3 and the spacer 11 can be joined together in a construction site, and this allows the hat-shaped steel sheet pile, the H-shaped steel member and the spacer having been separately transported to the site to be joined together in the site, followed by being driven into the ground in the integrated form. Alternatively, it would be possible also to mount the spacer 11 to either the hat-shaped steel sheet pile 2 or the H-shaped steel member 3 in advance.

[0087] FIGS. 13(a) and 13(b) show respectively modifications to the embodiment shown in FIG. 12.

According to one modification shown in FIG. 13(a), the spacers 11 are arranged discontinuously in the longitudinal direction of a steel sheet pile, in which case, the lower end of each spacer 11 is secured to the steel sheet pile by welding, and the upper end thereof is joined to the steel sheet pile using a combination of a joining bolt and an elongate bolt hole 7 in order to permit the steel sheet pile 2 to be longitudinally displaced in the occurrence of flexural deformation caused by an earth pressure or the like. To the spacers 11, an H-shaped steel member 3 as the rigidity increasing steel material as shown by chain double-dashed line is mounted.

[0088] It is noted that it would be possible also to provide an H-shaped steel member 3 whose flange has a bolt hole 7 having a size greater than a bolt hole having a size appropriate for the bolt diameter without the need to provide any elongate bolt hole 7 for each spacer 11.

[0089] According to another modification shown in FIG. 13(b), a spacer 11 and an H-shaped steel member 3 as the rigidity increasing steel material as shown by chain double-dashed line are joined to a steel sheet pile 2 in both the upper end and the lower end plus the middle of each of the spacer and the H-shaped steel member, in which case, the joined part of the middle of each of the spacer and the H-shape steel member is secured to the steel sheet pile using a bolt corresponding to a common-sized bolt hole 8, and the joined part of each of the upper end and the lower end thereof is given in the form of a bolt hole 7 having a size greater than a bolt hole having a size appropriate for the bolt diameter in order to permit the steel sheet pile and the H-shaped steel member and the spacer to be displaced from each other in the top-bottom direction.

[0090] FIG. 14 shows a still further embodiment of the steel sheet pile wall of the present invention, in which case, a steel sheet pile wall A is constructed by the manner in which the composite steel sheet piles 1 of the embodiment shown in FIG. 10 or 12, for instance, are successively connected together through joints provided at both ends of each hat-shaped steel sheet pile 2 in the width direction thereof, while being driven into the ground.

[0091] FIG. 15 shows a yet further embodiment of the steel sheet pile wall of the present invention, in which case, there is shown a steel sheet pile wall which is constructed in such a manner that the usual type of hat-shaped steel sheet pile 2 itself is partly combined with the composite steel sheet piles, instead of being constructed using only the composite steel sheet piles like the steel sheet pile wall A as shown in FIG. 14.

In either case of the embodiments shown in FIGS. 14 and 15, the steel sheet pile wall is constructed on condition that a high earth pressure acts on the hat-shaped steel sheet pile 2-side thereof.

[0092] FIG. 16 shows one embodiment of a composite steel sheet pile with a steel material interposed as a spacer in the case where a steel sheet pile and a shape steel material are joined together by tension-type bolted connection using more than one longitudinally spaced bolt, with FIGS. 16(a) and 16(b) are a plan view and an elevation view respectively showing the same.

[0093] Hat-shaped steel sheet piles 2 as the steel sheet piles and/or H-shaped steel members are mass-produced in the standardized forms. Thus, if an attempt is made to adapt such standardized hat-shaped steel sheet piles and/or H-shaped steel members to meet the requirements for design of the steel sheet pile wall, the flange of the H-shaped steel member 3 having an appropriate cross-section in view of design will sometimes fail to be seated into the web section of the hat-shaped steel sheet pile 2 from the dimensional point of view.

[0094] In contrast with the above, the result of interposition of a steel sheet or the like as the spacer 11 as shown in FIG. 16, for instance, is that the flange of the H-shaped steel member 3 can be joined to the inside of the hat-shaped steel sheet pile 2 in state where it is seated thereto. The embodiment in this case is the same as the above other embodiments in that the steel sheet pile 2 and the H-shaped steel member 3 are joined together by tension-type bolted connection using more than one longitudinally spaced bolt 9 in order that the deflection behaviors of the steel sheet pile 2 and the H-shaped steel member 3 may almost coincide with each other.

INDUSTRIAL APPLICABILITY

[0095] The composite steel sheet pile and the steel sheet pile wall of the present invention are **characterized in that** the composite steel sheet pile is such that the steel sheet pile and the rigidity increasing steel material are combined with each other as superposed beams. Thus, in applications to a retaining wall or the like, this configuration allows the deflection behaviors of the steel sheet pile and the rigidity increasing steel material to almost coincide with each other for eliminating labor and cost required for welding, shape measurement, correction work, processing management or

the like, and also allows the composite steel sheet pile and the steel sheet pile wall to be stored and transported with high efficiency.

REPRESENTATIONS OF REFERENCE NUMERALS

[0096] A ... Steel sheet pile wall

[0097] 1 ... Composite steel sheet pile, 2 ... Hat-shaped steel sheet pile, 3 ... H-shaped steel member, 4 ... Joint, 5 ... Joint, 6 ... Welding, 7 ... Elongate bolt hole, 8 ... Bolt hole, 9 ... Bolt, 11 ... Spacer, 12 ... Spacer, 13 ... Spacer

Claims

1. A composite steel sheet pile comprising a steel sheet pile and a rigidity increasing shape steel material extending in the longitudinal direction of the steel sheet pile, said shape steel material being disposed on one side of said steel sheet pile, wherein said shape steel material is joined to said steel sheet pile in more than one joining point of said shape steel material in the longitudinal direction thereof in such a manner that at least to one joining point thereof is applied a structure that is to permit said steel sheet pile and said shape steel material to be longitudinally displaced from each other in order that the deflection behaviors of said steel sheet pile and said shape steel material may almost coincide with each other.

2. The composite steel sheet pile according to claim 1, wherein said more than one joining point of said shape steel material includes both ends of said shape steel material in the longitudinal direction thereof.

3. The composite steel sheet pile according to claim 1, wherein said shape steel material includes H-shaped steel members.

4. The composite steel sheet pile according to claim 1, wherein one of said joining points is secured in position.

5. The composite steel sheet pile according to claim 1, wherein said steel sheet pile and said shape steel material are joined together by tension-type bolted connection using more than one longitudinally spaced bolt in order that the deflection behaviors of said steel sheet pile and said shape steel material may almost coincide with each other.

6. The composite steel sheet pile according to claim 5, wherein a tensile force × resulting from summing up the tensile forces of more than one longitudinally spaced bolt in applications of tension-type bolted connection to join said steel sheet pile and said shape steel material together meets the requirement given by the following expression (1).

$$X \geqq \{ (l - a) \cdot I_1 - a \cdot I_2 \} \cdot p / (I_1 + I_2) \quad \cdots \quad (1)$$

where l represents the width of said steel sheet pile, a represents the width of said shape steel material, I_1 represents the moment of inertia of area of said steel sheet pile, I_2 represents the moment of inertia of area of said shape steel material, and p represents an earth pressure acting on the shape steel material side of the composite steel sheet pile.

7. The composite steel sheet pile according to claim 5, wherein as to all or part of more than one joining point adapted to joining by tension-type bolted connection, a bolt hole of at least one of said steel sheet pile and said shape steel material is in the form of a bolt hole having a size greater than a bolt hole having a size appropriate for the bolt diameter, said bolt hole being of a structure that is to permit the bolt adapted to join said steel sheet pile and said shape steel material together to be displaced in the longitudinal direction of said steel sheet pile or said shape steel material.

8. The composite steel sheet pile according to claim 1, wherein said steel sheet pile includes hat-shaped steel sheet piles connected together by engagement of joints provided at both ends of each steel sheet pile in the width direction thereof, the connection being maid in such a manner that protrusions and recesses in a cross-section perpendicular to the longitudinal direction face the same direction.

9. The composite steel sheet pile according to claim 1, wherein said steel sheet pile and said shape steel material are joined together through a steel material as a spacer interposed between said steel sheet pile and said shape steel

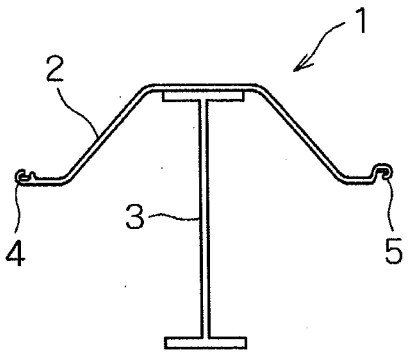
material.

10. A steel sheet pile wall comprising more than one steel sheet pile, the steel sheet piles being connected together through joints provided at both ends of each steel sheet pile, wherein said steel sheet piles employ, at least in part, the composite steel sheet pile according to claim 1.

11. The steel sheet pile wall according to claim 1, wherein said steel sheet piles that form said composite steel sheet piles are arranged on the earth pressure receiving side or the high earth pressure developing side thereof.

FIG.1

(a)



(b)

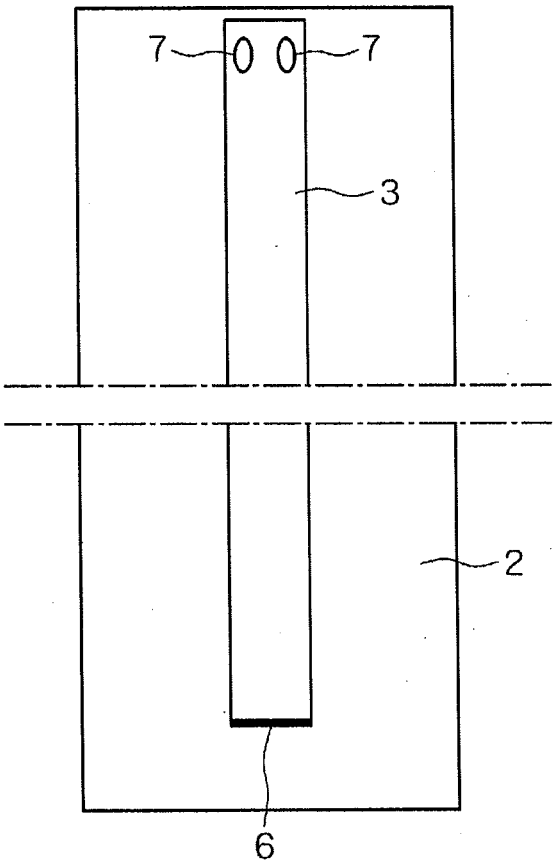


FIG.2

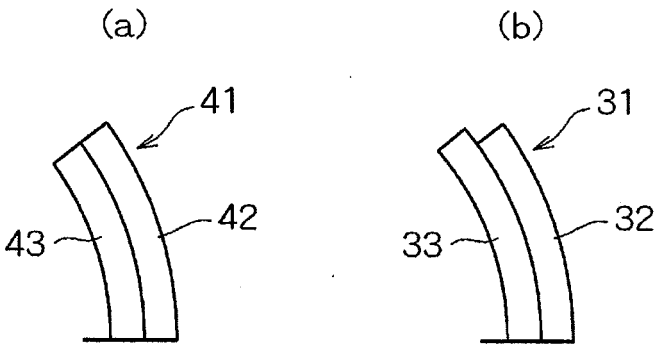


FIG.3

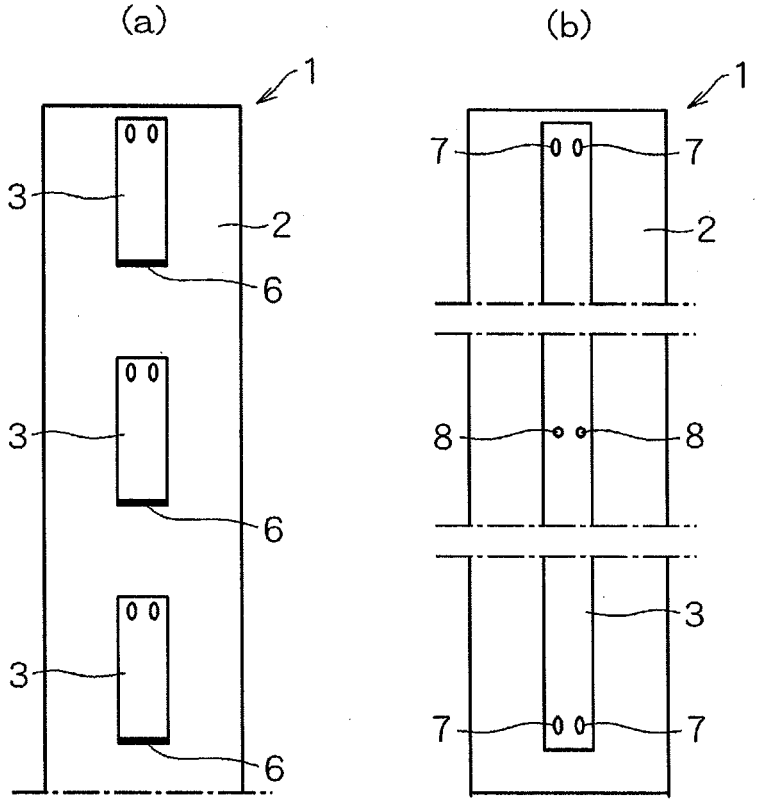
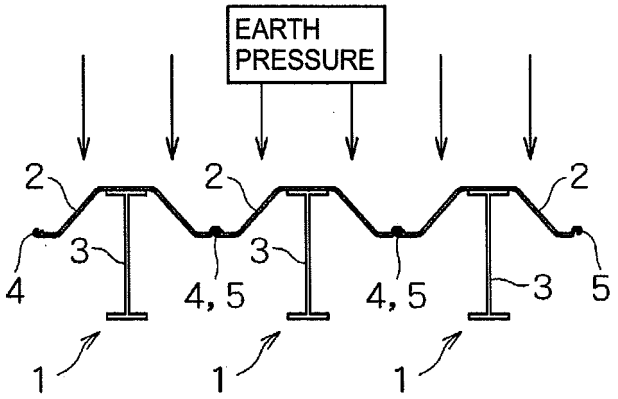


FIG.4


EARTH
PRESSURE
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2
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3
3
4
4, 5
4, 5
3
5
1
1
1

FIG.5

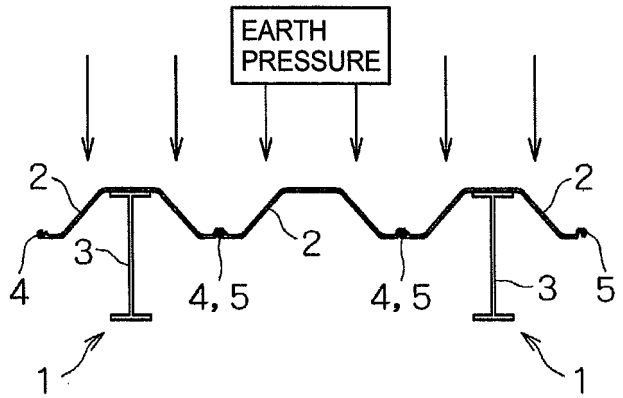
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FIG.6

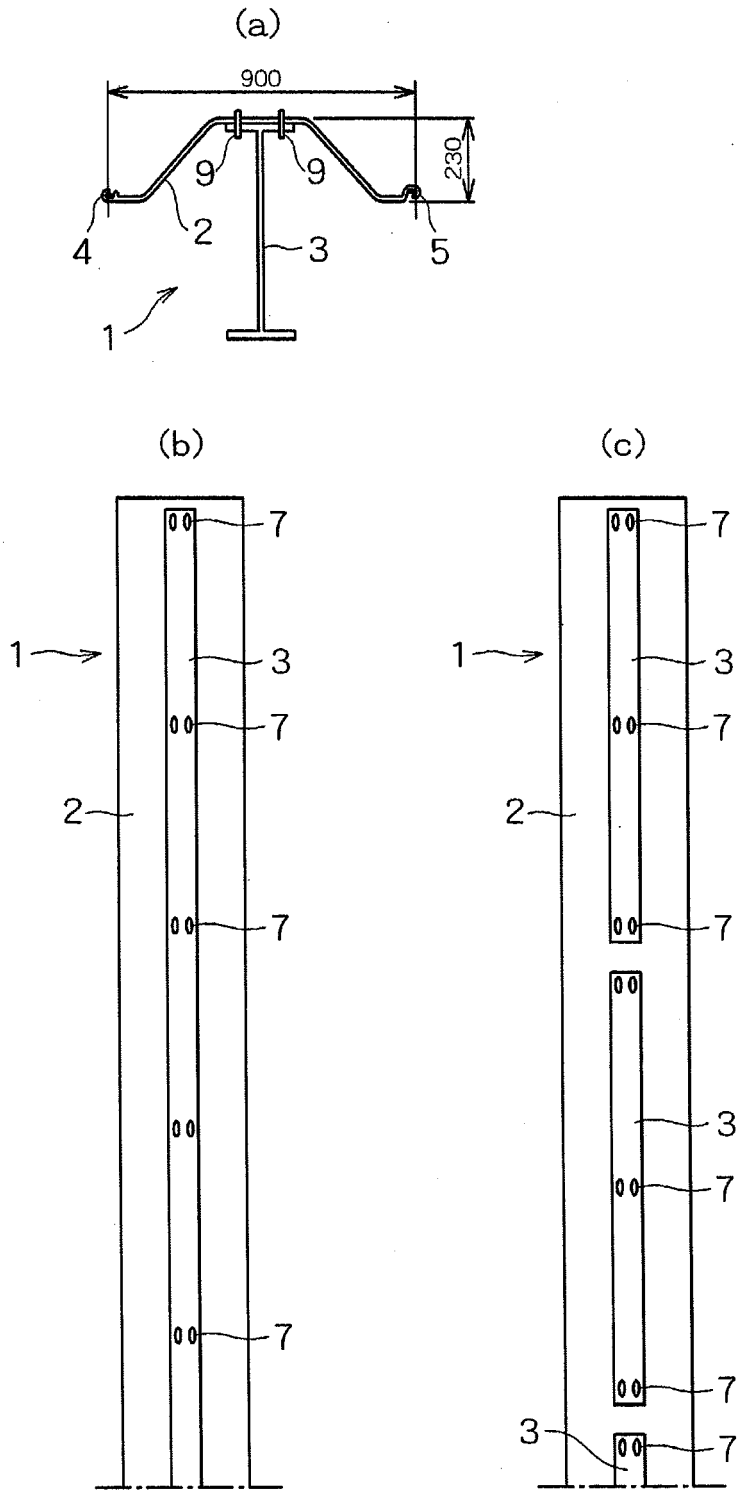


FIG.7

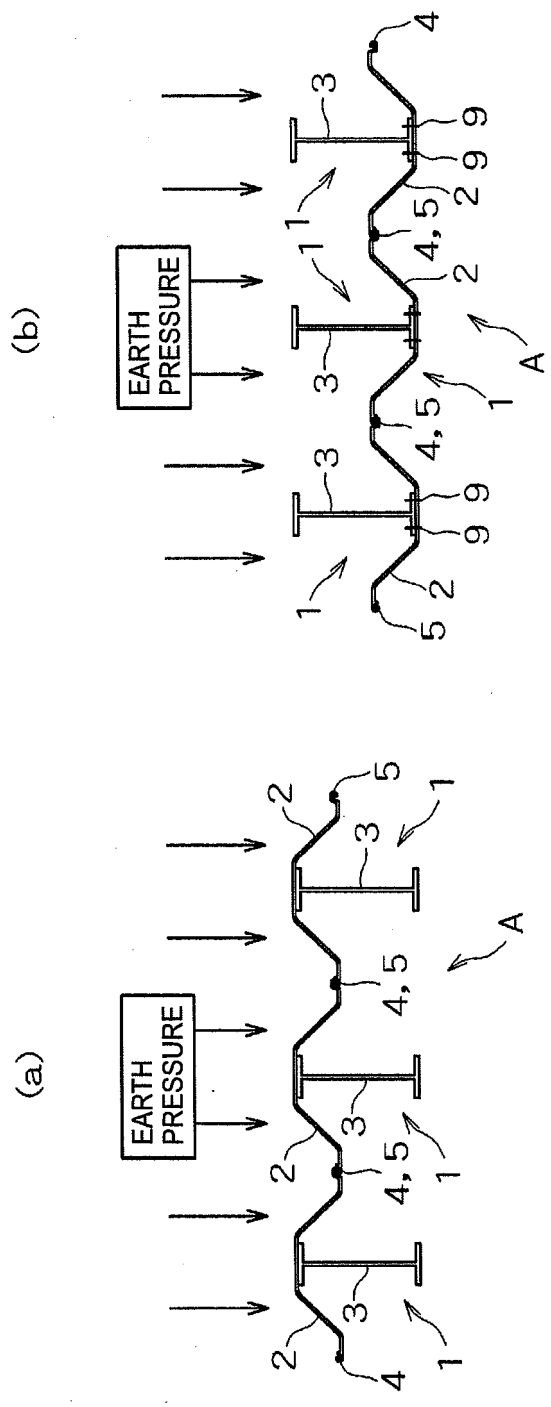


FIG.8

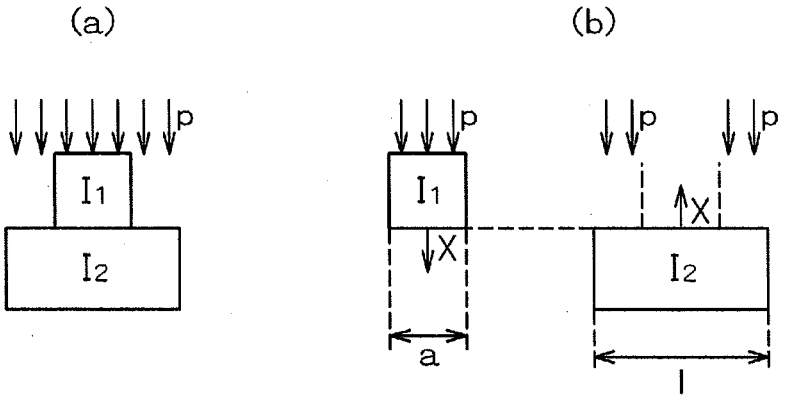


FIG.9

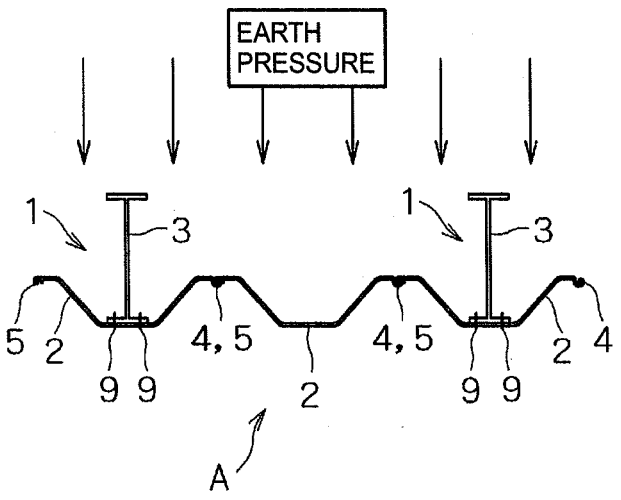
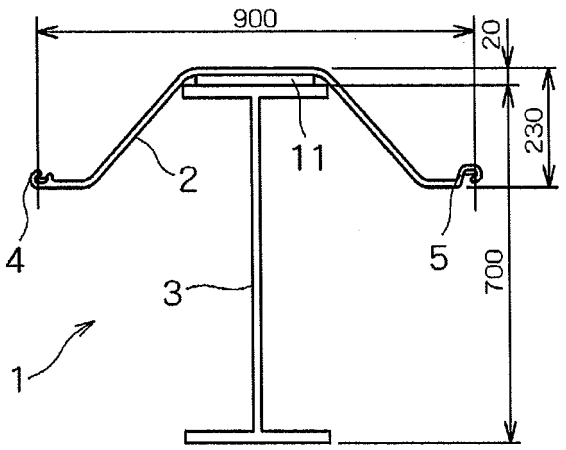


FIG.10

(a)



(b)

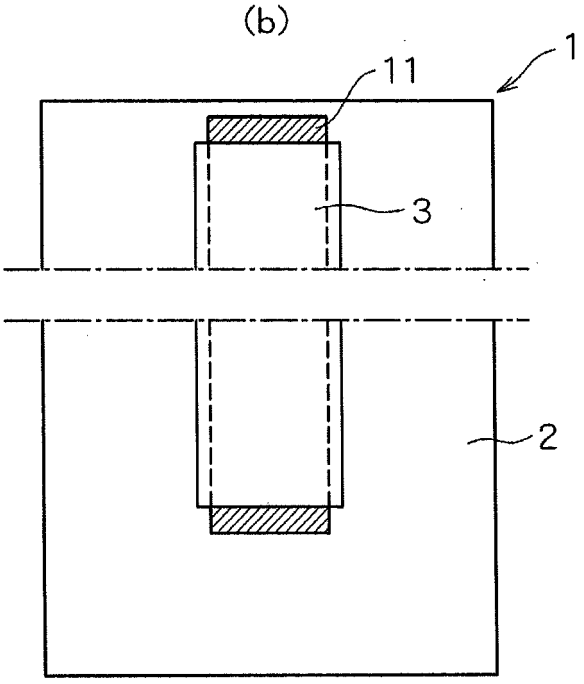


FIG.11

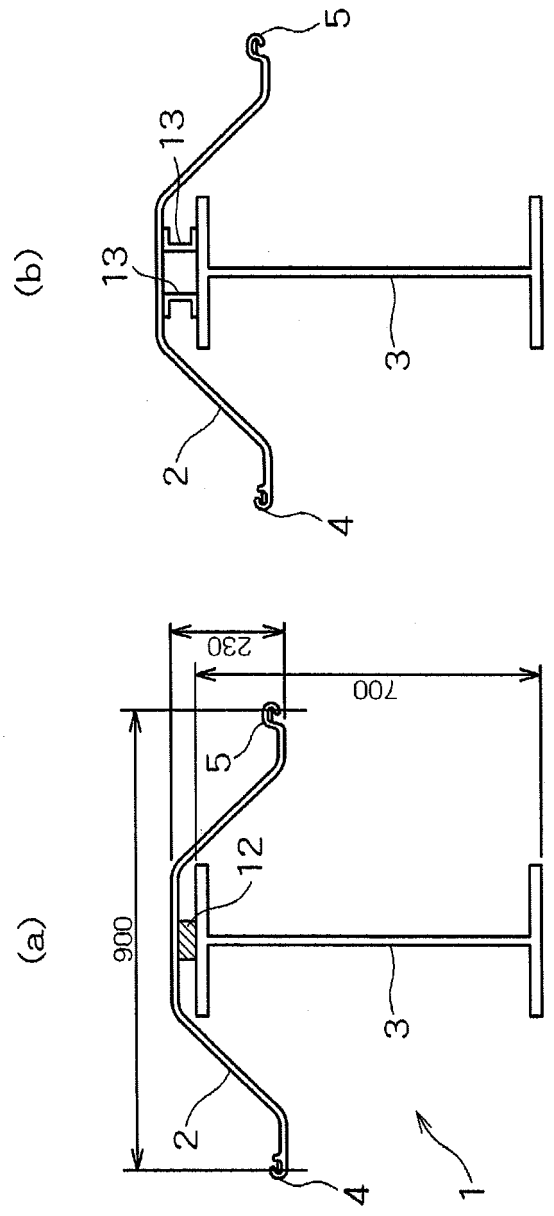


FIG.12

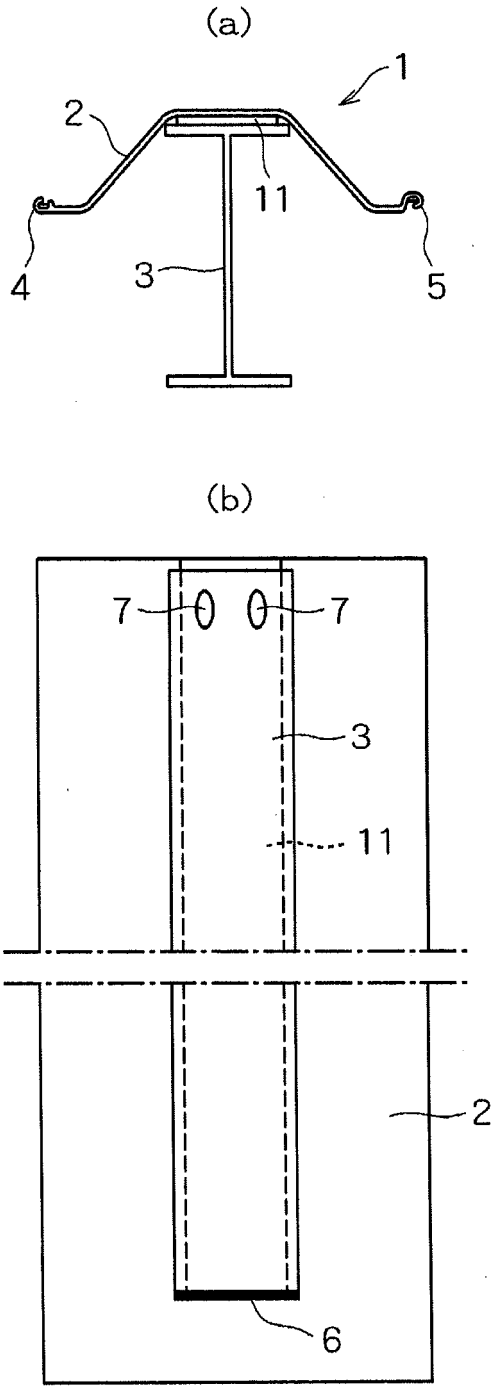


FIG.13

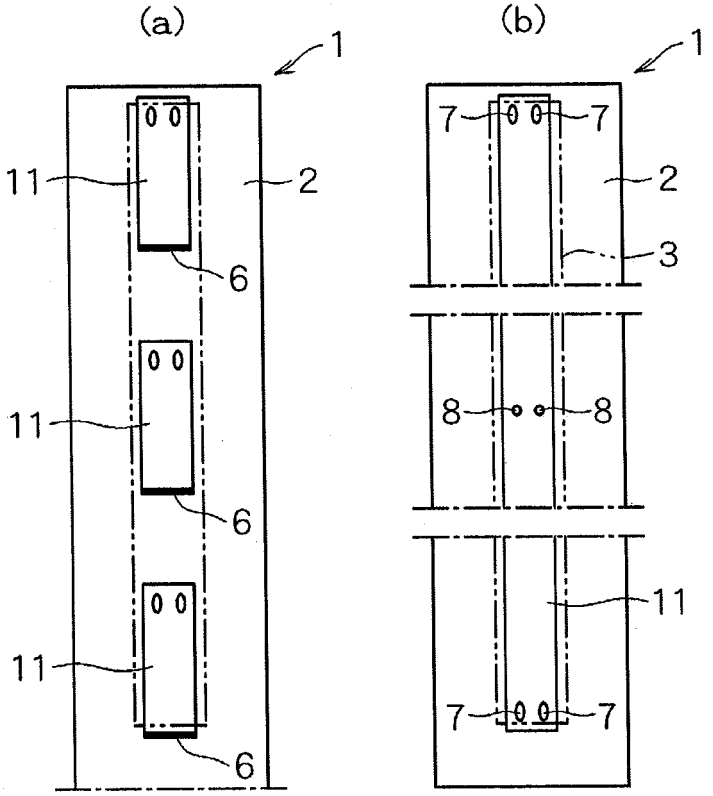


FIG.14

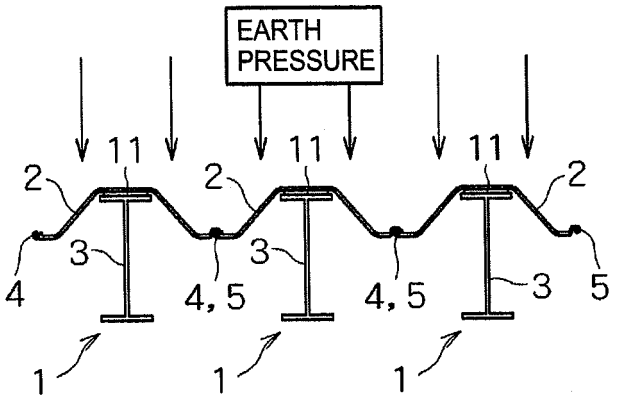


FIG.15

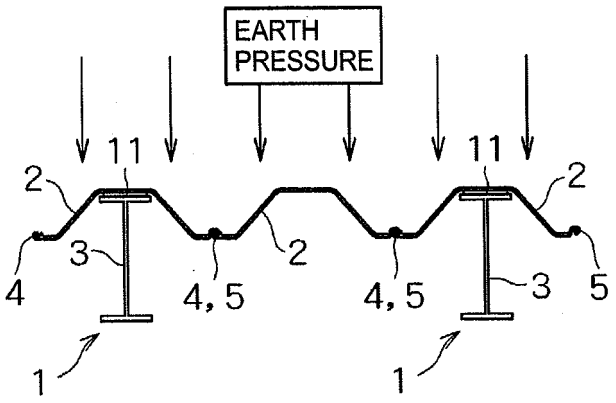


FIG.16

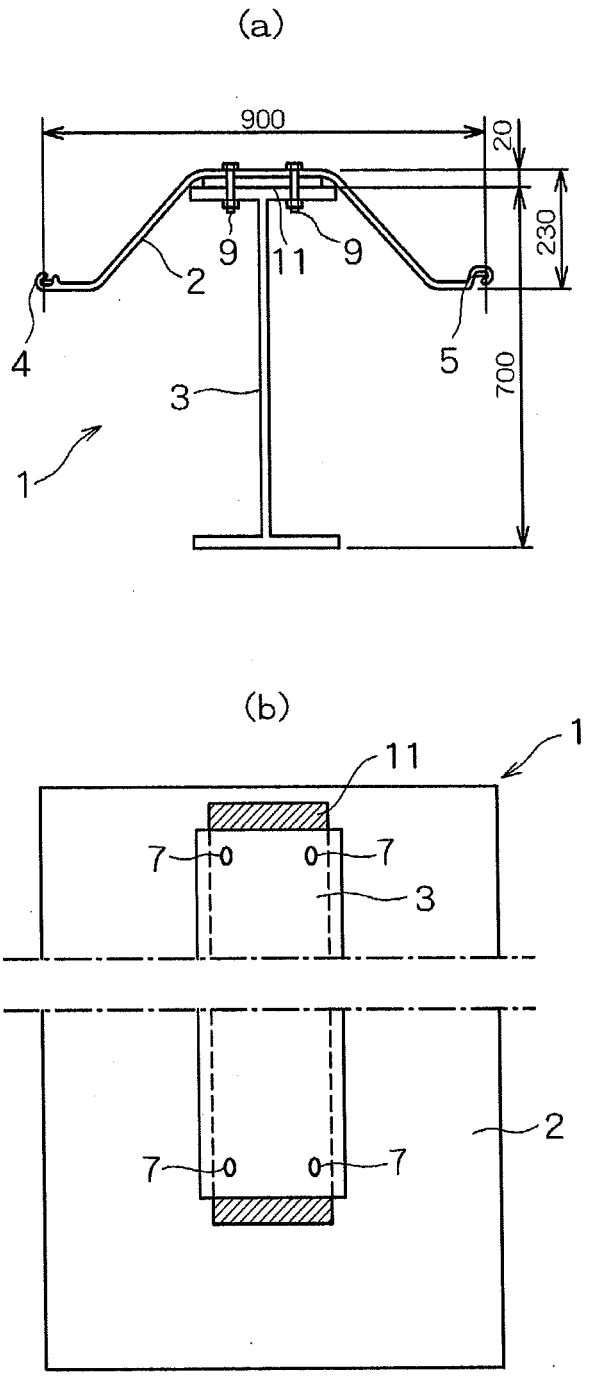


FIG.17

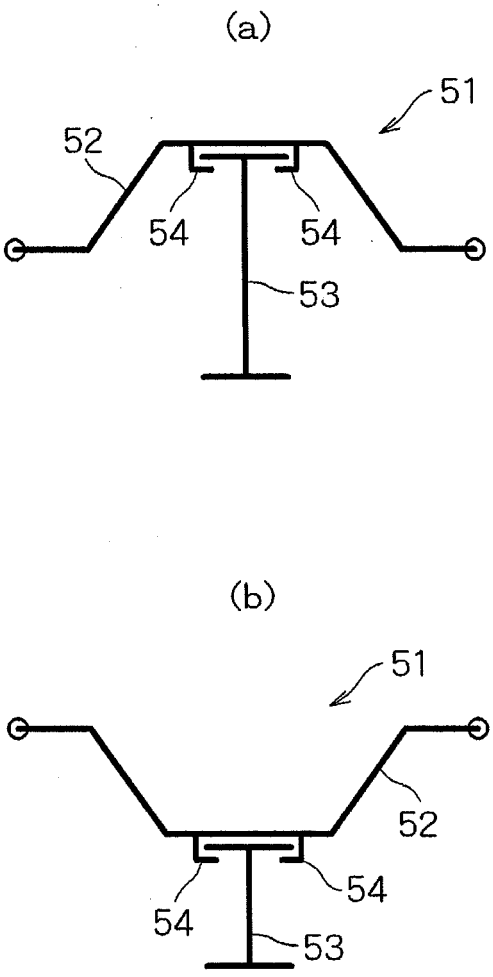


FIG.18

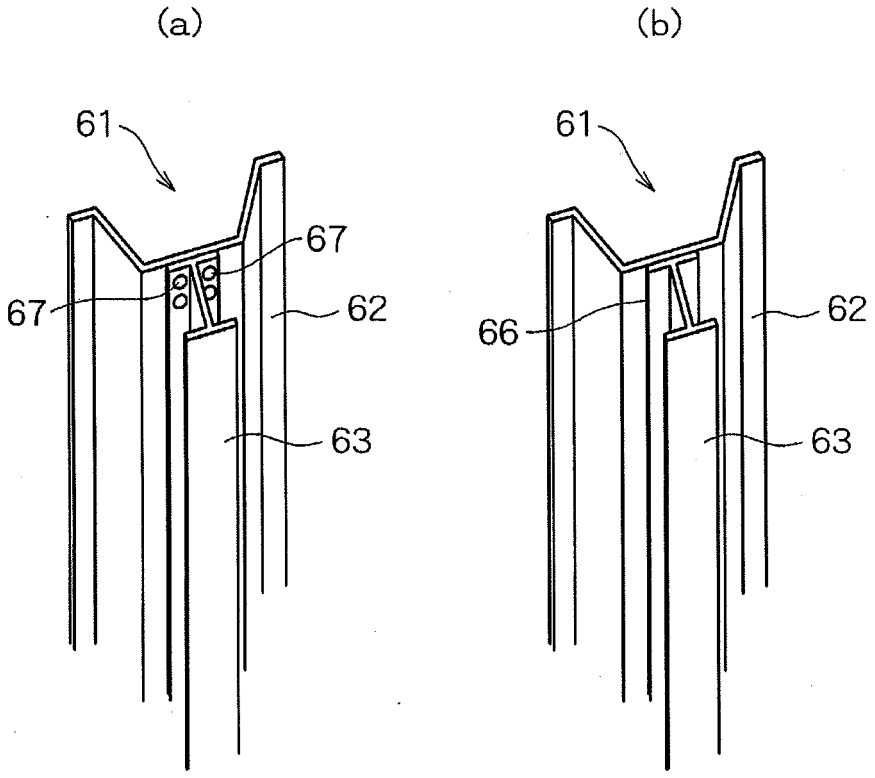
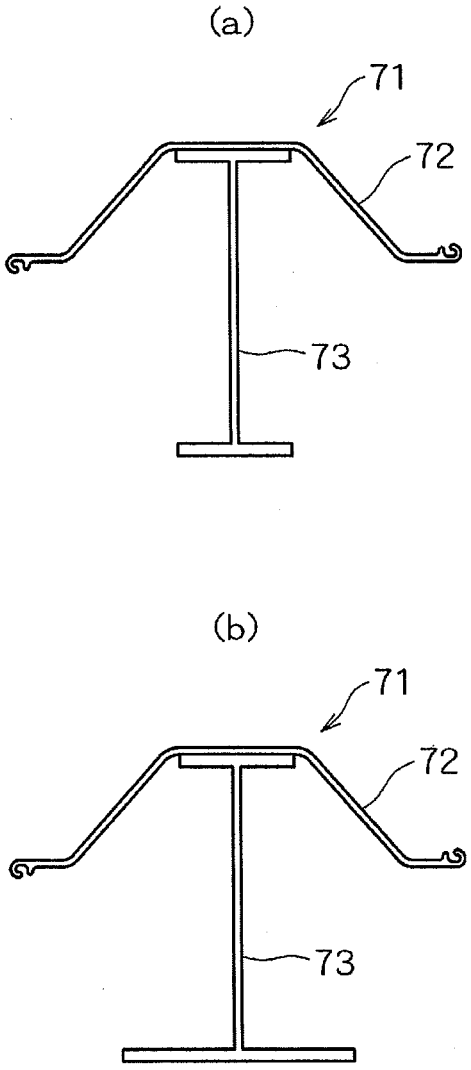


FIG.19



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/056973

A. CLASSIFICATION OF SUBJECT MATTER
E02D5/04(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)
E02D5/00-5/16

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2010
Kokai Jitsuyo Shinan Koho 1971-2010 Toroku Jitsuyo Shinan Koho 1994-2010

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	JP 2005-299202 A (Nippon Steel Corp.), 27 October 2005 (27.10.2005), paragraphs [0019] to [0024]; fig. 1 to 7 (Family: none)	1-3,11 8,10 4-7,9
Y A	JP 2008-267069 A (Nippon Steel Corp.), 06 November 2008 (06.11.2008), paragraphs [0032] to [0037]; fig. 3 to 7 (Family: none)	8,10 5
A	JP 2009-19373 A (Nippon Steel Corp.), 29 January 2009 (29.01.2009), paragraph [0034]; fig. 20 (Family: none)	9

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"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
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 July, 2010 (26.07.10)	03 August, 2010 (03.08.10)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/056973

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 11-50446 A (NKK Corp.), 23 February 1999 (23.02.1999), entire text; all drawings (Family: none)	1-11

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/056973

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The invention in claim 1 cannot be considered to be novel in the light of the invention described in the document 1 (JP 2005-299202 A (Nippon Steel Corp.), 27 October 2005 (27.10.2005), paragraphs 19 - 24, fig. 1 - 7), and does not have a special technical feature. Consequently, the following six inventions (invention groups) are involved in claims.

(continued to extra sheet)

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/056973

Continuation of Box No.III of continuation of first sheet(2)

Meanwhile, the invention in claim 1 having no special technical feature is classified into invention 1.

(Invention 1) claims 1 - 3, 8
(Invention 2) claim 4
(Invention 3) claims 5 - 7
(Invention 4) claim 9
(Invention 5) claim 10
(Invention 6) claim 11

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REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2008267069 A **[0008]**
- JP 2005299202 A **[0008]**
- JP 2008175029 A **[0008]**

Non-patent literature cited in the description

- *Structural Reform of Public Undertaking Cost,* 2005, URL: http:// www./mlit. go.jp/kisha/kisha06/13/131016_.html **[0074]**
- *Structural Reform of Public Undertaking Cost,* 2005, URL: http:// www. mlit. go.jp/kisha/kisha06/13/131016_.html **[0079]**