the joint between the column and the beam, and a side view illustrating the stress distribution of the reaction force due to the bearing pressure resistance at an interface between the portion embedded in the column concrete of the steel beam and the column concrete.

Fig. 13B is a side view illustrating the model for calculating the resistance of the joint between the column and the beam, and a side view illustrating an effective region of the bearing pressure resistance stress obtained when the maximum reaction force due to the bearing pressure resistance at the interface between the concrete and the upper and lower flanges of the column in a portion embedded in the column concrete of a steel beam acts on the steel beam, the actual stress distribution, and conversion into the stress block.

Fig. 14 is a graph illustrating the relationship between the moment and the rotation angle at a column face position of the joint, and illustrates both an experimental result and a calculation result according to the present disclosure.

Fig. 15 is a graph illustrating comparison between an experimental result of the rotational rigidity of the joint against repeatedly acting a load and a calculation result according to the present disclosure.

Fig. 16 is a view illustrating a calculation result of a fixation degree α_{rig} according to the present disclosure.

Fig. 17 is a view illustrating a ratio between a generated moment $M_{j,Ed}$ of the joint calculated according to the present disclosure and resistance $M_{j,Rd}$ of the joint.

DESCRIPTION OF EMBODIMENTS

[0019] A column-beam joint structure according to an embodiment of the present disclosure will be described with reference to Figs. 1 and 2. In the following description of the drawings, the same or similar components are denoted by the same or similar reference numerals. However, a relation between a thickness and a plane size in the drawings, a ratio of thickness of each device and each member, etc. differ from actual ones. Accordingly, specific thicknesses and dimensions should be determined by taking the following description into consideration. A relationship or a ratio of mutual dimensions may differ among the drawings.

[0020] As illustrated in Figs. 1 and 2, the column-beam joint structure of the present embodiment is applied to a joint 14 between a column 10 and a beam 12. A vertical direction of a building is indicated by an arrow Z direction, and one side in a direction in which the beam 12 extends and one direction in a horizontal direction of the building are indicated by an arrow X direction. The arrow Z direction is a vertical direction in Fig. 1, and the arrow X direction is a horizontal direction in Fig. 1.

[0021] In the following description of the directions X, Y and Z, signs “positive (+)” and

embedded inside the slab 22. The stud 26B in the slab 22 connects the steel beam 20 and the slab 22. The joint reinforcement bar 28 is an additional member that acts as a "resistance element" against rotation when the beam end 24 rotates about the rotation center 24E.

[0034] In addition, the steel beam 20 includes a face bearing plate 30 formed in a rectangular plate shape whose thickness direction is the longitudinal direction of the steel beam 20. In the present embodiment, the two face bearing plates 30 are fixed respectively to the +Y direction side and the -Y direction side with the web 20C interposed therebetween at the same position in the longitudinal direction of the steel beam 20.

[0035] A dimension measured along the +Y direction of the face bearing plate 30 is set to a dimension within a range in which the face bearing plate 30 does not protrude from a region surrounded by the upper flange 20A, the lower flange 20B, and the web 20C to the +Y direction side or the -Y direction side. In a state where the steel beam 20 is embedded in the concrete 32 of the column 10, a surface of the face bearing plate 30 on a side opposite to an axial center side of the column 10 in the X direction is substantially flush with the outer surface of the column 10. The axial center side of the column 10 is the right side in Fig. 1, and the side opposite to the axial center side of the column 10 is a surface on an outer side of the column 10.

[0036] On the other hand, an inner surface 30A of the face bearing plate 30 located on the axial center side of the column 10 is in contact with the concrete 32 of the column 10.

[0037] As illustrated in Fig. 1, when a vertical load in the -Z direction acts on the steel beam 20, the steel beam 20 is rotated counterclockwise by φ_j in Fig. 1 about the rotation center 24E of the beam end 24 in an XZ plane, and the steel beam 20 displaced to a position of a steel beam 20a indicated by a broken line in Fig. 1.

[0038] Here, a first shaft 24F that passes through the rotation center 24E and is parallel to the Z direction and a second shaft 24G that passes through the rotation center 24E and is parallel to the X direction are set. When the beam end 24 rotates about the rotation center 24E, a portion of the inner surface 30A of the face bearing plate 30 in the -Z direction across the second shaft 24G is defined as a first inner surface 30Aa of the face bearing plate.

[0039] When the steel beam 20 rotates toward the position of the steel beam 20a, a reaction force due to bearing pressure acts from the concrete 32 of the column 10, so that the first inner surface 30Aa of the face bearing plate 30 generates rotational resistance against the rotation of the beam end 24. That is, the first inner surface 30Aa of the face bearing plate 30 is an additional member that acts as a "resistance element" against rotation when the beam end 24 disposed inside the concrete 32 of the column 10 in the steel beam 20 rotates about the rotation center 24E.

[0040] When the vertical load in the -Z direction acts on the steel beam 20 and the steel beam

element 24Aa illustrated in Fig. 1 in the X direction is 200 mm, a central point 100 mm away from respective ends in the X direction can be adopted as the "point of action of the representative displacement" of the upper flange end outer surface resistance element 24Aa.

[0059] A distance between a center of gravity of the reaction force of the resistance element i and the elastic rotation center 24Ea is set to "$x_{l,i}$". In the present embodiment, the rotational rigidity of the joint 14 is calculated by the following Formula 1.

[Expression 3]

$$S_j = \sum_i (k_i \cdot x_{d,i} \cdot x_{l,i}) \qquad \text{Formula 1}$$

[0060] Here, the "center of gravity of the reaction force" in the setting of the distance $x_{l,i}$ refers to a line of action of a virtual concentrated load p that gives a moment equivalent to a moment acting on the rotation center by a distributed load w acting on a region s having a certain constant length or a constant area. However, for the virtual concentrated load p, a distance from the rotation center to the line of action is set assuming that the value is the same as the value obtained by integrating the distributed load w by the region s. For example, in the joint reinforcement bar 28 as the resistance element i, an intersection line with a plane at a position shifted by dr in the -Z direction from an upper surface of the slab 22 in a plane parallel to the XY plane in the XZ plane illustrated in Fig. 1 can be set as the center of gravity of the reaction force. Formula 1 allows characteristics of each resistance element and the rotational rigidity of the joint to be uniquely associated with each other for joints having a plurality of resistance elements and any details. The distance $x_{l,i}$ will be specifically described later with reference to Fig. 1 and Formula 1.21.

[0061] According to the above procedure, the rotational rigidity S_j of the joint can be obtained from the characteristics of each resistance element of the joint. A bending moment acting on the joint is uniquely determined from the obtained rotational rigidity of the joint, bending rigidity of the beam, span of the beam, and a load supported by the beam. The bending moment acting on the joint is defined as required moment resistance $M_{j,Ed}$ of the joint. In order to prevent the joint from being damaged, it is necessary to prevent the required moment resistance $M_{j,Ed}$ from exceeding a maximum moment resistance $M_{j,Rd}$ possessed by the joint to be described later. Here, the rotational rigidity S_j of the joint can be adjusted by adjusting a cross-sectional shape of the beam and each resistance element of the joint, and the required moment resistance $M_{j,Ed}$ of the joint can be adjusted by adjusting the rotational rigidity S_j of the joint and the span of the beam.

effective by assuming that the plate bending of the upper and lower flanges 20A and 20B is constrained by the concrete 32.

[0123] A value used to calculate the representative displacement due to the bearing pressure between the upper and lower flanges 20A and 20B of the steel beam 20 (beam end 24) embedded inside the column 10 and the concrete 32, that is, the distance $x_{d,i}$ between the line of action of the representative displacement of the resistance element i and the elastic rotation center of the portion of the steel beam disposed inside the concrete of the column is expressed by the following Formula 2.18 using the distance l_{eff} from the elastic rotation center to the edge end of the effective bearing pressure region from Formulas 2.13 and 2.14.

[0124] The arm length used to calculate the moment resistance, that is, the distance $x_{l,i}$ between the center of gravity of the reaction force of the resistance element and the elastic rotation center of the portion of the steel beam disposed inside the concrete of the column is expressed by the following Formula 2.19 using the distance l_{eff} from the elastic rotation center to the edge end of the effective bearing pressure region from Formulas 2.13 and 2.14.

[Expression 47]

$$x_{d,i} = x_{d,c} = \frac{l_{eff}}{2} \qquad \text{Formula 2.18}$$

[Expression 48]

$$x_{l,i} = x_{l,c} = \frac{2}{3} l_{eff} \qquad \text{Formula 2.19}$$

[0125] In the case of Fig. 3, the length of the effective bearing pressure region of the upper flange end outer surface resistance element 24Aa of the upper flange 20A is exemplified by "$l_{eff,t}$". The length of the effective bearing pressure region of the upper flange end inner surface resistance element 24Ba of the upper flange 20A is exemplified by "$l_{eff,b}$". The length of the effective bearing pressure region of the lower flange end inner surface resistance element 24Ca of the lower flange 20B is exemplified by "$l_{eff,t}$". The length of the effective bearing pressure region of the lower flange end outer surface resistance element 24Da of the lower flange 20B is exemplified by "$l_{eff,b}$". Each width of the effective bearing pressure region is exemplified by "b_{eff}".

[0126] (Elastic rigidity by bearing pressure of face bearing plate and concrete)

Next, the elastic rigidity regarding the bearing pressure resistance between the face

the rotational rigidity S_j is determined as a value satisfying the following Formula 3.

[Expression 123]

$$S_j = \sum_i (k_i \cdot x_{d,i} \cdot x_{l,i}) \qquad \text{Formula 3}$$

[0248] A tenth aspect is

the column-beam joint structure according to the ninth aspect, in which

at least one of a distance between respective ends of the steel beam or a cross-sectional shape of the steel beam is adjusted so that the required moment resistance does not exceed a maximum moment resistance that can be resisted by the column-beam joint.

[0249] An eleventh aspect is

the column-beam joint structure according to the eighth or tenth aspect, in which

the resistance element includes an additional member provided at the portion of the steel beam inside the concrete and at a peripheral edge of the portion, and

the required moment resistance or the maximum moment resistance of the column-beam joint is established by adjusting at least one of an arrangement, shape, or dimension of the additional member.

[0250] A twelfth aspect is

the column-beam joint structure according to any one of the eighth, tenth, and eleventh aspects, in which

a maximum reaction force borne by a resistance element i of the portion of the steel beam inside the concrete is denoted by $F_{i,Rd}$,

the maximum moment resistance of the column-beam joint is denoted by $M_{j,Rd}$,

a distance between a rotation center of the steel beam and a line of action of the reaction force is denoted by $x_{u,i}$, and

a minimum value of $M_{j,Rd}$ calculated using the following Formula 4 is established as the maximum moment resistance with a position of the rotation center as a variable.

[Expression 124]

$$M_{j,Rd} = \sum_i F_{i,Rd} \cdot x_{u,i} \qquad \text{Formula 4}$$

[0251] A thirteenth aspect is

the column-beam joint structure according to any one of the eighth to twelfth aspects, in which

an embedded length ratio obtained by dividing an embedded length of the end of the

steel beam in the concrete of the column by a beam depth of the steel beam is 0.6 or less.

[0252] <<Other aspects>>

From the present specification, the following other aspects are conceptualized.

[0253] That is, another first aspect is