

[DESCRIPTION]

[TITLE OF INVENTION]

BEAM AND COLUMN JOINING PORTION STRUCTURE

[Technical Field]

5 [0001]

The present invention relates to a beam and column joining portion structure and, more particularly, to a structure of a joining portion of a half-precast concrete (half PCa) beam and a column.

Priority is claimed on Japanese Patent Application No. 2015-198053, filed
10 October 5, 2015, the content of which is incorporated herein by reference.

[Background Art]

[0002]

Conventionally, owing to many advantages such as shortening of a construction period, improvement in the safety, improvement in the quality, and reduction in the cost,
15 it is performed to use PCa constructions manufactured in advance in a factory or the like as a beam and a column of a concrete building and build a building by assembling the beam and the column in a field.

[0003]

In addition, as a method of joining a beam and a column of PCa constructions,
20 for example, a method is used in which joining reinforcing bar are arranged on a side face of the column and a side end face of the beam joining to the side face of the column, and casting concrete is placed between the side end face of the beam and the side face of the column, in which the joining reinforcing bar are arranged, and the beam and the column are joined to be integrated through the joining reinforcing bar and the casting
25 concrete.

[0004]

In addition, a construction method is practically used in which a lower main reinforcement and a portion near the lower portion of the shear reinforcement are buried in concrete to form as a half PCa beam, a joining lower reinforcing bar (on-site arranged
5 main reinforcement) projecting from the column arranged to be overlapped with the lower main reinforcement projecting from the joining end face of the half PCa beam and be connected to the transverse reinforcement exposed to the upper side from an upper face, the joining upper reinforcing bar (on-site arranged main reinforcement) projecting from the column is overlapped with the upper main reinforcement, the joining
10 reinforcing bar projecting from the column and the main reinforcement of the beam are connected using the lap splice, and concrete is casted in a joining portion between the half PCa beam and the column to integrally join the beam and the column of the PCa constructions.

[0005]

15 In addition, as disclosed in Patent Document 1, there is also a construction method in which a joining reinforcing bar projecting from a column and a main reinforcement of a half PCa beam are connected with being spaced apart from each other by using a non-contact lap splice.

[Citation List]

20 [Patent Literature]

[0006]

[Patent Document 1]

Japanese Unexamined Patent Application, First Publication No. H11-81452

[Summary of Invention]

25 [Technical Problem]

[0007]

Meanwhile, while a design technique for a construction method for connecting a reinforcing bar of a column and a main reinforcement of a half PCa beam using the lap splice has been established, a design technique for a construction method of connecting the joining reinforcing bar of the column and the main reinforcement of the half PCa beam with being spaced apart from each other using the lap splice has not been sufficiently established.

[0008]

The present invention is made in consideration of the situations described above, and an object thereof is to provide a joining portion structure of a beam and a column enabling appropriate joining of the beam and the column by using the non-contact lap splice that overlaps a joining reinforcing bar of the column and a main reinforcement of a half PCa beam with a space.

[Solution to Problem]

[0009]

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

[0010]

(1) A beam and column joining portion structure according to one aspect of the present invention is a structure joining a beam and a column by connecting the beam and the column using the non-contact lap splice overlapping a joining reinforcing bar projecting from the column in a transverse direction with a main reinforcement of the beam to have a predetermined gap interposed therebetween, in which the lap splice length L of the joining reinforcing bar and the main reinforcement is set to be a required joint length L_d of the non-contact lap splice calculated using the following Equation (1)

or more.

[0011]

[Formula 1]

$$L_d = L_p + \frac{f_y \cdot a_s}{\phi \cdot \tau_{b \max}} \quad (1)$$

5 [0012]

Here, L_p is the ineffective length (mm) of the joint. f_y is the yield strength (N/mm²) of the reinforcing bar and is the specified yield strength. a_s is the cross-sectional area (mm²) of one column main reinforcement, ϕ is the circumference (mm) of one column main reinforcement, and $\tau_{b \max}$ is the bond strength (N/mm²) of the column main reinforcement.

[0013]

The joint ineffective length L_p is acquired by using the following Equation (2) when $1 \leq R_b/R_e \leq 2.5\gamma + 1$ and is acquired by using the following Equation (3) when $2.5\gamma + 1 < R_b/R_e$. In addition, when $L_p > 1.5d$, it is assumed that $L_p = 1.5d$.

15 [0014]

[Formula 2]

$$L_p = \left\{ 0.25 \cdot \frac{\beta}{\gamma} \cdot \left(\frac{R_d}{R_e} - 1 \right) \right\} \times d \quad (2)$$

[0015]

[Formula 3]

$$L_p = \left\{ 0.05 \cdot \frac{\beta}{\gamma} \cdot \left(\frac{R_d}{R_e} \right) + 0.5 \cdot \beta - 0.05 \cdot \frac{\beta}{\gamma} \right\} \times d \quad (3)$$

[0016]

Here, a is the clear span (mm) of the beam, D is the whole depth (mm) of the beam, and R_d is the design limit member angle (rad). R_e is the yield deformation angle (rad.) set in the ACI standard. d is the effective depth (mm) of the beam. In addition, γ and β are the influence factors according to a shear span ratio (a/D) and are acquired using the following Equations (4) and (5).

[0017]

[Formula 4]

$$\gamma = -0.70 \cdot \left(\frac{a}{D} \right) + 4.1, \quad \gamma \geq 0.25 \quad (4)$$

[0018]

[Formula 5]

$$\beta = 0.25 \cdot \left(\frac{a}{D} \right) - 0.13 \quad (5)$$

[Advantageous Effects of Invention]

15 [0019]

According to a beam and column joining portion structure of an aspect of the present invention, a beam and column joining portion structure having high reliability can be realized using a spaced non-contact lap splice of which a design method has not been conventionally established.

[Brief Description of Drawings]

[0020]

Fig. 1 is the cross-sectional view showing a beam and column joining portion structure according to one embodiment of the present invention.

5 Fig. 2 is the arrow view taken along line X1 – X1 shown in Fig. 1.

Fig. 3 is the diagram showing a reinforcing bar stress distribution of a beam and column joining portion structure according to one embodiment of the present invention.

Fig. 4 is the conceptual diagram showing a slippage strength of a beam and column joining portion structure according to one embodiment of the present invention.

10 Fig. 5 is the arrow view taken along line X1-X1 shown in Fig. 4 and is the conceptual diagram showing a slipping joint face of a beam and column joining portion structure according to one embodiment of the present invention.

Fig. 6 is the diagram showing a stress block method in ACI 318.

15 Fig. 7 is the diagram showing a ratio (L_p/d) of a slip ineffective length to an effective beam depth.

Fig. 8 is the cross-sectional view showing a test body used for checking the validity of a method of designing a beam and column joining portion structure according to one embodiment of the present invention.

Fig. 9 is the arrow view taken along line X1-X1 shown in Fig. 8.

20 Fig. 10 is the arrow view taken along line X2-X2 shown in Fig. 8.

Fig. 11 is the arrow view taken along line X3-X3 shown in Fig. 8.

[Description of Embodiments]

[0021]

Hereinafter, a beam and column joining portion structure according to one
25 embodiment of the present invention will be described with reference to Figs. 1 to 11.

Here, this embodiment relates to a structure joining a column made of reinforcing bar concrete (RC) and a precast concrete beam (PCa beam).

[0022]

First, a PCa beam 1 according to this embodiment, as shown in Figs. 1 and 2, is
 5 a “U”-shaped half PCa beam, has a widthwise-direction center portion of an axial-line O1 direction side end side (side end side) to be concave from the upper end toward the lower end, and includes a concrete placing space (a casting concrete portion) 2 in which casting concrete is placed to form a “U”-shaped cross-section.

[0023]

10 In addition, this half PCa beam 1 is formed such that the concrete placing space 2 is concave from an upper end up to a side lower than the center of the beam depth (the center in the height direction).

[0024]

In this way, the lower main reinforcement 3 of the half PCa beam 1 is buried in
 15 the concrete of the half PCa. In addition, the half PCa beam 1 formed such that the shear reinforcement 4 has a lower end side buried in concrete and an upper end side to project to the upper side from the axial-line O1 direction center portion of the half PCa beam 1 and the upper face of the concrete placing space 2.

[0025]

20 In addition, a covering depth between the upper face of the concrete placing space 2 of the half PCa beam 1 and the lower main reinforcement 3 is set to secure a predetermined gap of the non-contact lap splice 5 to be described later. Furthermore, the thickness of the half PCa in the “U”-shaped portion forming the concrete placing space 2 is about 80 mm.

25 [0026]

Meanwhile, a column 6 according to this embodiment is a PCa column or an RC column and is formed to project from a joining end face (column face portion) 6a joining the half PCa beam 1 in the horizontal direction while causing a joining lower reinforcing bar 10 (or a joining upper reinforcing bar) to be integrally buried in concrete.

5 [0027]

In a beam and column joining portion structure A according to this embodiment, the joining upper reinforcing bar 7 projecting from the column 6 is used as the upper main reinforcement of the half PCa beam 1 and is connected to an upper end side of the shear reinforcement 4 projecting from the upper face of the half PCa beam 1 to the upper
10 side. In addition, a reinforcement cap 8 is arranged such that the upper main reinforcement 7 is enclosed together with the shear reinforcement 4.

[0028]

In addition, a joining lower reinforcing bar 10 projecting from the column 6 is arranged near the upper face of the concrete placing space 2 of the half PCa beam 1 and
15 is arranged on the upper side of the lower main reinforcement 3 of the half PCa beam 1 buried in concrete with a predetermined gap interposed therebetween.

[0029]

Then, by placing concrete such that the shear reinforcement 4, the upper main reinforcement 7, and the reinforcement cap 8 are buried on the concrete placing space 2
20 and the half PCa, the half PCa beam 1 and the column 6 are joined.

[0030]

In the beam and column joining portion structure A according to this embodiment joining the half PCa beam 1 and the column 6 in this way, the joining lower reinforcing bar 10 projecting from the column 6 and the lower main reinforcement 3 of
25 the half PCa beam 1 overlap with each other with a predetermined gap interposed

therebetween, a joining portion joining the joining lower reinforcing bar 10 and the lower main reinforcement 3 is configured as the non-contact lap splice 5.

[0031]

Here, a design method of a case in which the joining portion of the joining lower reinforcing bar 10 projecting from the column 6 and the lower main reinforcement 3 of the half PCa beam 1 is the non-contact lap splice 5 as described above will be described.

[0032]

(Calculation of bending moment)

First, the bending moment of the beam and column joining portion structure according to this embodiment is calculated on the basis of 1-1) and 1-2) represented below.

[0033]

1-1) The stress intensity of the inside of the cross-section is calculated on the basis of “Reinforcing bar concrete structure calculation standard and commentary: 2010 edition” edited by Architectural Institute of Japan (hereinafter, referred to as an RC standard) or ACI 318, and an allowed bending moment or an ultimate bending strength is acquired. In addition, those may be acquired on the basis of references and standards applied to the corresponding country or region.

1-2) The minimum main reinforcement amount of the beam follows the rule of the applied design standard.

[0034]

(Calculation of shear)

Next, the shear of the beam and column joining portion structure according to this embodiment is calculated on the basis of 2-1), 2-2), and 2-3) represented below.

25 [0035]

2-1) An allowed shear force or an ultimate shear strength is acquired on the basis of the RC standard or ACI 318. In addition, those may be acquired on the basis of standards applied to the corresponding country or region.

2-2) The minimum transverse reinforcement ratio follows the rule of the applied design standard.

2-3) The shear force is calculated at the U-shaped header portion (concrete placing portion) and a joint end portion.

[0036]

(Design of non-contact lap splice)

10 The non-contact lap splice of the beam and column joining portion structure according to this embodiment is designed in the following sequence 3-1) to 3-5).

[0037]

3-1) A design limit maximum deformation angle R_d is set.

3-2) A required lap splice length L_d is calculated.

15 3-3) A required transverse reinforcement amount p_{wd} of the joining portion is calculated.

3-4) The conformance of the lap splice length L for the ACI standard is checked.

3-5) The shear design of portions other than the joining portion is performed.

[0038]

20 In this design method, the beam critical section is a column face portion, and the distribution of stress of the joining portion reinforcing bar is assumed to have a shape as shown in Fig. 3. In addition, the frictional property of the working joint interface of the joining portion and the transverse reinforcement contribute to the slippage strength, and the setting of the slipping joint face is as shown in Figs. 4 and 5.

25 [0039]

(Setting of design limit maximum deformation angle R_d)

A design limit member angle R_d of a case in which the lap splice is arranged in the yield hinge portion of the end portion of the beam is selected to be a limit deformation angle R_x or less on the basis of the ACI standard as represented in Equation

5 (6).

In addition, R_x is acquired using Equation (7), and R_e is acquired by Equation (8). Furthermore, in a case in which the lap splice is arranged in a portion other than the yield hinge portion, it is assumed that $R_d = R_e$.

[0040]

10 [Formula 6]

$$R_d \leq R_x \quad (6)$$

[0041]

[Formula 7]

$$R_x = C_d \cdot R_e \quad (7)$$

15 [0042]

[Formula 8]

$$R_e = \frac{\phi \cdot M_n \cdot l_b}{3E_c I_{cr}} \quad (8)$$

[0043]

Here, R_x is the limit deformation angle (rad). C_d is the plasticity magnification and is as represented in the following Table 1.

[0044]

[Table 1]

Plasticity magnification of each structure type to be applied

Structure type	Plasticity magnification
Special moment frame (SMF)	Not applied
Intermediate moment frame (IMF)	4.5
Ordinary moment frame (OMF)	3.5

5

[0045]

In addition, $\phi \cdot M_n$ is the designed ultimate bending strength (N·mm) at the lower end of the beam in tension and is acquired using Equations (9) and (10) represented below on the basis of a stress block method shown in Fig. 6.

10 [0046]

In addition, L_b is the beam clear span length (mm). E_c is the Young's modulus (N/mm²) of concrete and is represented by Equation (11). In addition, I_{cr} is the reduced sectional secondary moment of area (mm⁴) of the beam and is represented by Equation (12).

15 [0047]

Furthermore, f_c' is the designed reference strength (N/mm²) of placed concrete, and b is the beam width. I_g is the sectional secondary moment of area (mm⁴) of the beam.

[0048]

20 [Formula 9]

$$\phi \cdot M_n = \phi \cdot A_s \cdot f_y \cdot (d - 0.5 \times a) \quad (9)$$

[0049]

[Formula 10]

$$a = \frac{A_s \cdot f_y}{0.85 \cdot f'_c \cdot b} \quad (10)$$

[0050]

5 [Formula 11]

$$E_c = 4700 \cdot \sqrt{f'_c} \quad (11)$$

[0051]

[Formula 12]

$$I_{cr} = 0.35 \cdot I_g \quad (12)$$

10 [0052]

(Calculation of required lap splice length L_d of non-contact lap splice)

Next, the calculation of the required lap splice length L_d of the non-contact lap splice will be described.

In this embodiment, the required lap splice length L_d of the non-contact lap splice is calculated using Equation (13), and the lap splice length L is secured to be L_d or more.

[0053]

Here, L_p is the ineffective length (mm) of the joint. f_y is the yield strength

(N/mm²) of the reinforcing bar and is the specified yield strength. a_s is the cross-sectional area (mm²) of one beam main reinforcement, ϕ is the circumference (mm) of one beam main reinforcement, and $\tau_{b\max}$ is the bond strength (N/mm²) of the beam main reinforcement.

5 [0054]

[Formula 13]

$$L_d = L_p + \frac{f_y \cdot a_s}{\phi \cdot \tau_{b\max}} \quad (13)$$

[0055]

The joint ineffective length L_p is acquired by using the following Equation (14)

10 when $1 \leq R_b/R_e \leq 2.5 \times \gamma + 1$ and is acquired by using the following Equation (15) when $2.5 \times \gamma + 1 < R_b/R_e$. In addition, when $L_p > 1.5d$, it is assumed that $L_p = 1.5d$.

[0056]

Here, a is the shear span (mm) of the beam, D is the whole depth (mm) of the beam, and R_d is the design limit member angle (rad). R_e is the yield deformation angle

15 (rad) set in the ACI standard and is acquired by using Equation (8) represented above.

D is the effective depth (mm) of the beam when the lower end of the beam in tension.

In addition, γ and β are the influence factors according to the shear span ratio (a/D) and are acquired by the following Equations (16) and (17).

[0057]

20 [Formula 14]

$$L_p = \left\{ 0.25 \cdot \frac{\beta}{\gamma} \cdot \left(\frac{R_d}{R_e} - 1 \right) \right\} \times d \quad (14)$$

[0058]

[Formula 15]

$$L_p = \left\{ 0.05 \cdot \frac{\beta}{\gamma} \cdot \left(\frac{R_d}{R_e} \right) + 0.5 \cdot \beta - 0.05 \cdot \frac{\beta}{\gamma} \right\} \times d \quad (15)$$

5 [0059]

[Formula 16]

$$\gamma = -0.70 \cdot \left(\frac{a}{D} \right) + 4.1, \quad \gamma \geq 0.25 \quad (16)$$

[0060]

[Formula 17]

$$\beta = 0.25 \cdot \left(\frac{a}{D} \right) - 0.13 \quad (17)$$

10

[0061]

Table 2 shows an example of calculation of the ratio (L_p/d) of the joint ineffective length to the effective beam depth. Fig. 7 shows a ratio (L_p/d) of the joint ineffective length to the effective beam depth.

15 [0062]

[Table 2]

Example of calculation of ratio (L_p/d) of joint effective length to effective beam depth

a/D	Rd/Re
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	1.00	2.00	3.00	4.00	5.00	6.00
2.50	0.00	0.053	0.105	0.158	0.211	0.263
3.00	0.00	0.078	0.155	0.233	0.310	0.388
3.50	0.00	0.113	0.226	0.339	0.452	0.485
4.00	0.00	0.167	0.335	0.502	0.569	0.602
4.50	0.00	0.262	0.524	0.655	0.707	0.759
5.00	0.00	0.467	0.747	0.840	0.933	1.027
5.50	0.00	0.872	1.121	1.370	1.500	1.500
6.00	0.00	0.959	1.233	1.500	1.500	1.500

[0063]

The adhesive strength $\tau_{b\max}$ of the beam main reinforcement is calculated using the following Equation (18). Here, when $\sqrt{(22/d_b)} < 1.0$, it is assumed that $\sqrt{(22/d_b)} =$

5 1.0.

Here, f_c' is the cylinder compressive strength (N/mm²) of placed concrete and is the specified strength. d_b is the nominal diameter (mm) of the beam main reinforcement.

[0064]

10 [Formula 18]

$$\tau_{b\max} = 0.52\sqrt{f_c'} \cdot \sqrt{\frac{22}{d_b}} \quad (18)$$

[0065]

(Calculation of required transverse reinforcement amount p_{wd})

The required transverse reinforcement amount p_{wd} is calculated by the following Equation (19).

Here, α is the slippage strength margin and is assumed to be 1.3. A_{vf} is the total sectional area (mm²) of the beam lower end reinforcing bar in tension. f_y is the yield strength (N/mm²) of the beam main reinforcement and is the specified yield

strength. μ is the friction coefficient of the concrete working joint interface and is 1.0 when being processed by a checkered plate. f_{yt} is the yield strength (N/mm²) of the transverse reinforcement and is assumed to be a specified yield strength. B is the beam width (mm). L is the lap splice length (mm) and is secured to be the required lap splice length L_d or more.

[0066]

[Formula 19]

$$p_{wd} = \alpha \cdot \frac{A_{vf} \cdot 1.25 f_y}{\mu \cdot f_{yt} \cdot B \cdot L} \quad (19)$$

[0067]

10 (Checking conformity of lap splice length L with ACI standard)

Next, a result of checking that the lap splice length L set to be the required lap splice length L_d or more is the required lap splice length L_{d2} based on a case of all reinforcement in tension according to the ACI standard or more will be described.

[0068]

15 L_{d2} is calculated using the following Equation (20).

Here, when $(C_b + K_{tr}) / d_b > 2.5$, it is assumed that $(C_b + K_{tr}) / d_b = 2.5$.

[0069]

Here, f_y is the yield strength (N/mm²) of the beam main reinforcement and is assumed to be a specified yield strength. f_c' is the cylinder compressive strength

20 (N/mm²) of placed concrete and is assumed to be a specified strength. d_b is the nominal diameter (mm) of the beam main reinforcement, and λ is the coefficient according to the type of concrete and is assumed to be 1.0 in the case of normal concrete.

[0070]

ϕ_s is the safety coefficient and is assumed to be 1.0 in a case in which a reinforcing bar diameter D22 or more is used, and is assumed to be 0.7 otherwise. C_b is the minimum value (mm) among a distance C_{b1} from a reinforcing bar core to a side face, a distance C_{b2} from the reinforcing bar core to a bottom face, and 1/2 of an inter-reinforcing bar core distance C_{b3} .

[0071]

K_{tr} is the coefficient relating to the transverse reinforcement and is acquired using the following Equation (21).

10 A_{tr} is the sectional area (mm²) of one set of transverse reinforcement, S is a transverse reinforcement pitch (mm), and N is the number of beam main reinforcement bound to the transverse reinforcement.

[0072]

[Formula 20]

$$L_{d2} = 1.3 \times \left(\frac{f_y}{1.1\lambda\sqrt{f'_c}} \cdot \frac{\phi_s}{\left(\frac{C_b + K_{tr}}{d_b} \right)} \right) \cdot d_b \quad (20)$$

15

[0073]

[Formula 21]

$$K_{tr} = \frac{40 \cdot A_{tr}}{S \cdot n} \quad (21)$$

[0074]

(Shear design of portion other than joining portion)

Next, for a portion (normal portion) other than the joining portion, as represented in Equation (22), the shearing is designed such that the beam shear strength V_u is above an assumed maximum beam shear strength V_{pr} for design.

5 [0075]

Here, V_u is the beam shear strength of the normal portion and can be acquired using Equation (23). V_{pr} is the assumed maximum beam shear strength of the normal portion for design and can be acquired using Equation (24). Further, since $V_E > (V_D + V_E)/2$, $VC=0$ is satisfied.

10 [0076]

In addition, ϕ_1 is the reduction coefficient and is assumed to be 0.75. V_s is the shear strength of the beam and can be acquired using Equation (25). M_{pr} is the assumed maximum bending moment of the beam and can be acquired using Equation (26). l_b is the clear span of the beam.

15 [0077]

In addition, A_{tr} is the sectional area (mm^2) of one set of transverse reinforcement. f_{yt} is the yield strength (N/mm^2) of the transverse reinforcement and is assumed to be the specified yield strength. d is the effective depth (mm) of the beam, and s is the transverse reinforcement pitch (mm). ϕ_2 is the reduction coefficient and is assumed to be 1.0. A_s is the total sectional area (mm^2) of the beam main reinforcement in tension, and f_y is the yield strength (N/mm^2) of the beam main reinforcement and is assumed to be the specified yield strength. a_{st} is the stress block depth (mm) of concrete, f_c' is the designed reference strength (N/mm^2) of placed concrete, and b is the beam width (mm) and can be acquired using Equation (27).

25 [0078]

[Formula 22]

$$V_u > V_{pr} \quad (22)$$

[0079]

[Formula 23]

$$V_u = \phi_1 \cdot V_n = \phi_1 \cdot (V_c + V_s) = \phi_1 \cdot V_s \quad (23)$$

5

[0080]

[Formula 24]

$$V_{pr} = \frac{M_{pr}}{l_b} \quad (24)$$

[0081]

10 [Formula 25]

$$V_s = \frac{A_{tr} \times f_{yt} \times d}{s} \quad (25)$$

[0082]

[Formula 26]

$$M_{pr} = \phi_2 \cdot A_s \cdot 1.25 \cdot f_y \cdot (d - 0.5 \times a_{st}) \quad (26)$$

[0083]

[Formula 27]

$$a_{st} = \frac{A_s \cdot \phi \cdot 1.25 \cdot f_y}{0.85 \cdot f_c' \cdot b} \quad (27)$$

[0084]

5 The design method described above is applied under the following conditions
4-1) to 4-11) (see Fig. 1).

4-1) The diameters, the numbers, and the materials of beam lower end main
reinforcement of a fixing portion for the column and the beam main reinforcement inside
the PCa are the same.

10 4-2) The lower end main reinforcement of the end portion of the PCa is the
extremely placed one.

4-3) The design of the upper end main reinforcement follows the standard of
design references to be applied.

15 4-4) The minimum lap splice length is 40 times the diameter of the main
reinforcement or more.

4-5) The lap splice length is set in consideration of a construction error together
with the calculated required length.

20 4-6) In a case in which the structure form is an intermediate moment frame
(IMF), the diameters of the transverse reinforcement of Zone A are 10 mm or more, and
the gap is 200 mm or less. The transverse reinforcement of Zone B follows the rules of
the design standards to be applied.

4-7) In a case in which the structure form is the special moment frame (SMF),

and the lap splice is arranged in an area other than the plastic region, the standards of ACI 21.5.2.3 (a maximum gap between transverse reinforcement is $d/4$ or less and is 100 mm or less) are followed.

4-8) Top hooks of stirrups and core reinforcement are 135 degrees or 180 degrees with an excessive length of $6d_b$ or more.

4-9) The minimum clearance between adjacent reinforcing bars of the beam is $4/3$ times the diameter of coarse aggregates and is the diameter of the main reinforcement or more.

4-10) Basically, the column joining portion concrete and the beam end portion are simultaneously placed.

4-11) A gap between the joining lower portion reinforcing bar projecting from the column and the lower main reinforcement of the half PCa beam is defined to be $1/5$ of the lap splice length and is 150 mm or less.

[0085]

Next a result of checking the validity of the design method of a case in which the non-contact lap splice according to this embodiment described above is used will be described.

[0086]

Here, test bodies shown in Figs. 8 to 11 and Table 3 are used. In addition, 4-D25 (SD390) is used as the beam main reinforcement, and, as the transverse reinforcement, 2-D13@90 (SD390) is used for the joining portion, and 2-D13@135 (SD390) is used for the normal portion.

[0087]

Table 4 represents settings of the design limit member angle R_d . Table 5 represents a result of calculation of the required lap splice length L_{dl} . Table 6

represents a result of calculation of the required transverse reinforcement amount p_{wd} .

[0088]

[Table 3]

Shape dimension and material				
Beam width	B	mm	500	
Beam depth	D	mm	600	
Beam effective depth (lower end in tension)	d	mm	506	Column face
Beam effective depth (upper end in tension)	d'	mm	533	Column face
Diameter of main reinforcement	db	mm	25	
Number of main reinforcement	n	-	4	
Reinforcing bar cross-sectional area	as	mm ²	507	
Reinforcing bar circumference	fai	mm	79.8	
Main reinforcement yield strength	fy	N/mm ²	390	
Concrete	Fc'	N/mm ²	24	
Shear span of beam	a (lb)	mm	2700	
Shear span ratio	a/D		4.5	

5 [0089]

[Table 4]

1 Setting of design limit member angle Rd				
Plastic ratio of IMF	Cd		4.5	
Depth of stress block	an rd	mm	77.5	
Ultimate bending strength	ϕM_n	kN-m	369.5	
Concrete Young's modulus	Ec	N/mm ²	23025	
Cross-sectional secondary moment	I	mm ⁴	9.00.E+09	
Reduced cross-section secondary moment	Icr	mm ⁴	3.15.E+09	
Yield deformation angle	Re	%	0.459	
Limit deformation angle of IMF	Rx	%	2.063	
Design limit member angle	Rd	%	2.0	$\leq R_x$

[0090]

[Table 5]

2 calculation of required joint length Ld1				
Test equation		Ld1	mm	1313.5
	Hinge length	Lp	mm	340.8
	Yield deformation angle	Re	%	0.459
	Bond strength	τ_{bmax}	N/mm ²	2.55
	Plasticity deformation magnification	Rd/Re	-	4.36

	Similarity ratio X	γ	-	0.950	
	Similarity ratio Y	β	-	0.995	
Designed lap splice length		L	mm	1350	> Ld1 and 40 db

[0091]

[Table 6]

3 Calculation of required transverse reinforcement amount pwd					
	Slippage strength margin	α	-	1.3	
	Tensile reinforcing bar cross-sectional area	Avf	N/mm ²	2028	
	Frictional coefficient of working joint interface	μ	-	1	
	Yield strength of transverse reinforcement	fyt	N/mm ²	390	
	Transverse reinforcement cross-sectional area of one set	Atr	N/mm ²	254	
	Required transverse reinforcement amount	pwd	-	0.00488	
	Number of required transverse reinforcement	ntr	Pieces	12.97	
	Required transverse reinforcement pitch	S _{max}	mm	104.1	
Number of designed transverse reinforcement	n	Pieces	13		>ntr
Designed transverse reinforcement pitch	s	mm	100		<S _{max}
Designed transverse reinforcement ratio	pw	-	0.00508		>pwd
Designed slippage strength margin	α	-	1.303		>1.3

5 [0092]

Table 7 represents a result of checking that the lap splice length $L > L_{d2}$ (ACI).

Table 8 represents a result of checking the shear design of portions other than the joining portion. From these results, it has been checked that the design of a case in which the lap splice is used can be performed by using the design method according to this

10 embodiment.

[0093]

[Table 7]

Checking of lap splice length $L > L_{d2}$ (ACI)			
Concrete type	λ	-	1
Reinforcing bar diameter safety ratio	fai s	-	1
Minimum cover thickness	Cb	mm	52.5

Side face cover	Cb1		94
Bottom face cover	Cb2		95
Reinforcing bar pitch	Cb3		105
Transverse reinforcement coefficient	Ktr		25.4
Transverse reinforcement cross-sectional area of one set	Atr	mm ²	254
Coefficient	(Cb+Ktr)/db		2.5
ACI standard	Ld2	mm	940.8
Lap splice length	L>Ld2		OK

[0094]

[Table 8]

5 shear design of portion other than joining portion				
	Ultimate shear strength	Vu	kN	248.9
	Assumed maximum shear force	V _{pr}	kN	178.5
	Reduction coefficient for vu	fai tu	-	0.75
	Yield strength of transverse reinforcement	fyt2	N/mm ²	390
	Transverse reinforcement cross-sectional area of one set	Atr2	mm ²	254
	Transverse reinforcement pitch	S2	mm	160
Lower end in tension	Normal portion beam effective depth	d	mm	536
	Shear force	Vs	kN	331.9
Lower end in tension	Assumed maximum bending moment	M _{pr}	kN-m	482.0
Upper end in tension	Assumed maximum bending moment	M _{pr}	kN-m	479.0
	Stress block depth	a _{pr}	mm	96.9
	Reduction coefficient for mpr	fai M _{pr}	-	1
	Reduction coefficient for apr	fai a _{pr}	-	1
	Shear strength margin	Vu/V _{pr}	1.39	OK

5 [0095]

According to the beam and column joining portion structure of this embodiment, the beam and column joining portion structure having high reliability can be realized using the non-contact lap splice of which the design method has not been conventionally established.

10 [0096]

As above, while the beam and column joining portion structure according to one embodiment of the present invention has been described, the present invention is not

limited to the embodiment described above and may be appropriately changed in a range not departing from the concept thereof.

[Industrial Applicability]

[0097]

- 5 According to a beam and column joining portion structure of the present invention, the beam and column joining portion structure having high reliability can be realized using the non-contact lap splice of which the design method has not been conventionally established.

[Reference Signs List]

10 [0098]

1 Half PCa beam

2 Concrete placing space

3 Lower main reinforcement

4 Shear reinforcement

15 5 Non-contact lap splice

6 Column

6a Column face portion

7 Upper main reinforcement

8 Reinforcement cap

20 10 Joining lower reinforcing bar

A Joining portion structure of a beam and a column

O1 Axial line of a beam

[CLAIMS]

What is claimed is:

[Claim 1]

A structure joining a beam and a column by connecting the beam and the
 5 column using the non-contact lap splice overlapping a joining reinforcing bar projecting
 from the column in a transverse direction with main reinforcement of the beam to have a
 predetermined gap interposed therebetween,

wherein the lap splice length L of the joining reinforcing bar and the main
 reinforcement is set to be a required lap splice length L_d of the non-contact lap splice
 10 calculated using the following Equation (1) or more:

[Formula 1]

$$L_d = L_p + \frac{f_y \cdot a_s}{\phi \cdot \tau_{b \max}} \quad (1)$$

wherein L_p is the ineffective length (mm) of the joint, f_y is the yield strength
 (N/mm²) of the reinforcing bar and is the specified yield strength, a_s is the cross-sectional
 15 area (mm²) of one beam main reinforcement, ϕ is the circumference (mm) of one beam
 main reinforcement, and $\tau_{b \max}$ is the bond strength (N/mm²) of the beam main
 reinforcement;

wherein the joint ineffective length L_p is acquired by using the following
 Equation (2) when $1 \leq R_b/R_e \leq 2.5 \times \gamma + 1$ and is acquired by using the following Equation
 20 (3) when $2.5 \times \gamma + 1 < R_b/R_e$. When $L_p > 1.5d$, it is assumed that $L_p = 1.5d$, and

[Formula 2]

$$L_p = \left\{ 0.25 \cdot \frac{\beta}{\gamma} \cdot \left(\frac{R_d}{R_e} - 1 \right) \right\} \times d \quad (2)$$

[Formula 3]

$$L_p = \left\{ 0.05 \cdot \frac{\beta}{\gamma} \cdot \left(\frac{R_d}{R_e} \right) + 0.5 \cdot \beta - 0.05 \cdot \frac{\beta}{\gamma} \right\} \times d \quad (3)$$

wherein a is the clear span (mm) of the beam, D is the whole depth (mm) of the
 5 beam, and R_d is a design limit member angle (rad), R_e is the yield deformation angle
 (rad.) set in the ACI standard, d is the effective depth (mm) of the beam, and γ and β are
 the influence factors according to a shear span ratio (a/D) and are acquired using the
 following Equations (4) and (5).

[Formula 4]

$$\gamma = -0.70 \cdot \left(\frac{a}{D} \right) + 4.1, \quad \gamma \geq 0.25 \quad (4)$$

[Formula 5]

$$\beta = 0.25 \cdot \left(\frac{a}{D} \right) - 0.13 \quad (5)$$