

Specification

[Title of the Invention] JOINT STRUCTURE

[Technical Field of the Invention]

[0001]

The present invention relates to a joint structure.

This application claims the right of priority based on Japanese Patent Application No. 2022-029521 filed with the Japan Patent Office on February 28, 2022, the content of which is incorporated herein by reference.

[Related Art]

[0002]

A semi-rigid joint that takes into account a rotational restraint effect of a joint portion by reinforcing bars of a floor slab has been proposed as an existing technology. These semi-rigid joints are generally applied to intermediate joint portions of continuous beams. The intermediate joint portion mentioned herein means a joint portion where beams, which are semi-rigidly connected, are placed on both sides with a member (support member) interposed therebetween that supports the beams, and the floor slab is continuous across the support member.

The semi-rigid joint is suitable for properties with large floor areas per floor, which are located in suburban areas of cities, such as warehouses, factories, and airport terminals. On the other hand, buildings located in urban centers often adopt the following frame type. That is, a core wall of a RC structure (hereinafter, also simply referred to as a RC core wall, and the same applies to walls, beams, and the like) is disposed at a center of a relatively small flat surface. In addition, a single-span composite beam is disposed between a RC wall and a RC large beam of an outer peripheral frame. In this type of building, continuous beams are rarely used.

[0003]

In the case of such a frame type, reinforcing bars of a floor slab cannot be continuous across the RC wall. Therefore, a joint portion is generally a pinned joint. Therefore, a deflection of the beam increases, resulting in an uneconomical design.

[0004]

On the other hand, for a joint portion between a RC column and a RC beam, a method of bending and anchoring a main bar of the beam to the RC column is used (for example, refer to Patent Documents 1 and 2). In the case of the joint portion between the RC column and the RC beam, a bending moment acting on an end portion of the beam is transmitted to the column by a tensile force of the bent and anchored bar of the joint portion and a compressive force of the concrete. A shear force acting on the end portion of the beam is transmitted by integrally placing the concrete of the column and the beam and arranging shear reinforcing bars. According to existing documents, there are three reported failure modes of RC columns due to a tensile force on a bent and anchored bar of a RC beam: raking-out failure, side splitting failure, and local compression failure.

[Prior Art Document]

[Patent Document]

[0005]

[Patent Document 1] Japanese Patent No. 3826354

[Patent Document 2] Japanese Unexamined Patent Application, First Publication No. H11-148172

[Disclosure of the Invention]

[Problems to be Solved by the Invention]

[0006]

Even in a case where a semi-rigid joint that utilizes a reinforcing bar of a floor slab for a joint portion between a RC wall and a composite beam is used, a method of bending (hooking) and anchoring the reinforcing bar of the floor slab is considered. However, in a case of joining a steel framed beam and a RC wall, the steel framed beam and the RC wall are joined as described below in order to join different materials. That is, a shear plate as a measure for transmitting a shear force is anchored to a wall concrete with a shear connector or the like. The shear plate and a web of the steel framed beam are joined to each other with bolts.

In order to form this joint portion as a semi-rigid joint capable of further transmitting a moment, the reinforcing bar of the floor slab of the composite beam is bent and anchored to the RC wall.

In the joint portion between the RC wall and the composite beam, a failure in the RC wall due to a tensile force in the bent and anchored bar is also a problem.

[0007]

The present invention has been made in view of such problems, and an object thereof is to provide a joint structure capable of suppressing a failure in a wall of a RC structure in a joint structure of a joint portion where the wall of the RC structure and an end portion of a composite beam are joined.

[Means for Solving the Problem]

[0008]

In order to solve the above problems, the present invention proposes the following aspects.

(1) A first aspect of the present invention a joint structure of a joint portion where a wall of a RC structure and an end portion of a composite beam are joined, in which the wall includes a wall concrete, the composite beam includes a floor slab and a

steel framed beam that supports the floor slab from below, the floor slab includes a floor concrete, and a plurality of reinforcing bars embedded in the floor concrete and the wall concrete, each of the plurality of reinforcing bars includes a reinforcing bar main body extending in a longitudinal direction of the steel framed beam in the floor concrete and the wall concrete, and a diameter-increasing portion that is embedded in the wall concrete and has a length of the diameter-increasing portion larger than a diameter of the reinforcing bar main body in a radial direction of the reinforcing bar main body, the steel framed beam is discretely or continuously joined to the floor slab in the longitudinal direction by a shear connector, a cross-sectional area ratio R_{Ar} of the plurality of reinforcing bars satisfies Formula (1), and a projected anchorage length ratio (L_h/d_r) satisfies Formula (2).

Here, i is the number of layers of the plurality of reinforcing bars arranged in the floor concrete, $a_{r,i}$ is a cross-sectional area (mm^2) of each of the plurality of reinforcing bars, which is orthogonal to the longitudinal direction of the plurality of reinforcing bars, in an i -th layer, which is an i -th layer from top, p_i is a pitch (mm) in a width direction of the floor slab between the plurality of reinforcing bars in the i -th layer, $\sigma_{ry,i}$ is a yield stress (N/mm^2) of the plurality of reinforcing bars in the i -th layer, σ_c is a compressive strength (N/mm^2) of the wall concrete, $L_{h,i}$ is a projected anchorage length (mm), which is a length in the longitudinal direction of a portion of the plurality of reinforcing bars in the i -th layer anchored to the wall concrete, and $d_{r,i}$ is a diameter (mm) of each of the plurality of reinforcing bars in the i -th layer.

[0009]

$$R_{Ar} = \sum \left(\frac{a_{r,i}}{p_i} \cdot \frac{\sigma_{ry,i}}{\sigma_c} \right) < 30.70 \quad \cdot \cdot (1)$$

$$L_h/d_r = \min \left(\frac{L_{h,i}}{d_{r,i}} \right) > 15.600 \quad \cdot \cdot (2)$$

[0010]

The wall mentioned here means a structure that extends in each of an up-down direction and a horizontal direction, in which two or more steel framed beams are joined to one surface facing a direction along a horizontal plane. Alternatively, the wall means a structure that extends in each of the up-down direction and the horizontal direction, in which a width of the wall is twice or more a thickness of the wall in a plan view.

[0011]

In this disclosure, as a result of examinations in which a number of case studies are performed, the inventors examined conditions for suppressing a failure in the wall of the RC structure in the joint structure of the joint portion where the wall of the RC structure and the end portion of the composite beam are joined. As a result, in a case where the wall includes the wall concrete and the composite beam includes the floor slab having the floor concrete and the plurality of reinforcing bars, and the steel framed beam, the following conditions were found. That is, the conditions are that the cross-sectional area ratio R_{Ar} of the plurality of reinforcing bars satisfies Formula (1) and the projected anchorage length ratio (L_h/d_r) satisfies Formula (2).

Therefore, by causing the cross-sectional area ratio R_{Ar} to satisfy Formula (1) and causing the projected anchorage length ratio (L_h/d_r) to satisfy Formula (2), in the joint structure, a failure in the wall of the RC structure due to three failure modes can be suppressed.

[0012]

(2) A second aspect of the present invention may be the joint structure according to (1), in which, in the joint portion, a diameter ratio R_{dr} of the plurality of reinforcing bars anchored to the wall concrete satisfies Formula (3).

Here, the diameter ratio R_{dr} of the plurality of reinforcing bars is a diameter of the plurality of reinforcing bars per unit length in the width direction (-).

[0013]

$$R_{dr} = \sum \left(\frac{d_{r,i}}{p_i} \cdot \frac{\sigma_{ry,i}}{\sigma_c} \right) \geq 1.570 \quad \cdot \cdot (3)$$

[0014]

In this disclosure, as a result of examinations in which a number of case studies are performed, the inventors examined conditions in which compression failure can be suppressed in the joint structure of the joint portion where the wall of the RC structure and the end portion of the composite beam are joined. As a result, it was found that when the diameter ratio R_{dr} of the plurality of reinforcing bars satisfies Formula (3), in the joint structure, stiffness and proof stress of the joint portion can be increased while suppressing a failure in the wall of the RC structure due to the three failure modes.

Therefore, by causing the diameter ratio R_{dr} of the plurality of reinforcing bars to satisfy Formula (3), deflection of the composite beam in the joint structure can be suppressed.

[0015]

(3) A third aspect of the present invention may be the joint structure according to (1) or (2), in which the plurality of reinforcing bars are anchored to the wall concrete over a region equal to or larger than an effective width in the joint portion of the floor slab.

In this disclosure, the wall is equal to or longer than the effective width in the width direction compared to a general column of a RC structure. Therefore, in the joint structure, while anchoring the plurality of reinforcing bars to the wall concrete up to an outermost edge within the effective width that contributes to the stiffness and proof stress of the joint portion, a failure that may occur in the joint structure with the column of the RC structure, that is, cracking of concrete (of a cover portion) on sides of the anchored bar (reinforcing bar) in the wall concrete toward the outside in the width direction can be suppressed.

[0016]

(4) A fourth aspect of the present invention may be the joint structure according to any one of (1) to (3), in which the diameter-increasing portion extends downward from an end portion of the composite beam on a wall side in the reinforcing bar main body.

In this disclosure, the reinforcing bars can be appropriately anchored to the wall by only bending without performing special processing for mechanical anchorage on the reinforcing bars, thereby achieving a joint structure with good workability at a low cost.

[0017]

(5) A fifth aspect of the present invention may be the joint structure according to any one of (1) to (4), including: a shear plate joined to the wall; and a bolt that joins a web of the steel framed beam that is H-section steel and the shear plate to each other, in which a bolt hole which is formed in the web or the shear plate or combination thereof and through which the bolt passes has an elongated hole shape extending in the longitudinal direction.

[0018]

For example, a case where a pair of flanges of the steel framed beam are disposed to face each other in the up-down direction will be described. In a case where a lower flange at the end portion of the composite beam that supports a vertical load is joined to the wall concrete by a contact plate described later, welded joint, or the like so that a compressive force can be transmitted, an end portion of the steel framed beam rotates about a lower end (lower flange) thereof. Therefore, a bolt that is further away from the lower end, which is a center of rotation, has a larger movement amount in the longitudinal direction. When the bolt comes into contact with an opening circumferential edge portion of the bolt hole in the web or the like, a bearing force is transmitted. In general, a bolt hole diameter is slightly larger than a bolt shaft diameter. Therefore, in a case where rotation of the joint portion is small or in a case of a bolt located near the center of rotation, a bearing stress state is not immediately incurred due to a clearance between the bolt hole diameter and the bolt shaft diameter, and no bearing force is transmitted.

[0019]

However, when the rotation of the joint portion increases, the bolt that is farther from the lower end, which is the center of rotation, has a larger movement amount in the bolt due to the rotation with respect to a magnitude of the clearance, a bearing stress is likely to occur in the bolt. In the rotation about the lower end (lower flange) of the end portion of the steel framed beam, as the bolt is farther from the lower end which is the center of rotation, a bearing force is generated in a direction in which the shear plate is pulled out from the wall concrete. The shear plate is fixed to the wall concrete with an anchorage reinforcing bar, a headed stud, or the like. However, when a pull-out force of the anchorage reinforcing bar or the headed stud acts due to bearing force, a combined force with the pull-out force of the bent and anchored bar acts on the

wall concrete, and as a result, the wall concrete is more likely to fail, and a load-bearing capacity of the joint portion is more likely to be lost.

[0020]

In this disclosure, since the bolt hole has an elongated hole shape extending in the longitudinal direction, the clearance between the bolt hole diameter and the bolt shaft (shaft portion) diameter is large, and even when the composite beam receives a bending moment and the steel framed beam moves relative to the shear plate, the bolts move in the longitudinal direction in the bolt hole.

Therefore, even when the bolt moves with respect to the wall concrete, the bolt hole and the bolt shaft do not enter a bearing stress state. Therefore, pulling-out acting on the anchorage reinforcing bar and the headed stud for joining the shear plate to the wall due to the bearing force of the bolt is suppressed, and a failure in the wall concrete can be prevented.

In particular, in a case where an external force equal to or more than expected by design acts on a building due to some kind of accident, there is a concern that excessive rotation of the joint portion occurs. Even in such a case, it is possible to prevent combined tensile forces from acting on the wall concrete and prevent the wall concrete from being failed.

[0021]

(6) A sixth aspect of the present invention may be the joint structure according to any one of (1) to (5), including: a shear plate joined to the wall; and a bolt that joins a web of the steel framed beam that is H-section steel and the shear plate to each other, in which a bolt hole through which the bolt passes is formed in the web or the shear plate or combination thereof, and an average position of the bolt hole in a height direction of the steel framed beam is located below a center of the steel framed beam in the height

direction.

In this disclosure, compared to a case where the average position (centroid) of the bolt holes in the height direction coincides with the center of the steel framed beam in the height direction, the bolt becomes closer to the lower flange, which is the center of rotation, as a whole. Therefore, it becomes difficult for the bolt to move with respect to the wall concrete when the composite beam receives a bending moment and the steel framed beam moves relative to the shear plate.

Therefore, even when the bolt moves with respect to the wall concrete, the bolt hole and the bolt shaft do not enter a bearing stress state, pulling-out acting on the anchorage reinforcing bar and the headed stud for joining the shear plate to the wall due to the bearing force of the bolt is suppressed, and a failure in the wall concrete can be prevented.

[Effects of the Invention]

[0022]

In the joint structure of the present invention, in the joint structure of the joint portion where the wall of the RC structure and the end portion of the composite beam are joined, a failure in the wall of the RC structure can be suppressed.

[Brief Description of the Drawings]

[0023]

FIG. 1 is a floor framing diagram of a building in which a joint structure according to an embodiment of the present invention is used.

FIG. 2 is a cross-sectional view taken along a cutting-plane line A1-A1 in FIG. 1.

FIG. 3 is a cross-sectional view taken along a cutting-plane line A2-A2 in FIG. 2.

FIG. 4 is an enlarged view of a main part of a shear plate of the building.

FIG. 5 is a cross-sectional view of a main part in a joint structure of a first modification example of the embodiment of the present invention.

FIG. 6 is a cross-sectional view of a main part in a joint structure of a second modification example of the embodiment of the present invention.

FIG. 7 is a cross-sectional view of a main part in a joint structure of a third modification example of the embodiment of the present invention.

FIG. 8 is a plan sectional view of the building for describing raking-out failure.

FIG. 9 is a side sectional view of the building for describing raking-out failure.

FIG. 10 is a side sectional view of the building for describing compression failure.

FIG. 11 is a plan sectional view of a building in which a column and an end portion of a composite beam are joined for describing side splitting failure.

FIG. 12 is a diagram showing an effect of suppressing a failure in a RC wall in a case where values of a cross-sectional area ratio R_{Ar} of a floor reinforcing bar and (L_h/d_r) are limited.

FIG. 13 is a diagram showing a relationship between a diameter ratio R_{dr} of the floor reinforcing bar and axial stiffness of a bent and anchored bar of a wall concrete in a case of a wall thickness of 400 mm.

FIG. 14 is a diagram showing a relationship between the diameter ratio R_{dr} of the floor reinforcing bar and the cross-sectional area ratio R_{Ar} of the floor reinforcing bar in the case of a wall thickness of 400 mm.

FIG. 15 is a diagram showing a relationship between the axial stiffness of the bent and anchored bar of the wall concrete and deflection of the composite beam 25.

FIG. 16 is a diagram showing the axial stiffness of the bent and anchored bar of

the wall concrete with respect to the cross-sectional area ratio R_{Ar} of the floor reinforcing bar.

[Embodiments of the Invention]

[0024]

Hereinafter, a building in which an embodiment of a joint structure according to the present invention is used will be described with reference to FIGS. 1 to 16.

[0025]

[1. Configuration of Building in Which Joint Structure Is Used]

As shown in FIGS. 1 and 2, a building 1 includes a core wall 10, a plurality of columns 20, and a composite beam 25. In FIG. 1, the composite beam 25 (a floor slab 28 described later) is indicated by a two-dot chain line.

The core wall 10 has an angular tubular shape. The core wall 10 has a pair of first walls (walls) 11 and a pair of second walls (walls) 12. The first wall 11 and the second wall 12 are each support members. The pair of first walls 11 and the pair of second walls 12 are each of a reinforced concrete (RC) structure.

[0026]

As shown in FIG. 2, the first wall 11 has a wall concrete 14, a plurality of wall reinforcing bars 15, a baseplate 16, and a plurality of headed studs 17.

The wall concrete 14 has a plate shape that is rectangular when viewed in a thickness direction of the wall concrete 14. The wall concrete 14 is disposed in a state in which the thickness direction of the wall concrete 14 is along a horizontal plane and the wall concrete 14 extends in an up-down direction Z. The term “a member extends in an A direction” as mentioned in this specification means that an angle between a direction in which the member extends and the A direction is 30 degrees or less. This angle is more preferably 15 degrees or less.

[0027]

The plurality of wall reinforcing bars 15 have a plurality of vertical bars 15a and a plurality of horizontal bars 15b. The plurality of vertical bars 15a and the plurality of horizontal bars 15b are embedded in the wall concrete 14. The plurality of vertical bars 15a are disposed separated from each other and extend in the up-down direction Z. The plurality of horizontal bars 15b extend along the horizontal plane and are disposed in contact with the plurality of vertical bars 15a, respectively.

[0028]

As shown in FIGS. 2 and 3, the baseplate 16 is disposed on an outer surface of the wall concrete 14. A main surface 16b of the baseplate 16 is exposed to the outside.

As shown in FIG. 2, the plurality of headed studs 17 are fixed to a main surface 16a of the baseplate 16. The main surface 16a is a surface facing an inside of the wall concrete 14. The plurality of headed studs 17 protrude from the baseplate 16 toward the inside of the wall concrete 14. The plurality of headed studs 17 are embedded in the wall concrete 14.

As shown in FIG. 1, the pair of first walls 11 face each other in a direction along the horizontal plane.

[0029]

As shown in FIG. 2, the main surface 16b of the baseplate 16 is a surface of the baseplate 16 opposite to the main surface 16a. A shear plate 18 is joined to the main surface 16b by welding or the like. The shear plate 18 is joined to the first wall 11.

In the shear plate 18, bolt holes 18a shown in FIG. 4 are formed. The bolt hole 18a has an elongated hole shape extending in a longitudinal direction X of a second steel framed beam 27, which will be described later, when viewed in a thickness direction of the shear plate 18. In the present embodiment, the longitudinal direction

X is a direction along the horizontal plane. However, the longitudinal direction X may also be a direction inclined with respect to the horizontal plane.

In the shear plate 18, a plurality of the bolt holes 18a are formed. The plurality of bolt holes 18a are disposed side by side in a state of being separated from each other in the up-down direction Z.

The number of the bolt holes 18a formed in the shear plate 18 may also be one.
[0030]

As shown in FIG. 1, the pair of second walls 12 are configured similarly to the pair of first walls 11.

The second wall 12 is disposed in a state in which a thickness direction of the second wall 12 is along the horizontal plane and the second wall 12 extends in the up-down direction Z. The pair of second walls 12 face each other in a direction along the horizontal plane. The pair of second walls 12 connects end portions of each of the first walls 11 in a width direction.

In a space inside the core wall 10, an elevator shaft (not shown), a stair hall, or the like is disposed.

[0031]

The column 20 extends along the up-down direction Z. The plurality of columns 20 are disposed around the core wall 10 at positions separated from the core wall 10 while being at intervals from each other. For example, the column 20 is of an RC structure. The column may be made of steel, of a steel reinforced concrete (SRC) structure, of a concrete-filled steel tube (CFT) structure, or the like.

[0032]

As shown in FIGS. 1 and 2, the composite beam 25 includes a plurality of first steel framed beams (steel framed beams) 26, a plurality of second steel framed beams

(steel framed beams) 27, and the floor slab 28.

For example, the first steel framed beam 26 and the second steel framed beam 27 are each H-section steel made of steel. The first steel framed beam 26 and the second steel framed beam 27 may not be H-section steel, and may be, for example, T-section steel.

[0033]

The first steel framed beam 26 is spanned across between the core wall 10 and the column 20 adjacent to each other and between the columns 20 adjacent to each other, and extends in a direction along the horizontal plane which is a longitudinal direction of the first steel framed beam 26. The second steel framed beam 27 is spanned across between the core wall 10 and the first steel framed beam 26 adjacent to each other and between the first steel framed beams 26 adjacent to each other, and extends in the longitudinal direction X.

Hereinafter, in the longitudinal direction X, a first wall 11 side with respect to the composite beam 25 is referred to as a first side X1. In the longitudinal direction X, a composite beam 25 side with respect to the first wall 11 is referred to as a second side X2.

Since configurations of the first steel framed beam 26 and the second steel framed beam 27 are the same as each other, the second steel framed beam 27 will be described below as an example.

[0034]

As shown in FIGS. 2 and 3, the second steel framed beam 27 includes a first flange 31, a second flange 32, and a web 33. The first flange 31 and the second flange 32 are each disposed along the horizontal plane and face each other in the up-down direction Z. In the following, a direction orthogonal to the up-down direction Z and

the longitudinal direction X will be referred to as a width direction Y.

The first flange 31 is disposed above the second flange 32.

The web 33 is disposed between the first flange 31 and the second flange 32.

The web 33 joins a center of the first flange 31 in the width direction and a center of the second flange 32 in the width direction to each other.

As shown in FIG. 4, a plurality of bolt holes 33a are formed in each end portion of the web 33 in the longitudinal direction X (only one bolt hole 33a is shown in FIG. 4). For example, the bolt hole 33a has a circular shape when viewed in a thickness direction of the web 33. The plurality of bolt holes 33a are disposed side by side in a state of being separated from each other in the up-down direction Z.

The number of bolt holes 33a formed in the web 33 may also be one.

[0035]

As shown in FIGS. 2 and 3, the floor slab 28 has a deck plate 36, a floor concrete 37, a plurality of floor reinforcing bars (reinforcing bars) 38, and a plurality of connecting reinforcing bars 39.

The deck plate 36 is formed by bending a steel plate or the like. The deck plate 36 is disposed on the first flange 31 of the second steel framed beam 27.

The floor concrete 37 is formed in a flat plate shape and is disposed on the deck plate 36. The plurality of floor reinforcing bars 38 include a plurality of first floor reinforcing bars 42 and a plurality of second floor reinforcing bars 43.

[0036]

For example, the first floor reinforcing bar 42 is formed by bending a reinforcing bar. The first floor reinforcing bars 42 are embedded in the floor concrete 37 and the wall concrete 14. The first floor reinforcing bar 42 has a reinforcing bar main body 42a and a bent portion (diameter-increasing portion) 42b.

For example, the reinforcing bar main body 42a is formed in a columnar shape. The reinforcing bar main body 42a extends in the longitudinal direction X in the floor concrete 37 and the wall concrete 14.

Here, a diameter (length in a radial direction) of the reinforcing bar main body 42a means a nominal diameter of the reinforcing bar main body 42a. For example, in the case of deformed steel bars D10, D13, and D16 of steel bars for concrete reinforcement according to JIS G 3112, nominal diameters are 10 mm, 13 mm, and 16 mm, respectively.

[0037]

The bent portion 42b extends downward from an end portion of the reinforcing bar main body 42a on the first side X1. The bent portion 42b is embedded in the wall concrete 14. That is, the wall concrete 14 is disposed on each of the first side X1 and the second side X2 of the bent portion 42b.

A dimension L_v of the bent portion 42b projected in the up-down direction Z (a length of the bent portion 42b in the radial direction of the reinforcing bar main body 42a) is larger than the diameter of the reinforcing bar main body 42a. The dimension L_v is preferably a maximum length of the bent portion 42b in the radial direction of the reinforcing bar main body 42a. The dimension L_v of the bent portion 42b projected in the up-down direction Z is preferably 12 times or more the diameter of the reinforcing bar main body 42a.

[0038]

In addition, the diameter-increasing portion may be configured not only to have a width (dimension L_v of the bent portion 42b projected in the up-down direction Z) that is larger in the up-down direction Z than the diameter of the reinforcing bar main body 42a, but also to have a width (dimension of the bent portion 42b projected in the width

direction Y) that is larger in the width direction Y than the diameter of the reinforcing bar main body 42a.

The first floor reinforcing bar 42 is bent in a reference plane (XZ plane) parallel to each of the longitudinal direction X and the up-down direction Z. In this case, in the first floor reinforcing bar 42, an angle at which the bent portion 42b is bent with respect to the reinforcing bar main body 42a is about 90°.

[0039]

The second floor reinforcing bar 43 is configured similarly to the first floor reinforcing bar 42. The second floor reinforcing bar 43 has a reinforcing bar main body 43a and a bent portion 43b.

The reinforcing bar main body 43a extends in the longitudinal direction X. The reinforcing bar main body 43a is disposed below the reinforcing bar main body 42a.

The bent portion 43b extends downward from an end portion of the reinforcing bar main body 43a on the first side X1. The bent portion 43b is embedded in the wall concrete 14.

[0040]

A lower end of the bent portion 43b and a lower end of the bent portion 42b are at the same position in the up-down direction Z.

A dimension of the bent portion 43b projected in the up-down direction Z is defined in the same manner as the dimension L_v of the bent portion 42b and is larger than a diameter of the reinforcing bar main body 43a. The lower end of the bent portion 43b and the lower end of the bent portion 42b may be disposed at different positions in the up-down direction Z.

[0041]

The reinforcing bar main bodies 42a of the plurality of first floor reinforcing bars 42 are disposed at the same height in the up-down direction Z. The reinforcing bar main bodies 43a of the plurality of second floor reinforcing bars 43 are disposed at the same height in the up-down direction Z and below the plurality of reinforcing bar main bodies 42a.

As described above, the reinforcing bar main bodies 42a of the plurality of first floor reinforcing bars 42 constitute a first layer 38₁ of the floor reinforcing bars 38 from above. The reinforcing bar main bodies 43a of the plurality of second floor reinforcing bars 43 constitute a second layer 38₂ of the second floor reinforcing bar 38 from above. In the present embodiment, the number of layers of the floor reinforcing bars 38 arranged in the floor concrete 37 is two. The number of layers of the floor reinforcing bars 38 arranged in the floor concrete 37 is not limited.

[0042]

The reinforcing bar main body 42a of the plurality of first floor reinforcing bars 42 and the reinforcing bar main body 43a of the plurality of second floor reinforcing bars 43 are divided into a wall concrete 14 side and a floor concrete 37 side, and these may be integrated at a boundary between the wall concrete 14 and the floor concrete 37 using a screw type or grout injection type coupler.

[0043]

The connecting reinforcing bar 39 extends in the width direction Y. Connecting reinforcing bars 39₁, which are a part of the plurality of connecting reinforcing bars 39, are in contact with the reinforcing bar main bodies 42a of the plurality of first floor reinforcing bars 42. The connecting reinforcing bars 39₁ may be fixed to the reinforcing bar main bodies 42a of the plurality of first floor reinforcing bars 42 by annealed wires or by welding.

Connecting reinforcing bars 39₂, which are a remainder of the plurality of connecting reinforcing bars 39, are in contact with the reinforcing bar main bodies 43a of the plurality of second floor reinforcing bars 43.

It is sufficient that the connecting reinforcing bars 39₁ are in contact with the reinforcing bar main bodies 42a and the connecting reinforcing bars 39₂ are in contact with the reinforcing bar main bodies 43a.

[0044]

The floor slab 28 may not have the deck plate 36 and the plurality of connecting reinforcing bars 39. The number of floor reinforcing bars 38 included in the floor slab 28 may be one. In this case, the number of layers of the floor reinforcing bars 38 arranged in the floor concrete 37 is one.

[0045]

A plurality of headed studs (shear connectors) 46 are fixed to the first flange 31 of the second steel framed beam 27. The plurality of headed studs 46 are disposed at intervals in the longitudinal direction X and the width direction Y. The plurality of headed studs 46 are embedded in the floor concrete 37 through the deck plate 36 of the floor slab 28.

As described above, the second steel framed beam 27 is discretely joined to the floor slab 28 in the longitudinal direction X by the plurality of headed studs 46.

The shear connector may be a welded part at which the first flange 31 of the second steel framed beam 27 and the deck plate 36 are continuously welded in the longitudinal direction X. In this case, the second steel framed beam 27 is continuously joined to the floor slab 28 in the longitudinal direction X by the welded part.

[0046]

As shown in FIG. 2, the second flange 32 of the second steel framed beam 27

and the baseplate 16 of the first wall 11 are joined to each other through a contact plate 47 by welding, metal touch, or the like.

The plurality of floor reinforcing bars 38 are anchored to the wall concrete 14 over a region equal to or larger than an effective width (indicated as B_{eff} in FIG. 3) in the width direction Y at a joint portion 51 where the first wall 11 and an end portion of the composite beam 25 are joined. The effective width mentioned here is defined in Non-Patent Documents 1 and 2 below, and the like.

Non-Patent Document 1: “Eurocode 4: Design of composite steel and concrete structures - Part 1-1: General rules and rules for buildings”, December 2004, Authority: The European Union Per Regulation 305/2011, Directive 98/34/EC, Directive 2004/18/EC

Non-Patent Document 2: Edited by Architectural Institute of Japan, “Design Recommendations for Composite Constructions”, November 2010

[0047]

Specifically, the effective width B_{eff} of Non-Patent Document 1 is obtained by Formula (5-3) using Formulas (5-1) and (5-2).

[0048]

$$L_e = 0.15L \sim 0.25L \quad \cdot \cdot (5-1)$$

$$b_{eff,i} = \min \left(\frac{L_e}{8}, b_g \right) \quad \cdot \cdot (5-2)$$

$$B_{eff} = b_0 + \sum b_{eff,i} \quad \cdot \cdot (5-3)$$

[0049]

Here, L is a length of the second steel framed beam 27. L_e is a length of a

hogging bending region (a region where the second flange (lower flange) 32 of the second steel framed beam 27 is under compression) on a side in contact with the joint portion 51 in the longitudinal direction X of the second steel framed beam 27. In the case of the semi-rigid joint, as shown in Formula (5-1), the length L_e is about 0.15 times or more and 0.25 times or less the length L of the second steel framed beam 27.

[0050]

b_g is an interval in the width direction of the first flange 31 of the second steel framed beam 27 between a position of a core of the headed stud (shear connector) 46 on the second steel framed beam 27 and a position of a core of the headed stud (shear connector) 46 on either the adjacent first steel framed beam 26 or the adjacent second steel framed beam 27, whichever is closer. In a case where two or more rows of the headed studs 46 are disposed in the width direction, b_g is an interval between positions of cores of the innermost headed studs 46 in the width direction (the cores of the headed studs 46 are taken so that b_g is minimized).

Even in a case where the shear connector is other than the headed stud, the effective width can be obtained by the same procedure with reference to a centroid of the shear connector in the width direction.

[0051]

b_0 is an interval between the headed studs 46 installed in first flange 31 of the composite beam 25, in the width direction of the first flange 31 of the second steel framed beam 27. In a case where the headed studs 46 are arranged in one row, the interval b_0 is set to 0.

$b_{\text{eff},i}$ is an effective width of the composite beam 25 per one side of the floor slab 28. The one side means one side of both sides divided by an axis of the second steel framed beam 27 as a boundary in the width direction of the first flange 31. In a

case of a slab on both sides (the floor slab 28 extends to both sides), $i = 2$ is set, and in a case of a slab on one side (the floor slab 28 extends to only one side), $i = 1$ is set.

As a unit of the length L or the like, an SI unit or the like is used.

[0052]

As shown in FIGS. 3 and 4, the web 33 of the second steel framed beam 27 and the shear plate 18 are joined to each other by bolts 48 and nuts 49. More specifically, a shaft portion 48a of the bolt 48 is passed through each of the bolt hole 18a of the shear plate 18 and the bolt hole 33a of the web 33 of the second steel framed beam 27. A head portion 48b of a bolt 48 is locked to the shear plate 18 from a side opposite to the web 33.

[0053]

The nut 49 is locked to the web 33 from a side opposite to the shear plate 18. The nut 49 is fitted to the shaft portion 48a of the bolt 48. The shear plate 18 and a web 33 are interposed between the head portion 48b of the bolt 48 and the nut 49. A washer, although not shown, is interposed between the nut 49 and the web 33, and between the head portion 48b of the bolt 48 and the shear plate 18.

Of the bolt hole 18a of the shear plate 18 and the bolt hole 33a of the web 33, the bolt hole 18a is set to have an elongated hole shape. However, only the bolt hole 33a may have an elongated hole shape, or the bolt hole 18a and the bolt hole 33a may have an elongated hole shape.

[0054]

As described above, the second steel framed beam 27 supports the floor slab 28 from below the floor slab 28. The first steel framed beam 26 supports the floor slab 28 from below the floor slab 28, similarly to the second steel framed beam 27.

In general, a length of the first wall 11 in the width direction Y is larger than a

length of the column in the width direction Y.

[0055]

As shown in FIGS. 2 and 3, a joint structure 52 of a joint portion 51 where the first wall 11 and an end portion of the composite beam 25 are joined is configured as described above.

As shown in FIG. 1, similarly to the first wall 11, for the second wall 12, a joint structure 55 of a joint portion 54 where the second wall 12 and the end portion of the composite beam 25 are joined is configured.

The floor slab 28 may be a slab used for a roof (roof slab).

In addition, it is preferable that an upper end of the first wall 11 extends upward from an upper end of the composite beam 25. A length of the first wall 11 extending upward beyond the composite beam 25 is preferably equal to or more than a projected anchorage length (L_h).

[0056]

In FIG. 2, a displacement of the second steel framed beam 27 when a bending moment acts on the composite beam 25 due to a vertical load or the like is indicated by a two-dot chain line. In this case, an end portion of the second steel framed beam 27 in the longitudinal direction X rotates about a lower end thereof.

At this time, a tensile force acts on the floor reinforcing bar 38 in the longitudinal direction X of the second steel framed beam 27. The second flange 32 of the second steel framed beam 27 compresses the baseplate 16 via the contact plate 47.

[0057]

The configuration of the first floor reinforcing bar 42 can be modified as follows.

As shown in FIG. 5, the first floor reinforcing bar 65 may include a reinforcing

bar main body 66 and a diameter-increasing portion 67. The diameter-increasing portion 67 is formed in an annular shape and is provided at an end portion of the reinforcing bar main body 66 on the first side X1. The diameter-increasing portion 67 is anchored to the wall concrete 14 of the first wall 11. The reinforcing bar main body 66 is configured by providing annular second diameter-increasing portions 66b on an outer surface of a straight portion 66a extending in the longitudinal direction X. The diameter-increasing portion 67 may not be provided at the end portion of the reinforcing bar main body 66 but may be provided at a middle portion of the reinforcing bar main body 66 as long as the diameter-increasing portion 67 is anchored to the wall concrete 14.

For example, the first floor reinforcing bar 65 is formed of a deformed reinforcing bar. The diameter-increasing portion 67 is formed by a high-frequency induction heating method or rolling in a state in which an axial compressive force is applied to the reinforcing bar main body 66.

[0058]

As shown in FIG. 6, the first floor reinforcing bar 70 may include the reinforcing bar main body 42a and a diameter-increasing portion 71. The diameter-increasing portion 71 is formed in a circular or rectangular plate shape. The diameter-increasing portion 71 is disposed coaxially with the reinforcing bar main body 42a at the end portion of the reinforcing bar main body 42a. The diameter-increasing portion 71 may be formed by joining a component different from the reinforcing bar main body 42a by welding or the like, or by a high-frequency induction heating method or rolling in a state in which an axial compressive force is applied to the reinforcing bar main body 42a. It is preferable that a dimension L_v of the diameter-increasing portion 71 projected in the up-down direction Z is 11 times or more the diameter of the reinforcing

bar main body 42a.

[0059]

As in a first floor reinforcing bar 75 shown in FIG. 7, an angle θ at which a bent portion (diameter-increasing portion) 42c is bent with respect to the reinforcing bar main body 42a may be more than about 90° and may be 180° or less. In this case, the first floor reinforcing bar 75 is preferably bent on the reference plane (XZ plane) parallel to each of the longitudinal direction X and the up-down direction Z.

Even with the first floor reinforcing bars 65, 70, and 75, the same effect as that of the first floor reinforcing bar 42 of the present embodiment can be exhibited.

Regardless of the angle θ , a radius of an inside of the bent portion 42c is preferably set to three times or more a diameter of a floor reinforcing bar that is bent. A length of a straight portion of the bent portion 42c is preferably set to four times or more the diameter of the floor reinforcing bar in a case where the angle θ is 180° , six times or more the diameter of the floor reinforcing bar in a case where the angle θ is 135° or more and less than 180° , and eight times or more the diameter of the floor reinforcing bar in a case where the angle θ is 90° or more and less than 135° .

[0060]

Next, the results of examination on suppression of raking-out failure, side splitting failure, and compression failure in the joint structure 52 configured as described above will be described.

[0061]

[2. Description of Raking-out failure, Side splitting failure, and Compression Failure of Joint Structure]

First, raking-out failure, side splitting failure, and compression failure will be described with reference to FIGS. 8 to 11. In FIGS. 8 to 11, configurations are

simplified and some indications are omitted.

As shown in FIGS. 8 and 9, the raking-out failure means to a failure in which the wall concrete 14 is raked out as a cone-shaped lump R10 toward the composite beam 25 side and the entire floor reinforcing bar 38 loses its proof stress.

[0062]

As shown in FIG. 10, the wall concrete 14 is present in an inner region R1 where the first floor reinforcing bar 42 is bent. The compression failure means a failure in which the wall concrete 14 in the region R1 undergoes bearing stress and cracks when the first floor reinforcing bar 42 is pulled in the longitudinal direction X of the second steel framed beam 27. When the first floor reinforcing bar 42 is pulled and moves as indicated by a two-dot chain line L1, the wall concrete 14 in the region R1 moves to a region R2. At this time, the wall concrete 14 in the region R2 undergoes bearing stress and cracks.

[0063]

On the other hand, a joint structure 60 of a comparative example shown in FIG. 11 will be described. The joint structure 60 is a joint structure of a joint portion 62 where a column 61 of the RC structure and an end portion of the composite beam 25 are joined.

The column 61 has a shorter length in the width direction Y than the first wall 11, and thus, when the first floor reinforcing bar 42 is pulled in the longitudinal direction X of the second steel framed beam 27, side splitting failure may occur in which a portion of the wall concrete 14 in a region R4 that serves as a side cover of the first floor reinforcing bar 42 splits toward a side (width direction Y) of the column 61. However, since the first wall 11 of the joint structure 52 of the present embodiment is larger in length in the width direction Y than the columns 61, the wall concrete 14 that

serves as a side cover does not easily split, and side splitting failure does not occur.

[0064]

[3. Examination on Suppression of Raking-out failure, Side Splitting Failure, and Compression Failure of Joint Structure]

[3.1. Conditions for Case Study]

The inventors conducted a case study (case study method) on Sample Nos. 1 to 30 shown in Tables 1 to 3 with different specifications of the joint structure. In Sample Nos. 1 to 30, the number of layers of the floor reinforcing bar 38 is two.

[0065]

[Table 1]

Sample No.	Design conditions				
	Thickness of first wall	Material		Horizontal bar of first wall	
		Design strength of wall concrete	Design yield strength of floor reinforcing bar, $\sigma_{ry/i}$	Diameter	Pitch in up-down direction
	mm	N/mm ²	N/mm ²	mm	mm
1	400	30	550	13	200
2	400	35	550	13	200
3	400	40	550	13	200
4	400	45	550	13	200
5	400	50	550	13	200
6	400	55	550	13	200
7	400	60	550	13	200
8	400	65	550	13	200
9	400	70	550	13	200
10	350	30	550	13	200
11	350	50	550	13	200
12	350	70	550	13	200
13	300	30	550	13	200
14	300	50	550	13	200
15	300	70	550	13	200
16	400	55	550	13	200
17	400	55	550	13	200
18	400	55	550	13	200
19	400	55	550	13	200
20	400	55	550	13	200
21	400	55	550	13	200
22	400	55	550	13	200
23	400	55	550	13	200
24	400	55	550	13	200
25	400	55	550	13	200
26	400	55	550	13	200
27	400	55	550	13	200
28	400	55	550	13	200
29	400	55	550	13	200
30	400	55	550	13	200

[0066]

[Table 2]

Sample No.	Design conditions			
	First floor reinforcing bar			
	Diameter	Pitch	Projected anchorage length	Radius of inside of bend
	mm	mm	mm	mm
1	16	150	350	96
2	16	150	350	96
3	16	150	350	96
4	16	150	350	96
5	16	150	350	96
6	16	150	350	96
7	16	150	350	96
8	16	150	350	96
9	16	150	350	96
10	16	150	300	96
11	16	150	300	96
12	16	150	300	96
13	16	150	250	96
14	16	150	250	96
15	16	150	250	96
16	16	75	350	96
17	16	100	350	96
18	16	150	350	96
19	16	200	350	96
20	19	100	350	114
21	19	150	350	114
22	19	200	350	114
23	13	75	350	78
24	13	100	350	78
25	13	150	350	78
26	13	200	350	78
27	10	75	350	60
28	10	100	350	60
29	10	150	350	60
30	10	200	350	60

[0067]

[Table 3]

Sample No.	Design conditions			
	Second floor reinforcing bar			
	Diameter	Pitch	Projected anchorage length	Radius of inside of bend
	mm	mm	mm	mm
1	10	200	350	60
2	10	200	350	60
3	10	200	350	60
4	10	200	350	60
5	10	200	350	60
6	10	200	350	60
7	10	200	350	60
8	10	200	350	60
9	10	200	350	60
10	10	200	300	60
11	10	200	300	60
12	10	200	300	60
13	10	200	250	60
14	10	200	250	60
15	10	200	250	60
16	10	200	350	60
17	10	200	350	60
18	10	200	350	60
19	10	200	350	60
20	10	200	350	60
21	10	200	350	60
22	10	200	350	60
23	10	200	350	60
24	10	200	350	60
25	10	200	350	60
26	10	200	350	60
27	10	200	350	60
28	10	200	350	60
29	10	200	350	60
30	10	200	350	60

[0068]

For example, Sample No. 1 was designed under the following design

conditions.

A thickness of the first wall 11 is 400 mm. A design strength σ_c of the wall concrete 14 is 30 N/mm² (Newtons per square millimeter). A design yield strength $\sigma_{ry,i}$ of the floor reinforcing bar 38 is 550 N/mm². A diameter of the horizontal bar 15b of the first wall 11 is 13 mm. A pitch in the up-down direction Z is 200 mm.

[0069]

A diameter of the first floor reinforcing bar 42 is 16 mm. A pitch in the width direction Y is 150 mm. A projected anchorage length is 350 mm. The projected anchorage length mentioned here is a length in the longitudinal direction X of a portion of the first floor reinforcing bar 42 anchored to the wall concrete 14 (refer to the projected anchorage length L_h in FIG. 2). A bend is provided between the reinforcing bar main body 42a and the bent portion 42b in the first floor reinforcing bar 42. A radius of an inside of the bend is 96 mm. The radius of the inside of the bend was set to 6 times the diameter of the first floor reinforcing bar 42. Accordingly, compression failure was suppressed.

A diameter of the second floor reinforcing bar 43 is 10 mm. A pitch in the width direction Y is 200 mm. A projected anchorage length secures a cover thickness of 50 mm from the bent portions 42b and 43b to a surface of the wall 11, and is 350 mm. A radius of an inside of a bend is 60 mm.

[0070]

In addition, in Sample Nos. 1 to 30, the effective width B_{eff} was set to 1,050 mm. A bar arrangement region of the floor reinforcing bar 38 is set to be 1,050 mm or more and less than or equal to a control width of the second steel framed beam 27.

A design yield strength of the first floor reinforcing bar 42 and the second floor reinforcing bar 43 is 550 N/mm², and a design tensile strength is 650 N/mm².

[0071]

In Sample Nos. 1 to 30, it was determined that raking-out failure occurs when a raking-out failure proof stress according to Non-Patent Document 3 below is smaller than a tensile yield proof stress of a reinforcing bar within a slab effective width according to Non-Patent Document 1. That is, it was determined to be a failure mode that provides a minimum proof stress out of raking-out failure and tensile yielding. It was determined that side splitting failure occurs when a proof stress of a bent and anchored portion according to Non-Patent Document 4 below is smaller than the tensile yield proof stress of the reinforcing bar within the slab effective width according to Non-Patent Document 1. Compression failure can be prevented according to Non-Patent Document 4 when a dimension of a bend satisfies regulations of Non-Patent Document 5.

[0072]

In Sample Nos. 1 to 30, the radius of the inside of the bend was set to 6 times the diameter of the first floor reinforcing bar 42 to satisfy the regulations of Non-Patent Document 5. In Non-Patent Document 4, the same proof stress formula is used regardless of the failure modes of side splitting failure and compression failure.

Non-Patent Document 3: Edited by Architectural Institute of Japan, “Design Guidelines for Earthquake Resistant Reinforced Concrete Buildings Based on Inelastic Displacement Concept”, September 2001

Non-Patent Document 4: Fujii et al., “Re-evaluation of Test Data on 90 Degree Bent Bar Anchorage”, Journal of Structural and Construction Engineering (Transactions of AIJ), Volume 429, November 1991

Non-Patent Document 5: Edited by Architectural Institute of Japan, “Japanese Architectural Standard Specification for Reinforced Concrete Work JASS5”, July 2018

For each of Sample Nos. 1 to 30, various parameters were examined. The results will be described below.

[0073]

[3.2. Conditions for Suppressing Raking-out Failure]

A cross-sectional area ratio R_{Ar} of the floor reinforcing bar obtained by Formula (6) and a projected anchorage length ratio (L_h/d_r) obtained by Formula (7) were examined. The cross-sectional area ratio R_{Ar} of the floor reinforcing bar is a cross-sectional area ratio of the floor reinforcing bar 38 per unit length in the width direction Y of the floor slab 28 weighted by a strength ratio of the floor reinforcing bar and the wall concrete.

[0074]

$$R_{Ar} = \sum \left(\frac{a_{r,i}}{p_i} \cdot \frac{\sigma_{ry,i}}{\sigma_c} \right) \cdot \cdot (6)$$

$$L_h/d_r = \min \left(\frac{L_{h,i}}{d_{r,i}} \right) \cdot \cdot (7)$$

[0075]

Here, i is the number of the layers 38₁ and 38₂ of the floor reinforcing bar 38 that are arranged in the floor concrete 37. i is a natural number. In this example, i is 2. The cross-sectional area ratio R_{Ar} of the floor reinforcing bar is set to a value obtained by adding values of $((a_{r,i}/p_i) \cdot (\sigma_{ry,i}/\sigma_c))$ for all the layers 38₁ and 38₂.

$a_{r,i}$ is a cross-sectional area (mm²) of each floor reinforcing bar 38, which is orthogonal to the longitudinal direction X of the floor reinforcing bar 38, in an i-th layer 38_i, which is an i-th layer from the top. In a case where the i-th layer 38_i has a plurality of types of floor reinforcing bars 38 having different cross-sectional areas, the cross-sectional area is an average value of the cross-sectional areas of the floor

reinforcing bars 38 in the i-th layer 38_i.

p_i (for p_1 and p_2 , see FIG. 3) is a pitch (mm) in the width direction Y of the floor slab 28 between the floor reinforcing bars 38 in the i-th layer 38_i. $\sigma_{ry,i}$ is a design yield stress (N/mm²) of the floor reinforcing bar 38 in the i-th layer 38_i. σ_c is a compressive strength (N/mm²) of the wall concrete 14. $\sigma_{ry,i}$ is 550 N/mm².

[0076]

$L_{h,i}$ (mm) is a projected anchorage length of each floor reinforcing bar 38 in the i-th layer 38_i. In a case where the composite beam 25 has one layer, the projected anchorage length L_h (mm) is the projected anchorage length of the layer. $d_{r,i}$ is a diameter (mm) of each floor reinforcing bar 38 in the i-th layer. In a case where the i-th layer 38_i has a plurality of types of floor reinforcing bars 38 having different cross-sectional areas, $d_{r,i}$ is, the diameter $d_{r,i}$ of the floor reinforcing bar is an average value of diameters of the floor reinforcing bars 38 in the i-th layer 38_i.

In a case where the composite beam 25 has a plurality of layers, the projected anchorage length ratio (L_h/d_r) is a minimum value of the projected anchorage length ratios ($L_{h,i}/d_{r,i}$) of each layer.

[0077]

FIG. 12 and Table 4 show trial calculation results.

In FIG. 12, a horizontal axis represents the cross-sectional area ratio R_{Ar} (mm²/mm) of the floor reinforcing bar. A vertical axis represents a value of the projected anchorage length ratio (L_h/d_r).

[0078]

[Table 4]

Sample No.	Values of Formulas (6) to (14)					Axial stiffness k_r of floor reinforcing bar	Reduction ratio of deflection of rigid beam (magnitude of deflection with respect to pinned joint)	Comparative Example or Example
	Cross-sectional area ratio of floor reinforcing bar	Diameter of floor reinforcing bar	L_h/d_r					
	R_{Ar}	R_{dr}	First floor reinforcing bar	Second floor reinforcing bar	Minimum value of first and second floor reinforcing bars			
	mm ² /mm	mm/mm	-	-	-	kN/mm	-	
1	31.77	2.872	21.875	35	21.875	585.8	60%	Comparative Example
2	27.23	2.462	21.875	35	21.875	585.8	60%	Example
3	23.83	2.154	21.875	35	21.875	585.8	60%	Example
4	21.18	1.915	21.875	35	21.875	585.8	60%	Example
5	19.06	1.723	21.875	35	21.875	585.8	60%	Example
6	17.33	1.567	21.875	35	21.875	585.8	60%	Example
7	15.89	1.436	21.875	35	21.875	585.8	60%	Example
8	14.66	1.326	21.875	35	21.875	585.8	60%	Example
9	13.62	1.231	21.875	35	21.875	585.8	60%	Example
10	31.77	2.872	18.750	30	18.750	683.4	57%	Comparative Example
11	19.06	1.723	18.750	30	18.750	683.4	57%	Example
12	13.62	1.231	18.750	30	18.750	683.4	57%	Example
13	31.77	2.872	15.625	25	15.625	820.1	54%	Comparative Example
14	19.06	1.723	15.625	25	15.625	820.1	54%	Example
15	13.62	1.231	15.625	25	15.625	820.1	54%	Example
16	30.74	2.633	21.875	35	21.875	1109.2	50%	Comparative Example
17	24.03	2.100	21.875	35	21.875	847.5	54%	Example
18	17.33	1.567	21.875	35	21.875	585.8	60%	Example
19	13.98	1.300	21.875	35	21.875	454.9	64%	Example
20	32.28	2.400	18.421	35	18.421	1142.6	49%	Comparative Example
21	22.83	1.767	18.421	35	18.421	773.6	55%	Example
22	18.10	1.450	18.421	35	18.421	589.1	60%	Example
23	21.62	2.233	26.923	35	26.923	775.6	55%	Example
24	17.20	1.800	26.923	35	26.923	602.9	59%	Example
25	12.78	1.367	26.923	35	26.923	430.1	65%	Example

26	10.56	1.150	26.923	35	26.923	343.7	69%	Example
27	14.40	1.833	35.000	35	35.000	511.1	62%	Example
28	11.78	1.500	35.000	35	35.000	408.9	66%	Example
29	9.16	1.167	35.000	35	35.000	306.7	71%	Example
30	7.85	1.000	35.000	35	35.000	255.6	74%	Example

[0079]

For example, in Sample No. 1, the cross-sectional area ratio R_{Ar} of the floor reinforcing bar is 31.77 mm²/mm. The value of (L_h/d_r) is 21.875.

In FIG. 12, samples determined to have no raking-out failure are marked with ○ (white circle) as “OK”. In FIG. 12, samples determined to have raking-out failure are marked with ● (solid circle) as “NG”.

From FIG. 12, it can be seen that when the cross-sectional area ratio R_{Ar} of the floor reinforcing bar is smaller than 30.70 and the value of (L_h/d_r) is larger than 15.600, it can be determined that no raking-out failure occurs. That is, it was found that raking-out failure in the joint structure 52 can be suppressed when the cross-sectional area ratio R_{Ar} of the floor reinforcing bar satisfies Formula (8) and the projected anchorage length ratio (L_h/d_r) satisfies Formula (9).

[0080]

$$R_{Ar} < 30.70 \quad \cdot \cdot (8)$$

$$L_h/d_r > 15.600 \quad \cdot \cdot (9)$$

[0081]

[3.3. Conditions for Suppressing Compression Failure and Side Splitting Failure]

A diameter ratio R_{dr} of the floor reinforcing bar obtained by Formula (12) was examined.

[0082]

$$R_{dr} = \sum \left(\frac{d_{r,i}}{p_i} \cdot \frac{\sigma_{ry,i}}{\sigma_c} \right) \quad \cdot \cdot (12)$$

[0083]

The diameter ratio R_{dr} of the floor reinforcing bar is a diameter of the floor reinforcing bar 38 per unit length in the width direction Y of the floor slab 28 (-). The unit length mentioned here is a pitch p_i (mm) in the width direction Y of the floor slab 28 between the floor reinforcing bars 38 of the i-th layer 38_i. In this example, since i is 2, the diameter ratio R_{dr} of the floor reinforcing bar is set to a value obtained by adding values of $((d_{r,i}/p_i) \cdot (\sigma_{ry,i}/\sigma_c))$ for all the layers 38₁ and 38₂.

FIGS. 13 and 14, and Table 4 show the trial calculation results. Here, from among Sample Nos. 1 to 30, the trial calculation results for a wall thickness of 400 mm are extracted and shown.

The wall thickness is kept constant is because the projected anchorage length ratio (L_h/d_r) changes as the wall thickness changes.

[0084]

In FIGS. 13 and 14, horizontal axes represent the diameter ratio R_{dr} (mm/mm) of the floor reinforcing bar. A vertical axis of FIG. 13 represents a value of an axial stiffness k_r of the floor reinforcing bar. A vertical axis of FIG. 14 represents a value of the cross-sectional area ratio R_{Ar} of the floor reinforcing bar.

The axial stiffness k_r can be calculated by Formulas (13-1) and (13-2) according to Non-Patent Document 1.

[0085]

$$k_r = \sum_i \frac{E_r \cdot \Sigma a_{r,i}}{l_{j,i}} \quad \cdot \cdot (13-1)$$

$$l_{j,i} = 3.6 \cdot \frac{L_{h,i}}{2} \quad \cdot \cdot (13-2)$$

[0086]

Here, E_r is a Young's modulus (N/mm²) of the reinforcing bar. $\Sigma a_{r,i}$ is a sum

(mm²) of cross-sectional areas $a_{r,i}$ (mm²) of the floor reinforcing bars 38 within an effective width of the i-th layer 38_i, and $l_{j,i}$ is an effective length (mm) of the floor reinforcing bar 38 in the i-th layer 38_i.

For example, as shown in Table 4, in Sample Nos. 1, the diameter ratio R_{dr} of the floor reinforcing bar is 2.872 mm/mm, and the axial stiffness k_r is 585.8 (kN/mm).

In FIG. 13 and FIG. 14, samples determined to have no compression failure as shown in FIG. 11 based on Non-Patent Document 4 regarding a column-beam joint portion are marked with ○. In FIGS. 13 and 14, samples determined to have compression failure as shown in FIG. 11 based on Non-Patent Document 4 regarding a column-beam joint portion are marked with ●. In FIGS. 13 and 14, samples determined to have raking-out failure as shown in FIGS. 8 and 9 based on Non-Patent Document 3 are marked with x.

[0087]

From FIGS. 13 and 14, it can be seen that in a case where the diameter ratio R_{dr} of the floor reinforcing bar is 1.57 or more, it can be determined that compression failure as shown in FIG. 11 occurs. However, the inventors confirmed through experiments that the type of failure as shown in FIG. 11 does not occur in a case where a portion of the region R4 that serves as the side cover is sufficiently large.

The side splitting failure in FIG. 11 occurs when the first floor reinforcing bar 42 is pulled as shown in FIG. 10 and moves as indicated by the two-dot chain line L1, and the portion of the region R4 that serves as the side cover of the first floor reinforcing bar 42 splits toward the side (width direction Y) of the column 61. However, it was found by the experiments that, in a case where the portion of the region R4 that serves as the side cover is sufficiently large, the first floor reinforcing bar 42 is restrained by the concrete of the region R4, so that the movement as indicated by the

two-dot chain line L1 is unlikely to occur.

[0088]

That is, in the joint structure 52 of the joint portion 51 where the first wall 11 and the end portion of the composite beam 25 are joined, and the joint structure 55 of the joint portion 54 where the second wall 12 and the end portion of the composite beam 25 are joined, which are targets of the present invention, compression failure and side splitting failure do not occur even in a case of a dense amount of reinforcing bars in which the diameter ratio R_{dr} of the floor reinforcing bar satisfies Formula (14).

On the other hand, as shown in FIG. 13, increasing the amount of the floor reinforcing bars 38 of the composite beam 25 anchored to the wall concrete 14, in other words, increasing R_{dr} improves the stiffness of the reinforcing bars that resist rotation of the joint portion 51 and the joint structure 52, thereby suppressing deflection of the composite beam 25. In a case where the diameter ratio R_{dr} of the floor reinforcing bar is 1.570 or more, the axial stiffness k_r is 400 kN/mm or more. The axial stiffness k_r is proportional to rotational stiffness of the joint portion 51. The deflection of the composite beam 25 decreases as the rotational stiffness increases.

[0089]

FIG. 15 shows a trial calculation example of a relationship between the axial stiffness k_r of the floor reinforcing bar and the deflection of the composite beam 25. This trial calculation example is based on conditions in which the first steel framed beam 26 or the second steel framed beam 27 is H-section steel having cross-sectional dimensions of 700 x 200 x 9 x 12 (beam height x flange width x web thickness x flange thickness, unit: mm), and a thickness of the floor slab 28 is 130 mm, a length of the composite beam 25 is 10 m, and the joint portions 51 at both ends of the composite beam 25 have the same rotational stiffness.

According to these conditions, a ratio of a deflection δ of a beam center of the composite beam 25 to a deflection δ_{pin} of the composite beam 25 supported by pinned joints at both ends can be reduced to approximately $\delta/\delta_{pin} = 2/3 = 66.7\%$ when the axial stiffness k_r is 400 kN/mm.

[0090]

In a case of other conditions, for example, in a case where the beam height is 1,200 mm and the beam length is 25 m, the ratio can be reduced to approximately $\delta/\delta_{pin} = 2/5 = 40\%$ when the axial stiffness k_r is 400 kN/mm. In a case where the beam height is 400 mm and the beam length is 8 m, the ratio can be reduced to approximately $\delta/\delta_{pin} = 4/5 = 80\%$ when the axial stiffness k_r is 400 kN/mm. With a smaller axial stiffness k_r , the effect of reducing the deflection decreases, and in a case where rolled H-section steel is used for the first steel framed beam 26 or the second steel framed beam 27, it becomes difficult to reduce a cross-sectional weight of the first steel framed beam 26 or the second steel framed beam 27 while maintaining the same deflection amount.

In other words, since the rolled H-section steel has limited options for cross-sectional dimensions, reducing the weight of the first steel framed beam 26 or the second steel framed beam 27 in a case where the axial stiffness k_r is less than 400 kN/mm results in a reduction in the cross-sectional weight that exceeds the deflection reduction effect, leading to an increase in deflection due to the weight reduction.

[0091]

From the above, when the axial stiffness k_r is 400 kN/mm or more, the effect as a semi-rigid joint is enhanced regardless of the conditions of the beam height and the beam length, and the deflection of the beam can be effectively suppressed. Accordingly, in a case where the first steel framed beam 26 or the second steel framed beam 27 is the rolled H-section steel, the cross-sectional dimensions can be reduced,

and a weight reduction is achieved, thereby saving materials and enabling economic design.

On the other hand, as the amount of the floor reinforcing bar 38 increases, as shown in FIG. 14, the above-mentioned raking-out failure is more likely to occur.

[0092]

Therefore, the stiffness of the joint portion 51 and the joint structure 52 is increased by satisfying Formula (14), and raking-out failure is prevented by satisfying Formulas (8) and (9). Accordingly, rotational resistance of the joint portion 51 and the joint structure 52 can be increased to the maximum within a safe range without failure in the joint portion 51 and the joint structure 52, the deflection of the composite beam 25 can be suppressed.

In FIG. 14, a region R11 is a region in which compression failure, side splitting failure, and raking-out failure do not occur in the case of the column-beam joint portion. A region R12 is a region in which compression failure and side splitting failure occur in the case of the column-beam joint portion and no failure occurs in a case of a wall-beam joint portion. A region R13 is a region in which raking-out failure occurs.

[0093]

$$R_{dr} \geq 1.570 \cdot \cdot (14)$$

[0094]

FIG. 16 shows a change in the axial stiffness k_r of the floor reinforcing bar with respect to the cross-sectional area ratio R_{Ar} of the floor reinforcing bar. In FIG. 16, the thickness of the first wall 11 was set to 400 mm.

In general, as the cross-sectional area ratio R_{Ar} of the floor reinforcing bar increases, the axial stiffness k_r of the floor reinforcing bar increases. When the cross-sectional area ratio R_{Ar} of the floor reinforcing bar is 13.0 or more, the axial stiffness k_r

exceeds 400 kN/mm. Therefore, as described above, the effect as the semi-rigid joint is enhanced, and the deflection of the beam can be effectively suppressed.

[0095]

[4. Effects of Present Embodiment]

As described above, in the joint structure 52 of the present embodiment, as a result of examinations in which a number of case studies are performed, the inventors examined conditions for suppressing raking-out failure in the joint structure 52 of the joint portion 51 where the first wall 11 of the RC structure and the end portion of the composite beam 25 are joined. As a result, in a case where the first wall 11 includes the wall concrete 14 and the composite beam 25 includes the floor slab 28 having the floor concrete 37 and the floor reinforcing bars 38, and the second steel framed beam 27, the following conditions were found. That is, the conditions are that the cross-sectional area ratio R_{Ar} of the reinforcing bar satisfies Formula (8) and the projected anchorage length ratio (L_h/d_r) of the reinforcing bar satisfies Formula (9).

Therefore, by causing the cross-sectional area ratio R_{Ar} to satisfy Formula (8) and causing the projected anchorage length ratio (L_h/d_r) to satisfy Formula (9), in the joint structure 52, a failure in the first wall 11 of the RC structure due to three failure modes, raking-out failure, side splitting failure, and local compression failure, can be suppressed.

[0096]

The diameter ratio R_{dr} of the floor reinforcing bar satisfies Formula (14). As a result of examinations in which a number of case studies are performed, the inventors experimentally confirmed characteristics of the joint structure 52 of the joint portion 51 where the first wall 11 and the end portion of the composite beam 25 are joined, in which compression failure that can occur in the column-beam joint portion does not

occur in the wall-beam joint portion, and examined conditions in which the stiffness of the joint portion can be improved by utilizing the characteristics. As a result, it was found that when the diameter ratio R_{dr} of the reinforcing bar satisfies Formula (14), in the joint structure 52, the stiffness and proof stress of the joint portion 51 can be increased while suppressing a failure in the first wall 11 of the RC structure due to the three failure modes.

Therefore, by causing the diameter ratio R_{dr} of the reinforcing bar to satisfy Formula (14), the deflection of the composite beam 25 in the joint structure 52 can be suppressed. Specifically, by causing the diameter ratio R_{dr} of the reinforcing bar to satisfy Formula (14), the axial stiffness k_r exceeds 400 kN/mm. Therefore, as described above, the effect as the semi-rigid joint is enhanced, and the deflection of the composite beam 25 can be effectively suppressed.

[0097]

The plurality of floor reinforcing bars 38 are anchored to the wall concrete 14 over a region equal to or larger than the effective width of the joint portion 51 of the floor slab 28. As a result, the stiffness of the floor reinforcing bar 38 of the joint portion 51 and the joint structure 52 calculated by Formula (14) can be increased, and the rotational resistance of the joint portion increases, so that the deflection of the composite beam 25 is suppressed. The first wall 11 is longer than the effective width in the width direction Y compared to a general column of a RC structure. Therefore, in the joint structure 52, while anchoring the plurality of floor reinforcing bars 38 to the wall concrete 14 up to an outermost edge within the effective width that contributes to the stiffness and proof stress of the joint portion 51, a failure that may occur in the joint structure 52 with the column of the RC structure, that is, cracking of concrete on sides of the plurality of floor reinforcing bars 38 in the wall concrete 14 toward the outside in

the width direction Y can be suppressed.

[0098]

The bent portion 42b extends downward from the end portion of the reinforcing bar main body 42a on the first wall 11 side with respect to the composite beam 25. Therefore, for example, when a downward load acts on the composite beam 25, a reaction force of a tensile force acting on the reinforcing bar main body 42a acts on the wall concrete 14 as a compressive force from an inner corner of the bent portion 42b. This reaction force is balanced with a compressive force acting on the wall concrete 14 from the second flange 32 of the composite beam 25, so that internal forces of the wall concrete 14 can be more stably maintained in equilibrium.

[0099]

The bolt hole 18a of the shear plate 18 has an elongated hole shape extending in the longitudinal direction X. In a case where the second flange 32 at the end portion of the composite beam 25 that supports a vertical load is joined to the wall concrete 14 by the contact plate 47, welded joint, or the like so that a compressive force can be transmitted, the end portion of the steel framed beam rotates about the lower end thereof when the composite beam 25 receives a bending moment. Therefore, the bolt that is further away from the lower end, which is a center of rotation, has a larger movement amount in the longitudinal direction, and applies a larger bearing stress (compressive force) to the wall concrete.

[0100]

In this disclosure, since the bolt hole 18a has an elongated hole shape extending in the longitudinal direction X, a clearance between the bolt hole 18a and the shaft portion 48a of the bolt 48 is large, and even when the composite beam 25 receives a bending moment and the second steel framed beam 27 moves relative to the shear

plate 18, the bolt 48 moves in the longitudinal direction X in the bolt hole 18a.

Therefore, even when the bolt 48 moves with respect to the wall concrete 14, the bolt hole 18a and the shaft portion 48a of the bolt 48 do not enter a bearing stress state, and no bearing force is applied to the shear plate 18 from the bolt 48. Therefore, pulling-out of anchorage reinforcing bars of the shear plate 18 and the headed studs 17 is suppressed, and a failure in the wall concrete 14 can be prevented.

[0101]

In addition, an average position of the plurality of bolt holes 18a in a height direction of the second steel framed beam 27 (a beam height direction of the second steel framed beam 27) may be located below a center of the second steel framed beam 27 in the height direction. In other words, centroids of the plurality of bolt holes 18a may be located below an axial center of the second steel framed beam 27.

With this configuration, compared to a case where the average position of the plurality of bolt holes 18a in the height direction coincides with the center of the second steel framed beam 27 in the height direction, it becomes difficult for the bolt 48 to move with respect to the wall concrete 14 when the composite beam 25 receives a bending moment and the second steel framed beam 27 moves relative to the shear plate 18.

Therefore, the amount of movement of the bolt 48 with respect to the wall concrete 14 is suppressed, and a bearing stress applied by the bolt 48 to the wall concrete 14 can be suppressed.

[0102]

While one embodiment of the present invention has been described in detail with reference to the drawings, specific configurations are not limited to the embodiment, and modifications, combinations, deletions, and the like in the configurations may be made without departing from the gist of the present invention.

For example, in the embodiment, the diameter ratio R_{dr} of the floor reinforcing bar does not have to satisfy Formula (14). The bolt hole 18a of the shear plate 18 may have a circular shape when viewed in the thickness direction of the shear plate 18. The floor reinforcing bars 38 (42, 43) and the connecting reinforcing bars 39 may be round steel or deformed reinforcing bars.

[Industrial Applicability]

[0103]

A joint structure can suppress anchorage failure in a wall of a RC structure in a joint structure of a joint portion where the wall of the RC structure and an end portion of a composite beam are joined. Therefore, great industrial applicability is achieved.

[Brief Description of the Reference Symbols]

[0104]

11: First wall (wall)

12: Second wall (wall)

14: Wall concrete

18: Shear plate

18a: Bolt hole

20: Column

25: Composite beam

26: First steel framed beam (steel framed beam)

27: Second steel framed beam (steel framed beam)

28: Floor slab

37: Floor concrete

38: Floor reinforcing bar (reinforcing bar)

38₁, 38₂: Layer

46: Headed stud (shear connector)

48: Bolt

42, 65, 70, 75: First floor reinforcing bar (reinforcing bar)

42a, 66: Reinforcing bar main body

42b, 42c: Bent portion (diameter-increasing portion)

43: Second floor reinforcing bar (reinforcing bar)

51, 54: Joint portion

52, 55: Joining structure

67, 71: Diameter-increasing portion

X: longitudinal direction

CLAIMS

1. A joint structure of a joint portion where a wall of a RC structure and an end portion of a composite beam are joined,

wherein the wall includes a wall concrete,

the composite beam includes a floor slab and a steel framed beam that supports the floor slab from below,

the floor slab includes a floor concrete, and a plurality of reinforcing bars embedded in the floor concrete and the wall concrete,

each of the plurality of reinforcing bars includes

a reinforcing bar main body extending in a longitudinal direction of the steel framed beam in the floor concrete and the wall concrete, and

a diameter-increasing portion that is embedded in the wall concrete and has a length of the diameter-increasing portion larger than a diameter of the reinforcing bar main body in a radial direction of the reinforcing bar main body,

the steel framed beam is discretely or continuously joined to the floor slab in the longitudinal direction by a shear connector,

a cross-sectional area ratio R_{Ar} of the plurality of reinforcing bars satisfies Formula (1), and

a projected anchorage length ratio (L_h/d_r) satisfies Formula (2),

where i is the number of layers of the plurality of reinforcing bars arranged in the floor concrete, $a_{r,i}$ is a cross-sectional area (mm^2) of each of the plurality of reinforcing bars, which is orthogonal to the longitudinal direction of the plurality of reinforcing bars, in an i -th layer, which is an i -th layer from top, p_i is a pitch (mm) in a width direction of the floor slab between the plurality of reinforcing bars in the i -th

layer, $\sigma_{ry,i}$ is a yield stress (N/mm²) of the plurality of reinforcing bars in the i-th layer, σ_c is a compressive strength (N/mm²) of the wall concrete, $L_{h,i}$ is a projected anchorage length (mm), which is a length in the longitudinal direction of a portion of the plurality of reinforcing bars in the i-th layer anchored to the wall concrete, and $d_{r,i}$ is a diameter (mm) of each of the plurality of reinforcing bars in the i-th layer.

$$R_{Ar} = \sum \left(\frac{a_{r,i}}{p_i} \cdot \frac{\sigma_{ry,i}}{\sigma_c} \right) < 30.70 \quad \cdot \cdot (1)$$

$$L_h/d_r = \min \left(\frac{L_{h,i}}{d_{r,i}} \right) > 15.600 \quad \cdot \cdot (2)$$

2. The joint structure according to claim 1,

wherein, in the joint portion, a diameter ratio R_{dr} of the plurality of reinforcing bars anchored to the wall concrete satisfies Formula (3),

where the diameter ratio R_{dr} of the plurality of reinforcing bars is a diameter of the plurality of reinforcing bars per unit length in the width direction (-).

$$R_{dr} = \sum \left(\frac{d_{r,i}}{p_i} \cdot \frac{\sigma_{ry,i}}{\sigma_c} \right) \geq 1.570 \quad \cdot \cdot (3)$$

3. The joint structure according to claim 1 or 2,

wherein the plurality of reinforcing bars are anchored to the wall concrete over a region equal to or larger than an effective width in the joint portion of the floor slab.

4. The joint structure according to claim 1 or 2,

wherein the diameter-increasing portion extends downward from an end portion of the composite beam on a wall side in the reinforcing bar main body.

5. The joint structure according to claim 1 or 2, comprising:

a shear plate joined to the wall; and

a bolt that joins a web of the steel framed beam that is H-section steel and the shear plate to each other,

wherein a bolt hole which is formed in the web or the shear plate or combination thereof and through which the bolt passes has an elongated hole shape extending in the longitudinal direction.

6. The joint structure according to claim 1 or 2, comprising:

a shear plate joined to the wall; and

a bolt that joins a web of the steel framed beam that is H-section steel and the shear plate to each other,

wherein a bolt hole through which the bolt passes is formed in the web or the shear plate or combination thereof, and

an average position of the bolt hole in a height direction of the steel framed beam is located below a center of the steel framed beam in the height direction.