

DESCRIPTION

TITLE OF INVENTION: JOINING STRUCTURE, AND METHOD FOR DESIGNING JOINING STRUCTURE

5 TECHNICAL FIELD

[0001]

The present disclosure relates to a joint configuration and a design method of a joint configuration.

10 BACKGROUND ART

[0002]

For instance, a beam-end joint portion between an RC secondary beam/wall and a primary beam, or between a primary beam and a secondary beam is typically designed in a form of a rigid joint or a pinned joint. In an example of, for instance, a rigid joint between a primary beam and a secondary beam, flanges of the secondary beam are welded or bolted to the primary beam and then a web of the secondary beam is bolted to the primary beam. In case of a pinned joint, the web of the secondary beam is bolted to a shear plate attached to the primary beam while the flanges of the secondary beam are not jointed to the primary beam.

20 [0003]

Meanwhile, Non-Patent Literature 1 describes a semirigid joint using contact plates under loading conditions where the joints are subject to a hogging moment. This type of joints can be applied to a gravity frame that does not bear a horizontal force or a moment frame where antisymmetric bending does not occur because of a small horizontal force. Each contact plate is inserted in a gap between an end surface of a bottom flange of a supported steel beam and a supporting member and transmits a compression force applied on a compressed flange of the steel beam to the supporting member.

[0004]

30 However, a dimension of the gap between the end surface of the bottom flange of the steel beam and the supporting member usually depends on, for instance, fluctuation in erection accuracy. In this case, since the force is not transmitted unless

the thickness of the contact plate corresponds to the dimension of the gap, it is necessary for the thickness of the contact plate to be adjustable. Specifically, Patent Literature 1 discloses a use of a wedge-shaped component corresponding to the contact plate to compensate for the dimension fluctuation of the gap.

5 [0005]

Patent Literature 2 discloses that a contact member, which is inserted between a supporting surface and an H-section beam having a bottom flange whose end surface is obliquely angled, is provided with a first surface and a second surface slanted with respect to the first surface at an angle corresponding to the oblique angle of the bottom flange. Patent Literature 3 discloses a first wedge member and a second wedge member interposed between an H-section beam and a structural member. The first wedge member, which has an obliquely upwardly facing first slanted surface that faces the structural member in a horizontal direction, is fixed on a bottom flange of the H-section beam. The second wedge member, which has an obliquely downwardly facing second slanted surface that is in slide contact with the first slanted surface, is press-fitted between the first wedge member and the structural member.

CITATION LIST

20 PATENT LITERATURE(S)

[0006]

Patent Literature 1 JP 2005-282019 A

Patent Literature 2: JP 6631679 B1

Patent Literature 3: JP 6769549 B2

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NON-PATENT LITERATURE(S)

[0007]

Non-Patent Literature 1: EUROPEAN COMMITTEE FOR STANDARDIZATION, "Eurocode 4: Design of Composite Steel and Concrete Structures Part 1-8: Design of joints", May, 2005

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SUMMARY OF THE INVENTION

PROBLEM(S) TO BE SOLVED BY THE INVENTION

[0008]

However, in a case where a component corresponding to the contact plate is wedge-shaped as disclosed in Patent Literature 1, the wedge-shaped component is held at a predetermined position only by a friction force occurring between the wedge-shaped component and surfaces contacting therewith. Accordingly, the wedge-shaped component possibly drops off due to an impact and/or vibrations applied during a period under/after construction. Patent Literatures 2 and 3 also do not disclose any mechanism for keeping the position of the contact member against the impact and/or vibrations applied during the period under/after construction.

[0009]

Accordingly, an object of the present disclosure is to provide a joint configuration including a contact member inserted in a gap between components, and a design method of the joint configuration, the joint configuration being capable of keeping a surface contact of the contact member irrespective of a fluctuation in a size of the gap.

MEANS FOR SOLVING THE PROBLEM(S)

[0010]

A joint configuration according to an aspect of the present disclosure is formed between a first member and a second member, the joint configuration including: a contact member inserted into a gap defined in a first direction between the first member and the second member, in which the contact member includes: a first body portion having a first contact surface to be in surface contact with the first member and a second contact surface that is opposite to the first contact surface and is to be in surface contact with the second member; and an arm portion projecting from an end of the second contact surface, the arm portion being provided with at least one through hole extending along an axis intersecting the second contact surface or an extension plane of the second contact surface, the first contact surface and the second contact surface define a tapered shape of a taper angle θ in a cross section orthogonal to both of the first contact surface and the second contact surface, the arm portion projecting from a narrower end or a broader end of the tapered shape,

and the taper angle θ of the tapered shape is in a range defined by formulae below, where a friction coefficient of the second contact surface is μ , a tolerance of the gap is Δg_{req} , and a movable range of the contact member in a direction within the cross section and perpendicular to the first direction is Δh .

$$\theta \leq \theta_{max} = \tan^{-1} \left(\frac{1 - \sqrt{1 - 8\mu^2}}{2\mu} \right), \quad \theta \geq \theta_{min} = \tan^{-1} \frac{\Delta g_{req}}{\Delta h}$$

[0011]

A design method according to another aspect of the present disclosure is for designing a joint configuration formed between a first member and a second member, the joint configuration including: a contact member inserted into a gap defined in a first direction between the first member and the second member, in which the contact member includes: a first body portion having a first contact surface to be in surface contact with the first member and a second contact surface that is opposite to the first contact surface and is to be in surface contact with the second member; and an arm portion projecting from an end of the second contact surface, the arm portion being provided with at least one through hole extending along an axis intersecting the second contact surface or an extension plane of the second contact surface, and the first contact surface and the second contact surface define a tapered shape of a taper angle θ in a cross section orthogonal to both of the first contact surface and the second contact surface, the arm portion projecting from a narrower end or a broader end of the tapered shape, the method including: setting the taper angle θ of the tapered shape in a range defined by formulae below, where a friction coefficient of the second contact surface is μ , a tolerance of the gap is Δg_{req} , and a movable range of the contact member in a direction within the cross section and perpendicular to the first direction is Δh .

$$\theta \leq \theta_{max} = \tan^{-1} \left(\frac{1 - \sqrt{1 - 8\mu^2}}{2\mu} \right), \quad \theta \geq \theta_{min} = \tan^{-1} \frac{\Delta g_{req}}{\Delta h}$$

[0012]

According to the above arrangement, by inserting a suitable fastener into the through hole of the arm portion, a reaction force against a component in contact with the second contact surface can act as a force for the taper-shaped portion of the

contact member to enter the gap between the first member and the second member. Thus, the surface contact of the contact member can be maintained irrespective of a fluctuation in the size of the gap between the members.

5 BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

Fig. 1 illustrates a joint configuration according to a first exemplary embodiment of the present disclosure.

Fig. 2 is an enlarged cross-sectional view illustrating a part including a contact member of the joint configuration illustrated in Fig. 1.

Fig. 3 illustrates an example of a joint method of members using the contact member illustrated in Fig. 2.

Fig. 4 illustrates a modification of the joint configuration according to the first exemplary embodiment of the present disclosure.

Fig. 5 illustrates another modification of the joint configuration according to the first exemplary embodiment of the present disclosure.

Fig. 6 illustrates still another modification of the joint configuration according to the first exemplary embodiment of the present disclosure.

Fig. 7 illustrates a further modification of the joint configuration according to the first exemplary embodiment of the present disclosure.

Fig. 8 illustrates a still further modification of the joint configuration according to the first exemplary embodiment of the present disclosure.

Fig. 9 illustrates a still further modification of the joint configuration according to the first exemplary embodiment of the present disclosure.

Fig. 10 illustrates a still further modification of the joint configuration according to the first exemplary embodiment of the present disclosure.

Fig. 11 illustrates a joint configuration according to a second exemplary embodiment of the present disclosure.

Fig. 12 is a perspective view illustrating a contact member illustrated in Fig. 11.

Fig. 13 illustrates the contact member of Fig. 12 whose bolt and nut are removed.

Fig. 14 is a cross sectional view taken along an A-A line in Fig. 12.

Fig. 15A illustrates an example of an installation process of the contact member according to the second exemplary embodiment of the present disclosure.

Fig. 15B illustrates another example of the installation process of the contact member according to the second exemplary embodiment of the present disclosure.

Fig. 16A illustrates still another example of the installation process of the contact member according to the second exemplary embodiment of the present disclosure.

Fig. 16B illustrates a further example of the installation process of the contact member according to the second exemplary embodiment of the present disclosure.

Fig. 17A illustrates a still further example of the installation process of the contact member according to the second exemplary embodiment of the present disclosure.

Fig. 17B illustrates a still further example of the installation process of the contact member according to the second exemplary embodiment of the present disclosure.

Fig. 18 is a perspective view showing a joint configuration according to a modification of the second exemplary embodiment of the present disclosure.

Fig. 19 is an illustration explaining how an appropriate taper angle θ is calculated.

Fig. 20 is another illustration explaining how the appropriate taper angle θ is calculated.

Fig. 21 is still another illustration explaining how the appropriate taper angle θ is calculated.

Fig. 22 is a graph showing an example of a usage of the calculated taper angle θ .

Fig. 23 illustrates an example of a design of a cross-sectional compression resistance of the contact member.

Fig. 24 is an illustration explaining conditions for structural analysis of the joint configuration according to the example illustrated in Fig. 23.

Fig. 25A is a graph showing a magnitude of a moment generated at a joint portion in the analysis illustrated in Fig. 24.

Fig. 25B is another graph showing the magnitude of the moment generated at the joint portion in the analysis illustrated in Fig. 24.

Fig. 26A is a graph showing a characteristic value relating to bending resistance in the analysis illustrated in Fig. 24 for each dimension ratio of the contact member to a width of a bottom flange.

Fig. 26B is a graph showing another characteristic value relating to bending resistance in the analysis illustrated in Fig. 24 for each dimension ratio of the contact member to the width of the bottom flange.

Fig. 26C is a graph showing still another characteristic value relating to the bending resistance in the analysis illustrated in Fig. 24 for each dimension ratio of the contact member to the width of the bottom flange.

Fig. 27 illustrates how the characteristic values illustrated in Figs. 8A to 8C are calculated.

Fig. 28 illustrates a joint configuration according to a third exemplary embodiment of the present disclosure.

Fig. 29 illustrates a joint configuration not in accordance with the third exemplary embodiment of the present disclosure.

Fig. 30 is an illustration explaining conditions for a structural analysis of the joint configuration according to the third exemplary embodiment of the present disclosure.

Fig. 31 is another illustration explaining conditions for the structural analysis of the joint configuration according to the third exemplary embodiment of the present disclosure.

Fig. 32 is a graph showing a magnitude of a moment generated at a joint portion in the analyses illustrated in Figs. 30 and 31.

Fig. 33 is another graph showing the magnitude of the moment generated at the joint portion in the analyses illustrated in Figs. 30 and 31.

DESCRIPTION OF EMBODIMENT(S)

[0014]

Suitable exemplary embodiment(s) of the present disclosure will be described in detail below with reference to the attached drawings. It should be noted

that components of the same or substantially the same function(s) and structure(s) will be denoted by the same reference numerals in the specification and drawings, omitting repetition of description thereof.

[0015]

5 First Exemplary Embodiment

Fig. 1 illustrates a joint configuration according to a first exemplary embodiment of the present disclosure. Fig. 2 is an enlarged cross-sectional view illustrating a part including a contact member of the joint configuration illustrated in Fig. 1. As illustrated in Fig. 1, a joint configuration 10, which is formed between a first member (a steel secondary beam 11) and a second member (a steel primary beam 12, a fin plate 131, and a rib 132), includes a steel contact member 14. The secondary beam 11 is an H-section beam including a top flange 111, a bottom flange 112, and a web 113. The primary beam 12 is an H-section beam including a top flange 121, a bottom flange 122, and a web 123, whose member axial direction is orthogonal to a member axial direction of the secondary beam 11. The fin plate 131 is arranged to be orthogonal to the member axial direction of the primary beam 12 and welded to each of the top flange 121, the bottom flange 122, and the web 123. Further, the fin plate 131 is jointed to the web 113 of the secondary beam 11 by bolts 133. The rib 132, which is arranged parallel to the top flange 121 and the bottom flange 122 of the primary beam 12, is welded to each of the web 123 and the fin plate 131. A gap g in the member axial direction of the secondary beam 11 is created between an end surface 132E of the rib 132 and an end surface 112E of the bottom flange 112 of the secondary beam 11. The contact member 14 is inserted in the gap g.

[0016]

In the present exemplary embodiment, the end surface 112E of the bottom flange 112 is a vertical surface, whereas the end surface 132E of the rib 132 is a downwardly facing slanted surface. The contact member 14 is arranged to be in surface contact with each of the end surfaces 112E, 132E. Specifically, as illustrated in Fig. 2, the contact member 14 includes a body portion 141 and an arm portion 142 which are integrated. The body portion 141 has a first contact surface 141A to be in surface contact with the end surface 112E of the bottom flange 112 and a second contact surface 141B that is opposite to the first contact surface 141A and is to be in

surface contact with the end surface 132E of the rib 132. As described above, while the end surface 112E of the bottom flange 112 is a vertical surface, the end surface 132E of the rib 132 is a slanted surface. Accordingly, the first contact surface 141A and the second contact surface 141B, which are respectively in surface contact with the end surface 112E and the end surface 132E, are slanted with each other. Specifically, as illustrated in Fig. 2, the first contact surface 141A and the second contact surface 141B define a tapered shape with a taper angle θ in a cross section orthogonal to both of the first contact surface 141A and the second contact surface 141B.

[0017]

The above-mentioned taper angle θ of the tapered shape corresponds to an angle formed by the end surface 112E (vertical surface) and the end surface 132E (slanted surface) when the end surface 112E of the bottom flange 112 of the secondary beam 11 is arranged to face the end surface 132E of the rib 132. When the contact member 14 is inserted into the gap g between the bottom flange 112 and the rib 132, such a tapered shape of the body portion 141 of the contact member 14 allows the contact member 14 to move in an up-down direction to compensate for the fluctuation in the size of the gap g due to an erection error and the like. Accordingly, the first contact surface 141A and the second contact surface 141B can be kept in surface contact with the end surface 112E of the bottom flange 112 and the end surface 132E of the rib 132, respectively.

[0018]

Further, the arm portion 142 of the contact member 14 has a through hole 142A, into which a rod-shaped fastener (a bolt 143) is inserted. In the illustrated example, threaded grooves are formed on an inner circumferential surface of the through hole 142A (tapped hole). The bolt 143 is inserted into the through hole 142A to be screwed in the threaded grooves. The arm portion 142 projects from a narrower end of the tapered shape defined by the first contact surface 141A and the second contact surface 141B of the body portion 141 (i.e. from an end of the second contact surface 141B, where a distance between the first contact surface 141A and the second contact surface 141B is relatively small). In addition, the through hole 142A is formed along an axis L intersecting the second contact surface 141B or an

extension plane 141X of the second contact surface 141B. Due to such a positional relationship between the second contact surface 141B and the through hole 142A, when the second contact surface 141B is in surface contact with the end surface 132E of the rib 132, the axis of the through hole 142A intersects a top surface 132U of the rib 132. Accordingly, when the bolt 143 screwed in the threaded grooves of the through hole 142A is tightened, an end of the bolt 143 is brought into contact with the top surface 132U of the rib 132 to create a reaction force against the top surface 132U to apply a force in a direction for the taper-shaped body portion 141 to be pushed into the gap between the end surfaces 112E, 132E. At this time, since the contact member 14 is fixed by holding the rib 132 between the bolt 143 and the second contact surface 141B, the contact member 14 can be more stably kept at a predetermined position (i.e. a position for the contact member 14 to be in surface contact with both of the end surface 132E and the end surface 112E) as, for instance, compared with an instance where the contact member 14 is held only by a friction force acting between the contact member 14 and each of the end surface 132E and the end surface 112E.

[0019]

In the present exemplary embodiment, a compression force can be reliably transmitted between the bottom flange 112 and the rib 132 using the above-described surface contact between the end surface 132E of the rib 132 and the end surface 112E of the bottom flange 112 via the contact member 14. Further, since the web 113 of the secondary beam 11 is bolted to the fin plate 131, the compression force and a shear force are transmitted also between the web 113 and the fin plate 131. It should be noted that the web 113 and the fin plate 131 are not necessarily jointed only by bolts but may be welded.

[0020]

Further, the joint configuration of the present exemplary embodiment includes an RC slab 15 and shear connectors 16. The RC slab 15, which is provided at an upper side of the secondary beam 11 and the primary beam 12, includes a concrete 151, a rebar 152 embedded in the concrete 151 and extending at least in the member axial direction of the secondary beam 11, and a steel deck profile 153. In the RC slab 15, the rebar 152 acts as a tensile force transmitting member. The

shear connectors 16 (a locking member), which are each jointed to the corresponding one of the top flange 111 of the secondary beam 11 and the top flange 121 of the primary beam 12, are fixed in the concrete 151 of the RC slab 15. Since the secondary beam 11 is jointed to the RC slab 15 via the shear connectors 16, the compression force and tensile force in the member axial direction of the secondary beam 11 are also transmitted to the RC slab 15. The secondary beam 11, the primary beam 12, and the RC slab 15 thus can jointly resist a bending moment generated at an end of the secondary beam 11. It should be noted that a composite steel deck slab is optionally used in place of the RC slab 15. In this case, the entirety of the composite steel deck slab including the rebar acts as the tensile force transmitting member.

[0021]

Fig. 3 is an illustration explaining an example of a joint method of members using the contact member illustrated in Fig. 2. Initially, as illustrated in Fig. 3(a), the contact member 14 is inserted into the gap g so that the first contact surface 141A faces the end surface 112E of the bottom flange 112, the second contact surface 141B faces the end surface 132E of the rib 132, and the axis of the through hole 142A intersects the top surface 132U of the rib 132. By moving the contact member 14 in this state upward, or in a direction for the tapered shape of the body portion 141 to be pushed into the gap between the end surfaces 132E, 112E, the first contact surface 141A and the second contact surface 141B of the contact member 14 can be brought into surface contact with the end surface 112E of the bottom flange 112 and the end surface 132E of the rib 132, respectively, as illustrated in Fig. 3(b).

[0022]

When the bolt 143 inserted through the through hole 142A is tightened while the contact member 14 is in surface contact with the end surfaces 132E, 112E as described above, an end of the bolt 143 projects from the arm portion 142 to be brought into contact with the top surface 132U of the rib 132. As already described above, the contact member 14 can be fixed in this state by a reaction force against the top surface 132U, which acts as a force in a direction for the arm portion 142 to move away from the top surface 132U. Specifically, the contact member 14 is optionally moved upward by tightening the bolt 143 from the state illustrated in Fig.

3(a) and the tightening process of the bolt 143 is optionally stopped when the surfaces of the contact member 14 is brought into surface contact with the corresponding surfaces. Alternatively, the contact member 14 is optionally moved upward by other lifting means (e.g. hand, tool) and, upon the surfaces of the contact member 14 being in surface contact with the corresponding surfaces, while keeping the position of the contact member 14, the bolt 143 is optionally tightened until the bolt 143 is brought into contact with the top surface 132U.

[0023]

As described above, according to the present exemplary embodiment, the contact member 14 can be more stably held at a predetermined position. In addition, the contact member 14 in the present exemplary embodiment, which has a uniform sectional shape defined by the body portion 141 and the arm portion 142, can be easily produced by, for instance, extrusion molding. It should be noted that only a part of the contact member is optionally of a uniform sectional shape or the contact member is optionally not of a uniform sectional shape in some embodiments. Further, the contact member is optionally produced by casting, machining or the like process. The contact member and the fastener can be easily transported and stored in a pair by producing the contact member 14 in a form of an integrated component and inserting the bolt 143 (fastener) into the through hole 142A in advance. It should be noted that the contact member 14 is optionally fixed with a use of a rod-shaped fastener (e.g. a pin) other than the bolt 143, the rod-shaped fastener being capable of being inserted into the through hole 142A and whose position is fixable with respect to the contact member 14.

[0024]

Modifications of the joint configuration according to the first exemplary embodiment of the present disclosure will be described below. In an example illustrated in Fig. 4, an end surface 132F of the rib 132 is a vertical surface whereas an end surface 112F of the bottom flange 112 of the secondary beam 11 is a downwardly facing slanted surface. In this arrangement, the contact member 14 similar to the example illustrated in Figs. 1 to 3 is placed so that the first contact surface 141A is in contact with the end surface 132F of the rib 132, the second contact surface 141B is in contact with the end surface 112F of the bottom flange

112, and the bolt 143 inserted through the through hole 142A is in contact with a top surface 112U of the bottom flange 112. With this arrangement, in the same manner as the example illustrated in Figs. 1 to 3, the compression force can be reliably transmitted between the bottom flange 112 and the rib 132 while the contact member 14 is stably held at a predetermined position.

[0025]

In an example illustrated in Fig. 5, the end surface 132F of the rib 132 is a vertical surface whereas an end surface 112G of the bottom flange 112 of the secondary beam 11 is an upwardly facing slanted surface. It should be noted that the end surface 112G is, for instance, optionally formed through edge preparation for welding. In this arrangement, the contact member 14 similar to the example illustrated in Figs. 1 to 3 is placed so that the first contact surface 141A is in contact with the end surface 132F of the rib 132, the second contact surface 141B is in contact with the end surface 112G of the bottom flange 112, and the bolt 143 inserted through the through hole 142A is in contact with a bottom surface 112B of the bottom flange 112. With this arrangement, in the same manner as the example illustrated in Figs. 1 to 3, the compression force can be reliably transmitted between the bottom flange 112 and the rib 132 while the contact member 14 is more stably held at a predetermined position.

[0026]

In an example illustrated in Fig. 6, a joint configuration 10A is formed between the first member (the primary beam 12 and the fin plate 131) and the second member (the secondary beam 11). While the fin plate 131 is configured in the same manner as that in the example illustrated in Figs. 1 to 3, the rib is not provided. In this example, a cross-sectional height of the secondary beam 11 is equal to a cross-sectional height of the primary beam 12. In other words, a height of the top surface of the top flange 111 of the secondary beam 11 is equal in design to a height of the top surface of the top flange 121 of the primary beam 12. Further, a height of the bottom surface of the bottom flange 112 of the secondary beam 11 is equal in design to a height of the bottom surface of the bottom flange 122 of the primary beam 12. It should be noted that plate thicknesses of the flange and the web of the secondary beam 11 may be different from those of the primary beam 12. In the illustrated example, the plate

thicknesses of the top flange 121 and the bottom flange 122 of the primary beam 12 are larger than the plate thicknesses of the top flange 111 and the bottom flange 112 of the secondary beam 11.

[0027]

5 In the above-described example illustrated in Fig. 6, the end surface 112F of the bottom flange 112 of the secondary beam 11 faces a side end surface 122S of the bottom flange 122 of the primary beam 12 and the contact member 14 is inserted into the gap g created between the end surfaces. More specifically, the first contact surface 141A of the contact member 14 is in surface contact with the side end surface
10 122S of the bottom flange 122 of the primary beam 12 and the second contact surface 141B is in surface contact with the end surface 112F of the bottom flange 112 of the secondary beam 11. It should be noted that reference numerals denoting the first contact surface 141A and the second contact surface 141B are not illustrated in Figs. 6 to 10 for simplification. The bolt 143 inserted through the through hole of
15 the contact member 14 is in contact with the top surface 112U of the bottom flange 112 of the secondary beam 11. The rest of the arrangement is the same as those in the example illustrated in Figs. 1 to 3.

[0028]

20 It should be noted that the end surface 112F of the bottom flange 112 of the secondary beam 11, which is a downwardly facing slanted surface in the example illustrated in Fig. 6 as in the example illustrated in Fig. 4, is an upwardly facing slanted surface in some embodiments and a downwardly or upwardly facing slanted surface is optionally formed at a lateral side of the bottom flange 122 of the primary beam 12 in some other embodiments. The orientation of the contact member 14 is reversed in
25 the member axial direction of the secondary beam 11 or in the up-down direction in accordance with the orientation of the slanted surface(s). In either case, the compression force can be reliably transmitted between the bottom flange 112 of the secondary beam 11 and the bottom flange 122 of the primary beam 12 while the contact member 14 is more stably held at a predetermined position.

30 [0029]

In an example illustrated in Fig. 7, a joint configuration 10B is formed between the first member, which is provided by an RC primary beam 17, a base plate 181,

and a fin plate 182, and the second member provided by the secondary beam 11. The RC primary beam 17, whose member axial direction is orthogonal to the member axial direction of the secondary beam 11, includes a concrete 171 and a rebar 172 embedded in the concrete 171. The rebar 172 includes: a longitudinal reinforcement 172A extending in the member axial direction of the RC primary beam 17; and a stirrup 172B provided at an outer circumference of the RC primary beam 17 and wound around the longitudinal reinforcement 172A in a direction intersecting the longitudinal reinforcement 172A. The base plate 181 is jointed to the RC primary beam 17 by an anchor 184 jointed to the base plate 181 being fixed in the concrete 171. The fin plate 182, which is a plate-shaped component extending in a direction orthogonal to the RC primary beam 17 and the base plate 181, is welded to a plate surface 181S of the base plate 181 and jointed to the web 113 of the secondary beam 11 via bolts 183. It should be noted that the web 113 of the secondary beam 11 is optionally welded to the base plate 181 and the fin plate 182 is optionally omitted in some embodiments.

[0030]

In the above-described example illustrated in Fig. 7, the end surface 112F of the bottom flange 112 of the secondary beam 11 faces a plate surface 181S of the base plate 181 and the contact member 14 is inserted into the gap created between the end surface 112F and the plate surface 181S. More specifically, the first contact surface 141A of the contact member 14 is in contact with the plate surface 181S of the base plate 181 and the second contact surface 141B is in contact with the end surface 112F of the bottom flange 112 of the secondary beam 11. Further, the bolt 143 inserted through the through hole of the contact member 14 is in contact with the top surface 112U of the bottom flange 112 of the secondary beam 11. The RC slab 15 is located at an upper side of the secondary beam 11 and the RC primary beam 17. The secondary beam 11 is jointed to the RC slab 15 via the shear connectors 16, whereas the RC primary beam 17 is jointed to the RC slab 15 by placing the concrete 171 with the rebar 172 being exposed from the top surface and subsequently placing the concrete 151 of the RC slab 15 at the upper side of the concrete 171 to fix the rebar 172 in the concrete 151. The rest of the arrangement is the same as those in the example illustrated in Figs. 1 to 3. It should be noted that the end surface 112F

of the bottom flange 112 of the secondary beam 11, which is a downwardly facing slanted surface in the example illustrated in Fig. 7 as in the example illustrated in Fig. 4, is optionally an upwardly facing slanted surface in some embodiments. In this case, the orientation of the contact member 14 is reversed in the up-down direction.

5 [0031]

In an example illustrated in Fig. 8, a joint configuration 10C is formed between the first member, which is provided by an RC column 19A, the base plate 181, and the fin plate 182, and the second member provided by the secondary beam 11. The base plate 181 and the fin plate 182 are configured in the same manner as those in the example illustrated in Fig. 7. Also as in the example illustrated in Fig. 7, the contact member 14 is inserted between the end surface 112F of the bottom flange 112 of the secondary beam 11 and the plate surface 181S of the base plate 181. However, with regard to the RC column 19A and the RC slab 15, the rebar 152 of the RC slab 15 is fixed in the concrete of the RC column 19A via an extension 152E (starter bar). Specifically, for instance, the concrete of the RC column 19A is optionally placed while the extension 152E is protruded from a lateral surface of the RC column 19A or while a fitting hole for a coupler is exposed from the lateral side of the RC column 19A, the coupler being provided on an end of the extension 152E facing the lateral surface of the RC column 19A. Subsequently, the concrete 151 of the RC slab 15 is placed after jointing the extension 152E and the rebar 152. According to the above arrangement, the tensile force transmitted to the RC slab 15 by the bending moment generated at an end of the secondary beam 11 can be efficiently transmitted to the RC column 19A.

[0032]

25 In a joint configuration 10D of an example illustrated in Fig. 9, the RC column 19A of the example illustrated in Fig. 8 is replaced with an RC wall 19B, where the relationship of the base plate 181, the fin plate 182, the secondary beam 11, and the contact member 14 is the same as that in the example illustrated in Fig. 8. Further, the relationship between the RC wall 19B and the RC slab 15 is the same as the relationship between the RC column 19A and the RC slab 15 as described with reference to the example illustrated in Fig. 8.

30 [0033]

In a joint configuration of an example illustrated in Fig. 10, which is configured in the same manner as the example illustrated in Figs. 1 to 3, an end 143B of a bolt 143A has a spherical shape. When the bolt having a flat end surface is tightened to fix the contact member 14 with the bolt being in contact with the top surface 132U of the rib 132, the bolt contacts the top surface 132U at a periphery of the end surface to become eccentric at the contact point with respect to the rotation center of the bolt, so that the position of the contact member sometimes shifts in accordance with the rotation of the bolt when the bolt tightened, thereby making it difficult to correctly position the bolt. In the example illustrated in Fig. 10, since the end 143B of the bolt 143A has a spherical shape, the bolt 143A is in contact with the top surface 132U of the rib 132 at the center (i.e. an axis center of the bolt) when the bolt 143A is tightened. The contact point with the top surface 132U is thus coincident with the rotation center of the bolt 143A, thereby enabling a stable position of the contact member 14 when the bolt 143A is tightened. It should be noted that, though the entirety of the end 143B of the bolt 143A is spherical in the illustrated example, a bolt whose end is at least partially spherical or convex-shaped (e.g. clamping bolt) is optionally used in some embodiments, where the same advantages as the above can be achieved.

[0034]

It should be noted that the end 143B of the bolt 143A, which is in contact with the top surface 132U of the rib 132 in the example illustrated in Fig. 10, is alternatively in contact with the top surface 112U or the bottom surface 112B of the bottom flange 112 as in the examples illustrated in Figs. 4 and 5. Further, the bolt whose end is at least partially spherical or convex-shaped as in the example illustrated in Fig. 10 is applicable to the above-described modifications.

[0035]

Second Exemplary Embodiment

Fig. 11 illustrates a joint configuration according to a second exemplary embodiment of the present disclosure. As illustrated in Fig. 11, a joint configuration 20 is formed between the first member, which is provided by a steel primary beam 22, a fin plate 231, and a rib 232, and the first member provided by a steel secondary beam 21. The joint configuration 20 includes a steel contact member 24. The secondary beam 21 is an H-section beam including a top flange 211, a bottom flange

212, and a web 213. The primary beam 22 is an H-section beam including a top flange 221, a bottom flange 222, and a web 223, whose member axial direction (y direction) is orthogonal to a member axial direction (x direction) of the secondary beam 21. The fin plate 231, which is a plate-shaped component arranged to be orthogonal to the member axial direction of the primary beam 22, is welded to each of the top flange 221, the bottom flange 222, and the web 223. Further, the fin plate 231 is jointed to the web 213 of the secondary beam 21 by bolts 233. The rib 232, which is a plate-shaped member arranged parallel to the top flange 221 and the bottom flange 222 of the primary beam 22, is welded to each of the web 223 and the fin plate 231. A gap g in the member axial direction of the secondary beam 21 is created between an end surface 232E of the rib 232 and an end surface 212E of the bottom flange 212 of the secondary beam 21. The contact member 24 is inserted into the gap g.

[0036]

Fig. 12 is a perspective view of the contact member illustrated in Fig. 11. Fig. 13 is an illustration of the contact member illustrated in Fig. 12 whose bolt and nut are removed. Fig. 14 is a cross-sectional view taken along an A-A line in Fig. 12. As illustrated in these figures, the contact member 24 includes a first body portion 241 and an arm portion 242 which are integrated, and a second body portion 243 separated from the first body portion 241 and the arm portion 242. The first body portion 241 has a first contact surface 241A to be in surface contact with the end surface 232E of the rib 232 as illustrated in Fig. 11 and a second contact surface 241B opposite to the first contact surface 241A. The first contact surface 241A and the second contact surface 241B are slanted with each other. Specifically, the first contact surface 241A and the second contact surface 241B define a tapered shape with a taper angle θ in a cross section orthogonal to both of the first contact surface 241A and the second contact surface 241B illustrated in Fig. 14.

[0037]

Meanwhile, the second body portion 243 has a third contact surface 243A to be in surface contact with the second contact surface 241B formed on the first body portion 241 and a fourth contact surface 243B opposite to the third contact surface 243A and to be in surface contact with the end surface 212E of the bottom flange

212. Accordingly, the second contact surface 241B formed on the first body portion 241 of the present exemplary embodiment is indirectly in contact with the bottom flange 212 via the second body portion 243. It should be noted that, in the illustrated example, the second body portion 243 is formed with a channel 243C into which the bottom flange 212 (plate-shaped portion) is insertable and a bottom surface of the channel 243C defines the fourth contact surface 243B. The third contact surface 243A and the fourth contact surface 243B are slanted with each other. Specifically, the third contact surface 243A and the fourth contact surface 243B define a tapered shape with the taper angle θ in a cross section orthogonal to both of the third contact surface 243A and the fourth contact surface 243B as illustrated in Fig. 14.

[0038]

In the present exemplary embodiment, the contact surfaces formed on each of the first body portion 241 and the second body portion 243 have the above-described tapered shape. Accordingly, when the contact member 24 in a form of a combination of the first body portion 241 and the second body portion 243 is inserted into the gap g between the rib 232 and the bottom flange 212, a surface contact between the first contact surface 241A and the end surface 232E of the rib 232 and a surface contact between the fourth contact surface 243B and the end surface 112E of the bottom flange 112 can be maintained by moving the first body portion 241 in the up-down direction to compensate for the fluctuation in the size of the gap g due to, for instance, erection error to adjust a distance D (see Fig. 12) from the first contact surface 241A to the fourth contact surface 243B in the member axial direction of the secondary beam 21.

[0039]

Further, the contact member 24 of the present exemplary embodiment has a through hole 242A. A rod-shaped fastener (a bolt 244) fixed to the second body portion 243 is inserted into the through hole 242A in the arm portion 242. More specifically, the bolt 244 is screwed into a through threaded hole 243D formed in the top surface of the second body portion 243 to be fixed to the second body portion 243. As illustrated in Fig. 14, the arm portion 242 projects at an end of the second contact surface 241B from a broader end of the tapered shape defined by the first contact surface 241A and the second contact surface 241B of the first body portion

241 (i.e. from an end where a distance between the first contact surface 241A and the second contact surface 241B is relatively large). The through hole 242A of the arm portion 242 is formed along an axis L intersecting an extension plane 241X of the second contact surface 241B.

5 [0040]

With the above-described positional relationship between the second contact surface 241B and the through hole 242A, when the first body portion 241 and the second body portion 243 are combined as illustrated in Fig. 14 to bring the second contact surface 141B into surface contact with the third contact surface 243A, the axis L of the through hole 242A intersects the second body portion 243 to allow the bolt 244 fixed to the second body portion 243 to be inserted into the through hole 242A. The first body portion 241 (and the arm portion 242) and the second body portion 243 of the contact member 24 are thus mutually engaged, so that handleability for storing, transporting, and installing the contact member 24 is improvable.

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[0041]

Here, as illustrated in Fig. 13, the profile of the through hole 242A is shaped to have a first hole portion 242A1 extending in the member axial direction of the secondary beam 21 of the joint configuration 20, in other words, in a direction (x direction) orthogonal to both of the first contact surface 241A and the fourth contact surface 243B when the first body portion 241 and the second body portion 243 of the contact member 24 are assembled. Due to the presence of the first hole portion 242A1, the bolt 244 inserted through the through hole 242A is movable in the above x direction. Accordingly, even after the bolt 244 is inserted into the through hole 242A to mutually engage the first body portion 241 (and the arm portion 242) and the second body portion 243, the distance D from the first contact surface 241A to the fourth contact surface 243B can be adjusted by moving the first body portion 241 and the arm portion 242 in the x direction to slide the second contact surface 241B and the third contact surface 243A with each other.

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30 [0042]

Further, the profile of the through hole 242A further includes a second hole portion 242A2 extending in a direction (y direction) intersecting the first hole portion

242A1. The slide movement between the second contact surface 241B and the third contact surface 243A is restricted by pushing the bolt 244 received in the through hole 242A into the second hole portion 242A2, thereby fixing the distance D from the first contact surface 241A to the fourth contact surface 243B. The positional relationship between the first body portion 241 and the second body portion 243 can be fixed with the distance D being minimized as in later-described examples by, for instance, shaping the through hole 242A in an L-shape defined by the second hole portion 242A2 intersecting an end of the first hole portion 242A1 where the bolt 244 is located when the distance D is minimized.

[0043]

The bolt 244 is an example of the rod-shaped fastener fixed on the second body portion 243 and inserted into the through hole 242A of the arm portion 242. In the illustrated example, the bolt 244 has screwed grooves over the length thereof except for a head 244H. The bolt 244 is screwed into the through threaded hole 243D to be fixed to the second body portion 243. Further, a nut 245 is screwed on the bolt 244 to be located at a position between the arm portion 242 and the head 244H so that the arm portion 242 can be forced toward the second body portion 243. An additional nut screwed on the bolt 244 at a position between the arm portion 242 and the second body portion 243 is optionally provided to form a double nut for holding the arm portion 242 between the nut 245 and the additional nut. Due to the presence of the nut 245, the positional relationship between the first body portion 241 and the second body portion 243 can be fixed while the appropriate distance D is set as described in examples below.

[0044]

Further, in the illustrated example, the bolt 244 penetrates through the through threaded hole 243D of the second body portion 243 to protrude from a side surface of the channel 243C. An end of the bolt 244 can thus be brought into contact with the plate surface of the bottom flange 212 of the secondary beam 21 inserted in the channel 243C to hold the bottom flange 212 against an opposite side surface of the channel 243C. The second body portion 243 can be more reliably kept from dropping off from the bottom flange 212 when the bottom flange 212 is inserted into the channel 243C.

[0045]

It should be noted that the bolt 244 does not necessarily penetrate through the second body portion 243 in some embodiments. For instance, an additional bolt is optionally provided, penetrating through the opposite side surface of the channel 243C from the through threaded hole 243D (i.e. penetrating from a lower side in Fig. 14) to hold the inserted bottom flange 212 with an end of the additional bolt. It should be noted that, when the channel 243C has a width corresponding to the thickness of the bottom flange 212, the second body portion 243 does not drop off from the bottom flange 212 even without being held by the bolt 244. In other words, with the above-described bottom flange 212 being inserted in the channel 243C and held by the bolt(s), the second body portion 243 can be kept from being dropped off from the bottom flange 212 even when, for instance, the thickness of the bottom flange 212 does not match the width of the channel 243C due to variations in the thickness of the bottom flange 212.

[0046]

It should also be noted that the bolt 244 is optionally not screwed into the second body portion 243 to be fixed in some embodiments. For instance, the bolt 244 is optionally welded to the second body portion 243. In this case, the bolt 244 is optionally not provided with the head 244H. When the bolt 244 is screwed into the second body portion 243, the head 244H is optionally omitted with a use of, for instance, a headless bolt.

[0047]

In the present exemplary embodiment, a compression force can be reliably transmitted between the bottom flange 212 and the rib 232 through the above-described surface contact between the end surface 132E of the rib 232 and the end surface 112E of the bottom flange 212 via the contact member 24. Further, since the web 213 of the secondary beam 21 is bolted to the fin plate 231, the compression force and a shear force are also transmitted between the web 213 and the fin plate 231. It should be noted that the web 213 and the fin plate 231 are not necessarily jointed only by bolts but are optionally welded to each other.

[0048]

In addition, the contact member 24 in the present exemplary embodiment,

which has a uniform sectional shape defined by the first body portion 241, the arm portion 242, and the second body portion 243, can be easily produced by, for instance, extrusion molding. It should be noted that only a part of the contact member is optionally of a uniform sectional shape or the contact member is optionally not of a uniform sectional shape in some embodiments. Additionally, the contact member is optionally produced by casting, machining or the like process.

[0049]

Examples of an installation process of the joint configuration according to the second exemplary embodiment of the present disclosure will be described below. In an example illustrated in Fig. 15A, the bolt 244 is pushed into the second hole portion 242A2 (see Fig. 13) within the through hole 242A. As described above, since the through hole 242A of the present exemplary embodiment is in a form of an L-shape including the first hole portion 242A1 and the second hole portion 242A2, the positional relationship between the first body portion 241 and the second body portion 243 can be fixed with the distance from the first contact surface 241A to the fourth contact surface 243B being minimized by pushing the bolt 244 into the second hole portion 242A2. In transporting to a construction site, the contact member 24 is optionally jointed in this state to the secondary beam 21 in advance by inserting an end of the bottom flange 212 of the secondary beam 21 into the channel 243C of the second body portion 243. For instance, the second body portion 243 is optionally fixed to the bottom flange 212 by, after the bottom flange 212 is inserted into the channel 243C, tightening the bolt 244 with the bolt 244 being pushed into the second hole portion 242A2, so that the bolt 244 penetrates through the through threaded hole 243D to hold the bottom flange 212 inserted in the channel 243C.

[0050]

Meanwhile, in an example illustrated in Fig. 15B, the bolt 244 in the through hole 242A has shifted from the second hole portion 242A2 to the first hole portion 242A1 to allow a slide movement of the second contact surface 241B and the third contact surface 243A. The distance from the first contact surface 241A to the fourth contact surface 243B can thus be changed from a minimum distance D_1 illustrated in Fig. 15B to a larger distance D_2 and to a maximum distance D_3 in accordance with, for instance, a process illustrated in Figs. 16A and 16B or a process illustrated in Figs.

17A and 17B.

[0051]

For instance, the location of the contact member 24 can be easily matched with the size of the gap g between the end surface 212E and the end surface 232E by, after the contact member 24 is jointed in advance to the bottom flange 212 with the distance D being minimized (distance D_1) and with the the end surface 212E of the bottom flange 212 facing the end surface 232E of the rib 232, downwardly moving the first body portion 241 while causing a slide movement between the second contact surface 241B and the third contact surface 243A to gradually increase the distance D (distance D_2 and distance D_3) as in the example illustrated in Figs. 16A and 16B. The positional relationship between the first body portion 241 and the second body portion 243 is fixed by tightening the nut 245 toward the second body portion 243 as in examples illustrated in Figs. 17A (distance D_2) and 17B (distance D_3). The tightened nut 245 restricts the slide movement between the second contact surface 241B and the third contact surface 243A in a direction for decreasing the distance D . Accordingly, the contact member 24 can be kept from dropping off through the gap g due to a decrease in the distance D caused by a relative displacement between the first body portion 241 and the second body portion 243 after installation.

[0052]

Fig. 18 is a perspective view illustrating a joint configuration according to a modification of the second exemplary embodiment of the present disclosure. In the example illustrated in Fig. 18, contrary to the example illustrated in Fig. 11, the contact member 24 of a joint configuration 20A is placed such that the first body portion 241 is located near the bottom flange 212 and the second body portion 243 is located near the rib 232. In this case, the first contact surface 241A of the first body portion 241 is in contact with the end surface 212E of the bottom flange 212, the rib 232 is inserted into the channel 243C of the second body portion 243, and the end surface 232E of the rib 232 is in contact with the fourth contact surface 243B.

[0053]

As shown in the above example, the components to be jointed to the corresponding one of the first body portion 241 and the second body portion 243 of

the contact member 24 in the joint configuration are not specifically limited in the second exemplary embodiment of the present disclosure. A plate-shaped part of any component is insertable into the channel 243C of the second body portion 243. Further, the first contact surface 241A of the first body portion 241, which is in contact with the end surface of a plate-shaped component (e.g. the rib 232) in the above example, is optionally in contact with a larger wall surface. Accordingly, the modifications illustrated in Figs. 6 to 9 described in the above first exemplary embodiment are also applicable in the present exemplary embodiment.

[0054]

10 Range of Taper Angle θ

A study on the range of the taper angle θ of the tapered shape defined by the contact surfaces of the contact member in the above-described exemplary embodiments will be described below.

[0055]

15 Initially, as illustrated in Figs. 19 and 20, the taper angle θ of the tapered shape, which is defined by the contact surfaces in both of the first exemplary embodiment and the second exemplary embodiment, defines a relationship between a movable range Δg (a difference between a maximum value $g_{\max}$ and a minimum value $g_{\min}$) in the direction of the gap g (illustrated as x direction in the figure) for the contact member to be inserted into and a vertically movable range Δh for the members mutually in contact with each other at the contact surfaces (between the rib or the bottom flange and the first body portion of the contact member in the first exemplary embodiment and between the first body portion and the second body portion of the contact member in the second exemplary embodiment). It should be noted that the movable range Δh is defined as a relative movable range for the components to be movable in a direction perpendicular to the direction of the gap g within a cross section of the contact member including two contact surfaces. For instance, when a tolerance Δg_{req} of the gap g caused by erection error is not more than a movable range Δg of the contact member, a surface contact can be maintained between the contact surface of the contact member and the corresponding component (the secondary beam or the rib in the above example) or between the contact surfaces of the contact member. The above relationship is represented by a

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formula (1) below, from which a formula (2) defining a lower limit $\theta_{\min}$ of the taper angle θ can be derived.

[0056]

Formula 1

$$\Delta g_{req} \leq \Delta g = \Delta h \cdot \tan \theta \quad (1)$$

$$\theta_{\min} = \tan^{-1} \frac{\Delta g_{req}}{\Delta h} \quad (2)$$

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[0057]

In contrast, as illustrated in Fig. 21, the taper angle θ of the tapered shape defined by the contact surfaces in the first exemplary embodiment defines a relationship between a force derived from the compression force P transmitted between the components to push the contact member out of the gap g and a friction force between the contact surfaces, which resists the above force. Initially, on the contact surface slanted with respect to the direction of the gap g (illustrated as the x direction in the figure), the compression force P is decomposed into a force component P_{v1} in a direction perpendicular to the contact surface and a force component P_{vf1} in a direction along the contact surface. The force component P_{v1} is represented by a formula (3) below and the force component P_{vf1} is represented by a formula (4) below based on a relationship of the friction force applied in proportion to the force component P_{v1} . Herein, μ_1 is a static friction coefficient and the formula (4) represents a condition where the force component of the compression force P becomes equal to or less than the friction force to keep slide movement on the contact surface from being caused.

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[0058]

Formula 2

$$P_{v1} = P \cdot \cos \theta \quad (3)$$

$$P_{vf1} \leq \mu_1 \cdot P_{v1} = \mu_1 \cdot P \cdot \cos \theta \quad (4)$$

[0059]

Next, on the contact surface perpendicular to the direction of the gap g , the force component of the compression force P does not act in the direction for pushing the contact member out of the gap g . Further, a friction force P_{f2} in proportion to the compression force P acts. A maximum value of the friction force P_{f2} is represented by a formula (5) below. Here, μ_2 represents a static friction coefficient.

[0060]

Formula 3

$$P_{f2} \leq \mu_2 \cdot P \quad (5)$$

10 [0061]

In order to keep the contact member from being pushed out of the gap g , it is necessary that a vertically upward component ($P_{v1}\sin\theta$) of the force component P_{v1} of the compression force P does not exceed a sum of the friction forces P_{f2} , P_{vf2} each acting on the corresponding one of the contact surfaces and gravity mg acting on the contact member, which is represented by a formula (6) below. A formula (7) is obtained by substituting the above formulae (3) to (5) into the formula (6).

[0062]

Formula 4

$$P_{v1} \sin \theta \leq P_{f2} + P_{vf1} \cos \theta + mg \quad (6)$$

$$\cos \theta \sin \theta \leq \mu_2 + \mu_1 \cdot \cos^2 \theta + \frac{mg}{P} \quad (7)$$

20 [0063]

Here, the gravity mg acting on the contact member is sufficiently small as compared with the compression force P . For instance, supposing that a mass m of the contact member = 1 kg, a thickness t_f of the flange = 16 mm, flange width b_f = 200 mm, and yield stress of the flange is 345 N/mm², 20% of which is applied on the contact member as the compression force, $P = 104$ kN for $mg = 9.8$ N, where $mg/P = 1.0 \times 10^{-4}$. Accordingly, mg/P is practically negligible in the Formula (7). The formula

(7) can then be transformed into a formula (8) below. Further, supposing that $\mu_1 = \mu_2 = \mu$, a formula (9), which is a conditional expression for μ , can be derived. A formula (10) defining an upper limit $\theta_{\max}$ of the taper angle θ can be derived by solving the formula (9) for θ .

5 [0064]

Formula 5

$$\mu_2 + \mu_1 \cdot \cos^2 \theta \geq \cos \theta \sin \theta \quad (8)$$

$$\mu \geq \frac{\cos \theta \sin \theta}{1 + \cos^2 \theta} \quad (9)$$

$$\theta_{\max} = \tan^{-1} \left(\frac{1 - \sqrt{1 - 8\mu^2}}{2\mu} \right) \quad (10)$$

[0065]

The above formula (2) defines a lower limit $\theta_{\min}$ of the taper angle θ with reference to the tolerance Δg_{req} of the gap g and the movable range Δh in the vertical direction of the contact member. In contrast, the above formula (10) defines the upper limit $\theta_{\max}$ of the taper angle θ with reference to the static friction coefficient μ of the contact surface. The contact member can be designed using these relationships as, for instance, in a graph illustrated in Fig. 21. In the example illustrated in Fig. 21, the upper limit $\theta_{\max}$ of the taper angle θ is determined based on a given value of the static friction coefficient μ , where the tolerance Δg_{req} of the gap g is determined supposing that $\theta = \theta_{\max}$. In this example, the gap tolerance Δg_{req} , which is calculated by substituting the preset movable range Δh in the vertical direction and $\theta_{\min} = \theta_{\max}$ into the above formula (2), defines a critical value when the lower limit $\theta_{\min}$ calculated by the formula (2) coincides with the maximum value $\theta_{\max}$ calculated by the formula (10). It should be noted that it is possible to set the taper angle θ to be smaller than the upper limit $\theta_{\max}$ in consideration of safety factor. In this case, the gap tolerance Δg_{req} for the movable range Δh in the same vertical direction becomes smaller. When, for

instance, the gap tolerance Δg_{req} is insufficient to compensate for the erection error, the gap tolerance Δg_{req} can be increased by increasing the size of the joint member to enlarge the movable range Δh in the vertical direction or increasing the static friction coefficient μ by changing the material or finish of the contact surface(s). It should be noted that the static friction coefficient μ is, for instance, in a range from 0.18 to 0.25 when both contact surfaces are black oxidized, in a range from 0.10 to 0.25 when both contact surfaces are subjected to blasting or machining, in a range from 0.4 to 0.9 when both contact surfaces are covered with red or black rust, in a range from 0.5 to 0.9 when both contact surfaces are aluminum-spray finished, and in a range from 0.1 to 0.6 when both contact surfaces are formed by forging.

[0066]

Cross-sectional compression resistance of Contact Member

Fig. 23 illustrates an example of designing a cross-sectional compression resistance of the contact member, and is an enlarged illustration of a joint configuration similar to the second exemplary embodiment described above with reference to Fig. 11. In an illustrated joint configuration 20B, the rib 232 and the bottom flange 212 of the secondary beam 21 are in contact with each other via the contact member 24, so that the compression force in the member axial direction of the secondary beam 21 acting on the bottom flange 212 is transmitted between the bottom flange 212 and the rib 232. In the present exemplary embodiment, on each side of the web 213 (i.e. total two contact members 24A, 24B), one contact member is inserted between the bottom flange 212 and the rib 232. In other words, the contact members 24A, 24B in the illustrated example are located only at portions except for an intersection between the web 213 and the bottom flange 212. Further, the contact members 24A, 24B are not provided at ends in the width direction of the bottom flange 212.

[0067]

It should be noted that the resistance is calculated by multiplying the yield stress of the material by a cross-sectional area. Accordingly, the cross-sectional compression resistance of each of the contact member and the bottom flange is calculated by multiplying a standard yield stress of the steel material of the corresponding one of the members by a nominal cross-sectional area of the

corresponding one of the members in a cross section perpendicular to the direction for the compression force to be transmitted.

[0068]

In the present exemplary embodiment, since the contact members 24A, 24B are arranged as described above, a total dimension $w_{cp1}+w_{cp2}$ of the contact members 24A, 24B in the width direction of the bottom flange 212 becomes smaller than the width B_f of the bottom flange 212 ($w_{cp1} + w_{cp2} < B_f$). Accordingly, a contact area S_{cp} in the cross section orthogonal to the member axial direction of the secondary beam 21, in which the compression force is to be transmitted via the contact members 24A, 24B between the bottom flange 212 and the rib 232, is smaller than a cross-sectional area S_f of the bottom flange 212 ($S_{cp} < S_f$). The contact area S_{cp} herein refers to a minimum one of the contact area S_{cp1} between the first contact surface 241A of the contact member 24 and the rib 232 described above with reference to Fig. 12, a contact area S_{cp2} between the second contact surface 241B and the third contact surface 243A, and a contact area S_{cp3} between the fourth contact surface 243B and the bottom flange 212. It should be noted that, since the second contact surface 241B and the third contact surface 243A are slanted with respect to the member axial direction of the secondary beam 21, the contact area S_{cp2} is an area of an actual contact area projected on a plane orthogonal to the member axial direction of the secondary beam 21.

[0069]

By determining the contact area S_{cp} as described above, when the material strength of the contact members 24A, 24B is substantially equal to the material strength of the bottom flange 212, a compression resistance Y_{cp} of the contact members 24A, 24B becomes smaller than a cross-sectional compression resistance Y_f of the bottom flange 212. The above-described dimensional difference is present because, as described later, it is advantageous that the compression resistance Y_{cp} of the contact members 24A, 24B is smaller than the cross-sectional compression resistance Y_f of the bottom flange 212. Alternatively, when there is no dimensional difference ($w_{cp1} + w_{cp2} = B_f$), the material strength of the contact members 24A, 24B is optionally made smaller than the material strength of the bottom flange 212.

[0070]

Especially, when the secondary beam 21 is of a large span (e.g. 8 m or more), a design of the cross sectional profile of the secondary beam 21 for satisfying the restriction on an amount of flexure affords extra bending resistance and shear resistance, where an actual existing stress becomes smaller than the cross-sectional resistance (specifically the yield stress) of the secondary beam 21. Accordingly, it is believed that even when the compression resistance Y_{cp} of the contact member is made smaller than the cross-sectional compression resistance Y_f of the bottom flange 212, the compression resistance Y_{cp} still can sufficiently endure the actual existing stress. Further, after concrete 251 of an RC slab 25 is hardened, the tensile force transmitted via a rebar 252 and the compression force transmitted via the contact members 24A, 24B forms a balanced system to exhibit the bending resistance of the joint portion. Accordingly, the bending resistance of the joint portion does not change even without increasing the compression resistance Y_{cp} of the contact member to match the cross-sectional compression resistance Y_f of the bottom flange 212.

[0071]

Specifically, considering the bending resistance of the joint portion as described above, it is sufficient for the compression resistance Y_{cp} of the contact member 24 to be larger than smaller one of: a sum of the tensile resistance of the rebar 252 placed within an effective width area of the RC slab 25 of the joint configuration 20B for jointing the secondary beam 21 to the primary beam 22; and the shear resistance of shear connectors 26 placed within a negative bending area of the secondary beam 21. It should be noted that the effective width area of the RC slab 25 can be determined by a calculation method for a slab effective width of a composite beam defined in "Guideline/Manual for Designing Various Composite Structure" published by the Japan Society for Folk Architecture, or "Eurocode 4: Design of composite steel and concrete structures Part 1-1: General rules and rules for buildings" by EUROPEAN COMMITTEE FOR STANDARDIZATION. Further, the negative bending area of the secondary beam 21 refers to an area from the joint portion of the primary beam 22 to an inflection point of the bending moment toward the center in the member axial direction of the secondary beam 21, that is, an area for the bending moment acting on the secondary beam 21 to become tensile moment

at a side of the top flange 211 and compression moment at a side of the bottom flange 212.

[0072]

Based on the above findings, in the example illustrated in Fig. 23, the contact member is not placed over the entire width of the bottom flange 212 and the total dimension of the contact members 24A, 24B is made smaller than the width of the bottom flange 212. The contact members 24A, 24B thus become small in size and are more easily installable. Further, the amount of steel materials to be used for the contact members 24A, 24B can be reduced.

[0073]

In contrast, before the concrete 251 of the RC slab 25 is hardened while the joint configuration 20B is under construction, the tensile force is not transmitted via the top flange 211 of the secondary beam 21. In this state, slip resistance of the bolt 233 for jointing the web 213 of the secondary beam 21 to the fin plate 231 and the compression force transmitted via the contact members 24A, 24B form a balance system, thereby exhibiting bending resistance against a vertical load (primarily, self weights of the secondary beam 21 and the RC slab 25) acting on the secondary beam 21 and unhardened RC slab 25. In this case, when the compression resistance Y_{cp} of the above contact member is larger than necessary, the rotation center of the joint portion comes close to the bottom flange 212 to increase the force applied on the bolt 233 that is remote from the rotation center. The bolt 233 thus possibly slips against the web 213 and the fin plate 231 at an early stage to decrease the bending resistance and consequently increase the flexure of the secondary beam 21. In the example illustrated in Fig. 23, the bending resistance can be maintained and the flexure of the secondary beam 21 can be reduced by reducing the compression resistance Y_{cp} in a range without impairing the functionality to keep the rotation center of the joint portion away from the bottom flange 212 and bring the bolt 233 close to the rotation center to reduce the force applied on the bolt and consequently, restrain the slippage of the bolt.

[0074]

As described above, in the example illustrated in Fig. 23, the joint configuration 20B that does not directly joint the top flange 211 of the secondary

beam 21 to the primary beam 22 can be economically constructed without impairing functionality thereof. It should be noted that the modifications described above with reference to the second exemplary embodiment are also applicable to the example illustrated in Fig. 23. Further, the configuration in the first exemplary embodiment described above with reference to Fig. 1 and the modifications thereof also may be made such that the cross-sectional compression resistance of the contact member is smaller than the cross-sectional compression resistance of the bottom flange. In addition, whereas the total two contact members 24A, 24B (one for each side of the web 213 of the secondary beam 21) are inserted in the example illustrated in Fig. 23, a single contact member penetrating through the web 213 is optionally alternatively provided by, for instance, forming a scallap in the web 213. Further alternatively, three or more contact members are optionally inserted between the secondary beam 21 and the rib 232.

[0075]

Fig. 24 is an illustration explaining conditions for structural analysis of the joint configuration according to the example illustrated in Fig. 23. In order to evaluate the behavior of the contact member while a joint configuration of dimensions as illustrated in Fig. 24 is under construction (i.e. while the concrete of the RC slab is unhardened), an FEA (Finite Element Analysis) was performed for an instance where a 50 mm vertical displacement δ_b of the secondary beam was applied at a position 1500 mm away from the width center (symmetry plane) of the primary beam. The web of the secondary beam and the fin plate are jointed by six bolts (F10T 6-M20). The analysis was performed on six cases (Nos. 1 to 6), where a width w_{cp} ($= w_{cp1} = w_{cp2}$) of the contact member shown as Example in Fig. 23 was changed to 20 mm, 40 mm, and 80 mm and a friction coefficient μ_1 between the web of the secondary beam and the fin plate s_i changed to 0.45 and 0.80 as shown in Table 1 below (a friction coefficient μ_2 between the contact member and the bottom flange of the secondary beam and between the contact member and the rib was fixed at 0.45). As Comparatives, the analysis was also performed on a case (No. 7) provided with no contact member and two cases (Nos. 8 and 9), where the bottom flange and the rib were jointed over the entire width of the bottom flange and the friction coefficient μ_1 between the web of the secondary beam and the fin plate was changed between 0.45

and 0.80. The analysis was performed on total nine cases including Examples and Comparatives. It should be noted that, though the bolt screwed into the contact member resists the slippage caused between the contact member and the bottom flange of the secondary beam and between the contact member and the rib by its axial force when the contact member is fixed by tightening the bolt as illustrated in Figs. 19 to 21, the resistance of the bolt is ignored in the analysis for evaluation on the safe side.

[0076]

Table 1

Case	W_{cp} [mm]	μ_1	μ_2
No. 1	20	0.45	0.45
No. 2	20	0.80	0.45
No. 3	40	0.45	0.45
No. 4	40	0.80	0.45
No. 5	80	0.45	0.45
No. 6	80	0.80	0.45
No. 7	0	0.45	-
No. 8	100	0.45	Bonded
No. 9	100	0.80	Bonded

Table 1: Analysis Conditions

[0077]

Figs. 25A and 25B are graphs showing the magnitude of the moment generated at the joint portion in the analysis illustrated in Fig. 24. A moment M_j at the joint portion shown in the graphs is calculated as, supposing that the vertical displacement δ_b is caused on the secondary beam at a position away from the width center (symmetry plane) of the primary beam by a distance L_b , a product of a magnitude P of a load applied at the position and the distance L_b to the joint portion ($M_j = P \cdot L_b$). Fig. 25A shows the results of the cases (Nos. 1, 3, and 5) where the friction coefficient μ_1 between the web of the secondary beam and the fin plate is 0.45 together with the results of Comparatives (Nos. 7 and 8). Similarly, Fig. 25B shows the results of the cases (Nos. 2, 4, and 6) where the friction coefficient μ_1 is 0.80, together with the result of Comparative (No. 9). In both of the graphs, it is shown that the moment M_j (i.e. the bending resistance) is larger with respect to the same vertical displacement δ_b in cases where the sum of the width w_{cp} of the contact members is smaller than the flange width. This results show that, as described above, when the

tensile force is not transmitted at the side of the top flange, the rotation center of the joint portion shifts further away from the bottom flange as the compression resistance Y_{cp} of the contact member becomes smaller, thereby reducing the force applied at the bolt joint between the fin plate and the web of the secondary beam, thereby

5 restraining the slippage at the bolt joint to keep the bending resistance.

[0078]

Figs. 26A to 26C are graphs showing characteristic values relating to the bending resistance in the analysis illustrated in Fig. 24 for each dimension ratio $\Sigma w_{cp}/B_f$ of the contact member to the width of the bottom flange. The characteristic

10 values are normalized to be plotted with the analysis result of the cases (Nos. 8 and 9), where the width of the contact member is equal to the width of the bottom flange for each of the friction coefficients μ_1 of 0.45 and 0.80, being 1. Fig. 26A shows an initial rotational rigidity S_j . Fig. 26B shows a yield moment resistance $M_{j,y}$. Fig. 26C shows plastic moment resistances $M_{j,pl}$. The calculation methods of these

15 characteristic values are shown in Fig. 27. It should be noted that ϕ_j in the graph shown in Fig. 27 is a rotation angle of the secondary beam with respect to the primary beam at the joint portion.

[0079]

In any of the graphs shown in Figs. 26A to 26C, it is shown that the

20 characteristic values related to the bending resistance is significantly improved when the dimension ratio $\Sigma w_{cp}/B_f$ is in a range from 0.2 to 0.8 (i.e. when a total dimension Σw_{cp} of the contact member is in a range from 20% to 80% of the width of the bottom flange of the secondary beam) as compared with an instance where the dimension ratio $\Sigma w_{cp}/B_f$ is 0 (i.e. without the contact member), and is not less than the value in

25 an instance where the dimension ratio $\Sigma w_{cp}/B_f$ is 1. It should be noted that the width B_f of the bottom flange of the secondary beam is 200 mm in the example illustrated in Fig. 24. In order to stably transmit the stress, it is preferable that the width w_{cp} per contact member is 20 mm or more. In this case, the dimension ratio $\Sigma w_{cp}/B_f$ becomes $20 \times 2/200 = 0.2$ or more.

[0080]

Third Exemplary Embodiment

Fig. 28 illustrates a joint configuration according to a third exemplary

embodiment of the present disclosure. A joint configuration 30 illustrated in Fig. 28 includes a steel secondary beam 31, a steel primary beam 32, a steel fin plate 331, a steel rib 332, a steel contact member 34, an RC slab 35, and shear connectors 36. The secondary beam 31 is an H-section beam including a top flange 311, a bottom flange 312, and a web 313. The primary beam 32 is an H-section beam including a top flange 321, a bottom flange 322, and a web 323. The primary beam 32 as well as the fin plate 331 and the rib 332 define a supporting member facing a longitudinal end surface of the secondary beam 31.

[0081]

In the above-described joint configuration 30, the fin plate 331, which is a first portion of the supporting member, is welded to each of the top flange 321, the bottom flange 322, and the web 323 of the primary beam 32 and jointed to the web 313 of the secondary beam 31 using the bolts 333. The rib 332, which is a second portion of the supporting member, is welded to the fin plate 331 and the web 323 and is in contact with the bottom flange 312 of the secondary beam 31 via the contact member 34. The contact member 34, which is inserted into a gap between the bottom flange 312 of the secondary beam 31 and the rib 332, is a component whose dimension is adjustable in accordance with the size of the gap to be kept in contact with the bottom flange 312 and the rib 332 irrespective of the size of the gap, thereby transmitting the compression force from the bottom flange 312 to the rib 332.

[0082]

It should be noted that the supporting member including the primary beam 32, the fin plate 331, and the rib 332 does not include a portion directly jointed to the top flange 311 of the secondary beam 31. The RC slab 35, which is provided at an upper side of the secondary beam 31 and the primary beam 32, includes a concrete 351, a rebar 352 embedded in the concrete 351 and extending at least in the member axial direction of the secondary beam 31, and a steel deck profile 353. In the RC slab 35, the rebar 352 acts as a tensile force transmitting member. The shear connectors 36 (locking member), which are each jointed to the corresponding one of the top flange 311 of the secondary beam 31 and the top flange 321 of the primary beam 32, are fixed to the concrete 351 of the RC slab 35. Since the secondary beam 31 is jointed to the RC slab 35 via the shear connectors 36, the compression force and the

tensile force in the member axial direction of the secondary beam 31 are also transmitted to the RC slab 35. The secondary beam 31, the primary beam 32, and the RC slab 35 thus can jointly resist a bending moment generated at an end of the secondary beam 31. It should be noted that a composite steel deck slab is optionally used in place of the RC slab 35. In this case, the entirety of the composite steel deck slab including the rebar acts as the tensile force transmitting member.

[0083]

In the beam-to-beam joint configuration according to the above-described present exemplary embodiment, a rotational resistance caused by jointing the fin plate 331 and the web 313 against an in-plane rotation of the web 313 around a height center CH of the web 313 (a rotation center) at a longitudinal end surface of the secondary beam 31 (sometimes simply referred to as a "rotational resistance" hereinafter) is larger above a height center line CL of the web 313 than below the height center line CL. Specifically, in the example illustrated in Fig. 28, since the fin plate 331 is overlapped with the web 313 above the height center line CL and the bolts 333 for jointing the web 313 to the fin plate 331 are provided only above the height center line CL, the rotational resistance against the in-plane rotation of the web 313 around the the height center CH (rotation center) acts solely above the height center line CL, whereas the rotational resistance is practically zero below the height center line CL. As described later, the bolt(s) is optionally provided also below the height center line CL. In this case, the rotational resistance below the height center line CL is larger than zero and is smaller than the rotational resistance above the height center line CL.

[0084]

Fig. 29 illustrates a joint configuration not according to the third exemplary embodiment of the present disclosure. In an example illustrated in Fig. 29, a fin plate 331P overlaps the web 313 equally both above and below the height center line CL of the web 313 and the same number of the bolts 333 are arranged in a line both above and below the height center line CL. Before the concrete 351 of the RC slab 35 is hardened while constructing the beam-to-beam joint configuration, since the tensile force is not transmitted via the top flange 311 of the secondary beam 31, the bending resistance is exhibited against a vertical load acting on the secondary beam

31 by a balance system formed by the tensile force transmitted by slip resistance of the bolts 333 and the compression force transmitted via the contact member 34. In Reference Example, since the line of action of the tensile force of the three bolts 333 (illustrated as bolts 333P), which are located below the height center line CL among the six bolts 333, is close to the line of action of the compression force passing through the contact member 34, the moment contributing to the bending resistance becomes small.

[0085]

In contrast, in the example illustrated in Fig. 28, the bolts 333, the number of which is six same as in Reference Example, are all (i.e. including the three bolts 333 arranged in parallel (illustrated as bolts 333Q)) located above the height center line CL unlike Reference Example. With regard to the bolts 333Q, since the line of action of the tensile force gets away from the line of action of the compression force passing through the contact member 34, the moment contributing to the bending resistance becomes larger than that of the three bolts 333P in Reference Example. Accordingly, the bending resistance exhibited as a sum of the resistances of the six bolts 333 becomes larger in the example illustrated in Fig. 28 than in the example illustrated in Fig. 29. In other words, in the example illustrated in Fig. 28, as compared with the example illustrated in Fig. 29, the rigidity and resistance of the beam-to-beam joint configuration can be improved by changing the arrangement of the same number of bolts before the concrete 351 of the RC slab 35 is hardened while the joint configuration is being constructed.

[0086]

It should be noted that the bolts 333 for jointing the web 313 of the secondary beam 31 to the fin plate 331, which are provided only above the height center line CL in the example illustrated in Fig. 28, are optionally also provided below the height center line CL in some embodiments. Also in this case, the rigidity of the beam-to-beam joint configuration before the concrete 351 is hardened can be improved as in the above example as shown in formula (11) below when a product of a resistance P_i of N pieces of the bolt(s) 333 located above the height center line CL and a distance d_i from the height center line CL is larger than a product of a resistance P_j of M pieces of the bolt(s) 333 located below the height center line CL and the distance

d_j from the height center line CL. Herein, the resistances P_i, P_j of each of the bolts 333 are each defined as smaller one of the slip resistance or shear resistance per bolt 333. For instance, the formula (11) is optionally satisfied when the number of the bolts 333 provided above the height center line CL is larger than the number of the bolts provided below the height center line CL. Alternatively, the formula (11) is optionally satisfied by, though the same number of the bolts 333 are provided both above and below the height center line CL, locating the bolts above the height center line CL farther from the height center line CL. In the example illustrated in Fig. 28, M = 0 in the formula (11) (in this case, the formula (11) holds irrespective of the value of N).

[0087]

Formula 6

$$\sum_{i=1}^N P_i d_i > \sum_{j=1}^M P_j d_j \quad \cdot \cdot \cdot \quad (1 \quad 1)$$

[0088]

As described above, in the example illustrated in Fig. 28, the joint configuration 30 that does not directly joint the top flange 311 of the secondary beam 31 to the primary beam 32 can be economically constructed without impairing functionality thereof. It should be noted that, since the joint configuration 30 is the same as the second exemplary embodiment except for the arrangement of the bolts 333, the modifications described above with reference to the second exemplary embodiment are also applicable to the example illustrated in Fig. 28. Further, the configuration of the first exemplary embodiment described above with reference to Fig. 1 and the modifications thereof are also optionally made such that the rotational resistance against the in-plane rotation of the secondary beam web around the height center (rotation center) of the secondary beam web is larger above the height center line of the secondary beam web than below the height center line. In addition, the configuration of the present exemplary embodiment is optionally made such that the cross-sectional compression resistance of the contact member is smaller than the cross-sectional compression resistance of the bottom flange as described above with reference to Fig. 23.

[0089]

Figs. 30 and 31 are illustrations explaining conditions for structural analysis of the joint configuration according to the third exemplary embodiment of the present disclosure. In order to evaluate the behavior of the contact member while a beam-to-beam joint configuration of dimensions as illustrated in Figs. 30 and 31 is under construction (i.e. while the concrete of the RC slab is unhardened), an FEA (Finite Element Analysis) was performed for an instance where a 50 mm vertical displacement δ_b of the secondary beam was applied at a position 1500 mm away from the width center (symmetry plane) of the primary beam. Fig. 30 shows a model corresponding to the example described with reference to Fig. 28 (sometimes referred to as a "first example" hereinafter). Fig. 31 shows a model corresponding to the example described with reference to Fig. 29 (sometimes referred to as a "second example" hereinafter).

[0090]

In both of the models, the web of the secondary beam and the fin plate are jointed by six bolts (F10T 6-M20). The bolts are arranged in 3×2 (i.e. two columns of three bolts above the height center line of the secondary beam web) in the first example, whereas the bolts are arranged in 6×1 (i.e. three bolts each provided in a single column across the height center line of the secondary beam web: total six bolts) in the second example. The analysis was performed on six cases in total, specifically, on four cases with a width w_{cp} ($= w_{cp1} = w_{cp2}$) of the contact member illustrated in Fig. 23 being 40 mm, where the friction coefficient μ_1 between the secondary beam web and the fin plate is changed between 0.45 and 0.80 as shown in Table 1 below (a friction coefficient μ_2 between the contact member and the bottom flange of the secondary beam and between the contact member and the rib is fixed at 0.45) and on two cases with the bottom flange of the secondary beam being jointed to the rib over the entire width as Comparative.

[0091]

Table 2

Case	W_{cp} [mm]	Bolt Arrangement	μ_1	μ_2
No. 3	40	6×1	0.45	0.45
No. 3d		3×2		
No. 4		6×1	0.8	0.45
No. 4d		3×2		
No. 8	(100)	6×1	0.45	Bonded
No. 8d		3×2		

Table 2: Analysis Conditions

[0092]

Fig. 32 is a graph showing results of comparison for the magnitude of the moment generated at the joint portion in the analyses illustrated in Figs. 30 and 31 between instances where the dimension of the contact member is smaller than the width of the bottom flange of the secondary beam (Nos. 3 and 3d) and instances where the bottom flange of the secondary beam is jointed to the rib over the entire width (Nos. 8 and 8d). The moment M_j at the joint portion shown in the graphs is calculated as, supposing that the vertical displacement δ_b is caused on the secondary beam at a position away from the width center (symmetry plane) of the primary beam by a distance L_b , a product of a magnitude P of a load applied at the position and the distance L_b to the joint portion ($M_j = P \cdot L_b$). In contrast, a rotation angle φ_j of the joint portion is calculated by dividing a horizontal displacement δ_{ft} of the secondary beam at the side of the top flange and a horizontal displacement δ_{fb} of the secondary beam at the side of the bottom flange by a cross-sectional height z_j of the secondary beam ($\varphi_j = (\delta_{ft} - \delta_{fb})/z_j$).

[0093]

As shown in the graph, the moment M_j (i.e. the bending resistance) is larger in the first example (No. 3d), where the bolts are provided only above the height center line of the secondary beam web than in the second example (No. 3), where the bolts are evenly arranged in the height direction of the secondary beam web, per the same rotation angle φ_j of the joint portion. The results show, as described above, when the tensile force is not transmitted via the top flange, the larger number of the bolts provided at a position remote from the bottom flange (specifically, above the height center line of the secondary beam web) results in more improvement in the bending resistance due to the increase in the sum of the moment contributing to the

bending resistance caused by the slip resistance of the bolts.

[0094]

Further, as shown in the graph, when the dimension of the contact member is smaller than the width of the bottom flange of the secondary beam, the moment M_j in the first example (No. 3d) is overall larger than that in the second example (No. 3). In addition, when the bottom flange of the secondary beam is jointed to the rib over the entire width, the moment M_j of the first example (No. 8d) exceeds that in the second example (No. 8) from the start of displacement of the secondary beam until surpassing an elastic limit. This result also shows that the bending resistance of the beam-to-beam joint configuration is improved by providing the bolts above the height center line of the secondary beam web. Furthermore, since the moment M_j is maximized in the first example (No. 3d), where the dimension of the contact member is smaller than the width of the bottom flange of the secondary beam and the bolts are provided above the height center line of the secondary beam web, it is understood that the combination of the bolt arrangement of the present exemplary embodiment with the compression resistance of the compression force transmitting unit (e.g. the contact member) that is smaller than the cross-sectional compression resistance of the bottom flange of the secondary beam offers a synergetic effect.

[0095]

Fig. 33 is a graph showing the magnitude of the moment generated at the joint portion in the analyses illustrated in Figs. 30 and 31 for an instance where the friction coefficient μ_1 between the secondary beam web and the fin plate is different from that in the instance of Fig. 32 (Nos. 4 and 4d). In the example shown in the graph, the moment M_j in the first example exceeds that in Reference Example in a period from the start of the displacement of the secondary beam until surpassing the elastic limit.

[0096]

Table 2 shows an initial rotational rigidity S_j , a yield moment resistance $M_{j,y}$, and plastic moment resistances $M_{j,pl}$ in the above cases. The calculation methods of these characteristic values are the same as those shown above in Fig. 27. Typically, after confirming that the bending moment M_j (values of vertical axes in Figs. 32 and 33) that is supposed in design to act on the joint portion is equal to or less than the

yield moment resistance $M_{j,y}$, the flexure of the beam is calculated with the use of the initial rotational rigidity S_j . When the bending moment M_j that is supposed to act on the joint portion exceeds the yield moment resistance $M_{j,y}$, the initial rotational rigidity S_j cannot be used for calculation of the flexure due to permanent deformation (deformation being left even after removing a load). With regard to the load supposed to be applied during construction in the present exemplary embodiment, since the joint portion is typically kept to be elastically deformed (i.e. without being permanently deformed), the larger yield moment resistance $M_{j,y}$ means the greater load endurable by the joint portion.

10 [0097]

Table 3

Determined characteristic values of $M_j-\phi_j$ relationships

Model	Initial rotational stiffness, S_j [kNm/rad]	Global yield moment resistance, $M_{j,y}$ [kNm]	Global plastic moment resistance, $M_{j,pl}$ [mm]	S_j of each/ S_j of 1 bolt row [-]	$M_{j,y}$ of each / $M_{j,y}$ of 1 bolt row [-]	$M_{j,pl}$ of each / $M_{j,pl}$ of 1 bolt row [-]
NO. 3	40060	93	194	1.00	1.00	1.00
NO. 3d	49187	162	213	1.23	1.75	1.10
NO. 4	45129	121	209	1.00	1.00	1.00
NO. 4d	46062	197	207	1.02	1.63	0.99
NO. 8	37104	92	132	1.00	1.00	1.00
NO. 8d	48297	126	127	1.30	1.37	0.97

[0098]

Suitable exemplary embodiments of the present disclosure have been detailed above with reference to the attached drawings. However, the scope of the present disclosure is not limited by the exemplary embodiments. It would be obvious for those skilled in the art to which the invention pertains that various modifications and revisions are conceivable within the technical idea described within claims, and

it is understood that such modifications and revisions are naturally within the technical scope of the present disclosure.

EXPLANATION OF CODES

5 [0099]
 10, 10A, 10B, 10C, 10D...joint configuration, 11...secondary beam, 111...top flange, 112...bottom flange, 112B...bottom surface, 112E, 112F, 112G...end surface, 112U...top surface, 113...web, 12...primary beam, 121...top flange, 122...bottom flange, 122S...side end surface, 123...web, 131...fin plate, 132...rib, 132E,
10 132F...end surface, 132U...top surface, 133...bolt, 14...contact member, 141...body portion, 141A...first contact surface, 141B...second contact surface, 141X...extension plane, 142...arm portion, 142A...through hole, 143, 143A...bolt, 143B...end, 15...RC slab, 151...concrete, 152...rebar, 152E...extension, 153...steel deck profile, 16...shear connector, 17...RC primary beam, 171...concrete,
15 172...rebar, 172A...longitudinal reinforcement, 172B...stirrup, 181...base plate, 181S...plate surface, 182...fin plate, 183...bolt, 184...anchor, 19A...RC column, 19B...RC wall, 20, 20A, 20B...joint configuration, 21...secondary beam, 211...top flange, 212...bottom flange, 212E...end surface, 213...web, 22...primary beam, 221...top flange, 222...bottom flange, 223...web, 231...fin plate, 232...rib,
20 232E...end surface, 233...bolt, 24, 24A, 24B...contact member, 241...first body portion, 241A...first contact surface, 241B...second contact surface, 241X...extension plane, 242...arm portion, 242A...through hole, 242A1...first hole portion, 242A2...second hole portion, 243...second body portion, 243A...third contact surface, 243B...fourth contact surface, 243C...channel, 243D...through
25 threaded hole, 244...bolt, 244H...head, 245...nut, 25...RC slab, 251...concrete, 252...rebar, 26...shear connector, 30...joint configuration, 31...secondary beam, 311...top flange, 312...bottom flange, 313...web, 32...primary beam, 321...top flange, 322...bottom flange, 323...web, 331...fin plate, 332...rib, 333, 333Q...bolt, 34...contact member, 35...RC slab, 351...concrete, 352...rebar, 353...steel deck
30 profile, 36...shear connector, CH...height center, CL...height center line, L...axis

CLAIM(S)

1. A joint configuration formed between a first member and a second member, the joint configuration comprising:

a contact member inserted into a gap defined in a first direction between the

5 first member and the second member, wherein

the contact member comprises:

a first body portion comprising a first contact surface to be in surface contact with the first member and a second contact surface that is opposite to the first contact surface and is to be in surface contact with the second member; and

10 an arm portion projecting from an end of the second contact surface, the arm portion being provided with at least one through hole extending along an axis intersecting the second contact surface or an extension plane of the second contact surface,

the first contact surface and the second contact surface define a tapered shape of a taper angle θ in a cross section orthogonal to both of the first contact surface and the second contact surface, the arm portion projecting from a narrower end or a broader end of the tapered shape, and

the taper angle θ of the tapered shape is in a range defined by formulae below, where a friction coefficient of the second contact surface is μ , a tolerance of the gap is Δg_{req} , and a movable range of the contact member in a direction within the cross section and perpendicular to the first direction is Δh ,

$$\theta \leq \theta_{max} = \tan^{-1} \left(\frac{1 - \sqrt{1 - 8\mu^2}}{2\mu} \right), \quad \theta \geq \theta_{min} = \tan^{-1} \frac{\Delta g_{req}}{\Delta h}$$

2. The joint configuration according to claim 1, wherein

the arm portion projects from the narrower end of the tapered shape, and

25 the joint configuration further comprises at least one rod-shaped fastener inserted through the corresponding at least one through hole.

3. The joint configuration according to claim 2, wherein the at least one through hole is a tapped hole, and the at least one fastener is a bolt screwed into the tapped hole to be fastened.

30 4. The joint configuration according to claim 3, wherein at least a part of an end of the bolt is spherical or convex-shaped.

5. The joint configuration according to claim 1, wherein the arm portion projects from the broader end of the tapered shape, the at least one through hole comprises a first hole portion having a profile extending along the first direction,

5 the contact member further comprises:

a second body portion separated from the first body portion and the arm portion, the second body portion comprising a third contact surface to be in surface contact with the second contact surface and a fourth contact surface that is opposite to the third contact surface and is to be in surface contact with the second member, the third contact surface and the fourth contact surface defining a tapered shape in a cross section including the first direction; and

10

at least one rod-shaped fastener fixed to the second body portion and inserted through the corresponding at least one through hole, and

15 the second contact surface is indirectly in contact with the second member via the second body portion.

6. The joint configuration according to claim 5, wherein

the at least one fastener comprises a threaded groove on at least a part in an axial direction, and

20 the joint configuration further comprises at least one nut screwable onto the corresponding at least one fastener and configured to be tightened to force the arm portion toward the second body portion.

7. The joint configuration according to claim 5 or 6, wherein

25 the second body portion further comprises a channel into which a plate-shaped portion of the second member is insertable, and

the fourth contact surface defines a bottom surface of the channel.

8. The joint configuration according to claim 7, wherein the at least one fastener comprises a threaded groove on at least a part in an axial direction, the at least one fastener being screwed in the second body portion to be fixed to the second body portion and penetrating through the first body portion and protruding from a side surface of the channel.

30

9. The joint configuration according to any one of claims 5 to 8, wherein the at

least one through hole further comprises a second hole portion having a profile extending along a direction intersecting the first direction.

10. The joint configuration according to any one of claims 1 to 9, wherein

one of the first member and the second member is an H-section beam comprising a top flange, a bottom flange, and a web and the other of the first member and the second member is a supporting member comprising a first portion bolted to the web and a second portion facing the bottom flange and not comprising a portion directly jointed to the top flange,

one of the first contact surface and the second contact surface of the contact member is in contact with the bottom flange and the other of the first contact surface and the second contact surface is in contact with the second portion, and

a cross-sectional compression resistance of the contact member is smaller than a cross-sectional compression resistance of the bottom flange.

11. The joint configuration according to claim 10, wherein, in a cross section orthogonal to the first direction matching a member axial direction of the H-section beam, both of a contact area of the first contact surface and a contact area of the second contact surface are smaller than a cross-sectional area of the bottom flange.

12. The joint configuration according to claim 10 or 11, wherein a material strength of the contact member is smaller than a material strength of the bottom flange.

13. The joint configuration according to any one of claims 1 to 12, wherein

one of the first member and the second member is an H-section beam comprising a top flange, a bottom flange, and a web and the other of the first member and the second member is a supporting member comprising a first portion bolted to the web and a second portion facing the bottom flange and not comprising a portion directly jointed to the top flange,

one of the first contact surface and the second contact surface of the contact member is in contact with the bottom flange and the other of the first contact surface and the second contact surface is in contact with the second portion, and

a rotational resistance caused by jointing the first portion to the web against an in-plane rotation of the web around a height center of the web as a rotation center on a longitudinal end surface of the the H-section beam is larger above a height

center line of the web than below the height center line of the web.

14. The joint configuration according to claim 13, wherein
the web is bolted to the first portion, and

a product of a resistance and a distance from the height center line is
5 calculated for each of bolts located above the height center line, a product of a
resistance and a distance from the height center line is calculated for bolts located
below the height center line, and a sum of the products for the bolts located above
the height center line is larger than a sum of the products for the bolts located below
the height center line.

15. The joint configuration according to claim 13 or 14, wherein the number of
the bolts located above the height center line is larger than the number of the bolts
located below the height center line.

16. The joint configuration according to claim 13 or 14, wherein the bolts for
joining the web to the first portion is located only above the height center line.

17. The joint configuration according to any one of claims 1 to 16, wherein
one of the first member and the second member is an H-section beam
comprising a top flange, a bottom flange, and a web and the other of the first member
and the second member is a supporting member comprising a first portion bolted to
the web and a second portion facing the bottom flange and not comprising a portion
20 directly jointed to the top flange, and

the joint configuration further comprises:

an RC slab or a composite steel deck slab comprising concrete and
a tensile force transmitting member embedded in the concrete and extending in a
member axial direction of the H-section beam, the RC slab or the composite steel
25 deck slab being provided at an upper side of the H-section beam and the supporting
member; and

a locking member jointed to the top flange and the supporting
member, the locking member being fixed to the concrete of the RC slab or the
composite steel deck slab.

18. The joint configuration according to claim 17, wherein a compression
resistance of the contact member is equal to or more than a smaller one of: a tensile
resistance of the tensile force transmitting member located within an effective width

area of the RC slab or the composite steel deck slab of the joint configuration; and a shear resistance of the locking member located within a negative bending area of the H-section beam.

19. A design method of a joint configuration formed between a first member and a second member, the joint configuration comprising:

a contact member inserted into a gap defined in a first direction between the first member and the second member, wherein

the contact member comprises: a first body portion comprising a first contact surface to be in surface contact with the first member and a second contact surface located opposite to the first contact surface to be in surface contact with the second member; and an arm portion projecting from an end of the second contact surface, the arm portion having at least one through hole extending along an axis intersecting the second contact surface or an extension plane of the second contact surface, and

the first contact surface and the second contact surface define a tapered shape of a taper angle θ in a cross section orthogonal to both of the first contact surface and the second contact surface, the arm portion projecting from a narrower end or a broader end of the tapered shape,

the method comprising:

setting the taper angle θ of the tapered shape in a range defined by formulae below, wherein a friction coefficient of the second contact surface is μ , a tolerance of the gap is Δg_{req} , and a movable range of the contact member in a direction within the cross section and perpendicular to the first direction is Δh ,

$$\theta \leq \theta_{max} = \tan^{-1} \left(\frac{1 - \sqrt{1 - 8\mu^2}}{2\mu} \right), \quad \theta \geq \theta_{min} = \tan^{-1} \frac{\Delta g_{req}}{\Delta h}$$