

[DESCRIPTION]

[TITLE OF INVENTION]

RC MEMBER JOINING STRUCTURE

[Technical Field]

5 [0001]

The present invention relates to a reinforced concrete (RC) member joining structure.

Priority is claimed on Japanese Patent Application No. 2015-198054, filed October 5, 2015, the content of which is incorporated herein by reference.

10 [Background Art]

[0002]

Conventionally, a technology for shortening a construction period by increasing precast concrete (PCa) construction ratio and reducing cast-in-place concrete has been developed and implemented.

15 [0003]

For example, there is a construction method in which a plurality of sleeves (sheath pipes) of mechanical joints are arranged in an upper end portion of a stub, and a precast concrete column projecting a plurality of main reinforcement from a lower end portion toward the lower side is installed and joined on the stub.

20 [0004]

In this construction method, each of the plurality of main reinforcement projecting to the lower side of the PCa column is plugged inside a sleeve of the mechanical joint of the stub. Then, a grout material is injected into inside sleeves of the plurality of mechanical joints of the stub and a joint portion between PCa columns

25 vertically adjacent to each other, and the stub and the PCa columns are integrally joined

(for example, see Patent Document 1).

[Citation List]

[Patent Literature]

[0005]

5 [Patent Document 1]

Japanese Unexamined Patent Application, First Publication No. 2012-77547

[Summary of Invention]

[Technical Problem]

[0006]

10 Meanwhile, while a design technique for connecting main reinforcement of one pair of RC members using a mechanical joint has been established, a design technique for connecting main reinforcement using non-contact lap splice overlapping the main reinforcement while having a gap formed between the main reinforcement has not been sufficiently established.

15 [0007]

The present invention is in consideration of the situation described above, and an object thereof is to provide an RC member joining structure enabling RC members to be appropriately joined using a non-contact lap splice.

[Solution to Problem]

20 [0008]

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

[0009]

(1) In an RC member joining structure according to one aspect of the present
25 invention, one RC member is formed by extending main reinforcement from a joining

end face to the outer side, and the other RC member is a column and is formed by having sheath pipes buried to open to the joining end face in parallel with the main reinforcement, the main reinforcement of the one RC member is inserted into the sheath pipe, a grout material is filled inside the sheath pipe, the main reinforcement of the one

5 RC member and a main reinforcement of the other RC member are connected by a non-contact lap splice with a gap therebetween, and the required lap splice length L_b of the non-contact lap splice is set in accordance with Equations (1) to (6) below.

[0010]

[Formula. 1]

$$L_d \geq \max(L_{d1}, L_{d2}) \quad (1)$$

10

[0011]

[Formula. 2]

$$L_{d1} = \left\{ \frac{\frac{L_b - h_b}{d_b} \cdot \tau_{b \max} + \frac{1}{4} \cdot \sigma_y \cdot \left(1 - \frac{h_b}{H}\right)}{\tau_{b \max} + \frac{d_b}{4H} \cdot \sigma_y} \right\} \cdot \frac{1}{1 - \gamma_t} \cdot d_b \quad (2)$$

[0012]

15 [Formula 3]

$$L_{d2} = \left(\frac{1}{4} \cdot \frac{\sigma_y}{\tau_{sb \max}} \cdot \frac{d_b}{D_s} + \frac{L_b - h_b}{d_b} \right) \cdot \frac{1}{1 - \gamma_t} \cdot d_b \quad (3)$$

[0013]

[Formula 4]

$$L_b = 0.26(R_d - R_y) \cdot d_{cy} \quad (4)$$

[0014]

[Formula 5]

$$\tau_{b\max} = \alpha \cdot 0.658 \sqrt{f_c} \quad (5)$$

5 [0015]

[Formula 6]

$$\tau_{sb\max} = \alpha \cdot 0.366 \sqrt{f_c} \quad (6)$$

[0016]

Here, L_d is a lap splice length (mm), and d_b is the nominal diameter (mm) of the
 10 main reinforcement of the column. L_b is the ineffective lap splice length (mm) at
 bottom end and is acquired by Equation (4). σ_{yf} is the yield strength (N/mm²) of the
 main reinforcement of the column.

[0017]

H is the shear span (mm) of the column. h_b is a grout thickness at the joint
 15 (mm). D_s is the sheath pipe outer diameter (mm). $\tau_{b\max}$ is the bond strength (N/mm²)
 of the main reinforcement of the column and is acquired by Equation (5). $\tau_{sb\max}$ is the
 bond strength (N/mm²) of the sheath pipe and is acquired by Equation (6).

[0018]

γ_t is the ratio of the joint upper ineffective length to the lap splice length. R_d is
 20 the design limit member angle (%). R_y is the yield member angle (%). d_{cy} is the

effective depth (mm) of the column and is the distance from a compressive stress fiber of the cross-section of a pedestal portion to a centroid position of the steel reinforcement in tension (joint reinforcement).

[0019]

- 5 α is the bond strength reduction coefficient. f_c is the concrete design reference strength (N/mm²).

[0020]

- (2) In the RC member joining structure described in “(1)” above, a yield moment M_Y at the cross-section based on arrangement of main reinforcement of the other RC member
10 arranged on the inner side of the sheath pipe may be above an acting bending moment M_{LE} at the joint end point, and the required lap splice length L_d may be set so as not to yield in flexure at a cross-section of the joint end point of the non-contact lap splice by satisfying a condition of Equation (7) below.

[0021]

- 15 [Formula 7]

$$M_{LE} = \phi_e \cdot M_{cy} \cdot \frac{H - L_d - h_b}{H - L_b} < M_Y \quad (7)$$

[0022]

Here, M_Y is the yield moment (kNm) at the cross-section according to the column main reinforcement at the joint end point and is acquired by Equation (8) below.

- 20 M_{LE} is the moment (kNm) acting on the joint end point. M_{cy} is the yield moment (kNm) at the cross-section of the pedestal and is acquired by Equation (9) below. ϕ_e is the coefficient of bending moment and is 1.0.

[0023]

A_s is total the cross-sectional area (mm^2) of the steel reinforcement in tension.

d_y is the effective depth (mm) of the column and is a distance from the compressive fiber stress of the joint end point cross-section to the centroid position of the steel

reinforcement in tension. a is the stress block depth (mm) of concrete and is calculated

5 by Equation (10) from the balance at the cross-section. F_c is the concrete design

reference strength (N/mm^2), f_y is the specified yield strength (N/mm^2) of the main reinforcement of the column, and b is a member width (mm).

[0024]

[Formula 8]

$$10 \quad M_Y = A_s \cdot f_y \cdot (d_Y - 0.5 \times a) \cdot 10^{-6} \quad (8)$$

[0025]

[Formula 9]

$$M_{cy} = A_s \cdot f_y \cdot (d_{cy} - 0.5 \times a) \cdot 10^{-6} \quad (9)$$

[0026]

15 [Formula 10]

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

[0027]

(3) In the RC member joining structure described in “(1)” or “(2)” described above, the required transverse reinforcement amount p_{wd} in a lap splice section may be

20 set in accordance with Equation (11) and Equation (12).

[0028]

[Formula 11]

$$p_{wd} \geq \frac{C_s}{C_s + D_s} \cdot \frac{\sigma_{td}}{f_{wy}} \quad (11)$$

[0029]

5 [Formula 12]

$$\sigma_{td} = \frac{1}{\alpha} \max \left(0.78 \cdot \tau_b / \sigma_{td}, 1.6 \cdot \tau_{sb} / \sigma_{t0} \right) \times \sigma_{tav} \quad (12)$$

[0030]

Here, C_s is the smaller value of a gap (mm) between sheath pipes and twice the minimum covering thickness (mm) of the sheath pipe. D_s is the sheath pipe outer diameter (mm), and p_{wd} is the required transverse reinforcement ratio. f_{wy} is the specified yield strength (N/mm²) of the transverse reinforcement.

[0031]

σ_{td} is the design splitting stress intensity (N/mm²). σ_{t0} is the reference splitting strength (N/mm²). σ_{tav} is the average stress intensity (N/mm²) acting on a splitting face when concrete is failed in splitting and is acquired by Equation (13).

[0032]

α is the bond reduction coefficient. τ_b is the working bond stress (N/mm²) of the main reinforcement in a column and is acquired by Equation (14) below. τ_{sb} is the working bond stress (N/mm²) of the sheath pipe and is acquired by Equation (15) below.

20 [0033]

f' is a pulling strength (N/mm²) of concrete and is acquired by Equation (17)

below.

[0034]

[Formula 13]

$$\sigma_{lav} = \frac{\left(\frac{C_s}{D_s} + 2\right) \cdot f_t}{\left(\frac{C_s}{D_s} + 1\right)^2 + 1 + \left\{\left(\frac{C_s}{D_s} + 1\right)^2 - 1\right\} \cdot \frac{f_t}{f_c}} \quad (13)$$

5 [0035]

[Formula 14]

$$\tau_b = \frac{d_b}{4} \cdot \frac{\sigma_y}{L_d + h_b - L_t - L_b} \left(1 - \frac{L_d + h_b - L_t}{H}\right) \quad (14)$$

[0036]

[Formula 15]

$$\tau_{sb} = \frac{d_b^2}{4D_s} \cdot \frac{\sigma_y}{L_d + h_b - L_t - L_b} \quad (15)$$

10

[0037]

[Formula 16]

$$L_t = 0.13 \times L_d \quad (16)$$

[0038]

15 [Formula 17]

$$f_t = 0.56 \cdot \sqrt{f_c} \quad (17)$$

[Advantageous Effects of Invention]

[0039]

According to an RC member joining structure of one aspect of the present
 5 invention, the structure of a joining portion having high reliability can be realized by
 using the non-contact lap splice of which a design method has not been conventionally
 established.

[Brief Description of Drawings]

[0040]

10 Fig. 1 is the diagram showing an RC member joining structure according to one
 embodiment of the present invention.

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

Fig. 3 is the arrow view taken along line X2-X2 shown in Fig. 1.

Fig. 4 is the arrow view taken along line X3-X3 shown in Fig. 1.

15 Fig. 5 is the diagram showing a steel reinforcement stress distribution of an RC
 member joining structure according to one embodiment of the present invention.

Fig. 6 is the diagram showing one example of dimension settings when
 calculating a required transverse reinforcement ratio of the RC member joining structure
 according to one embodiment of the present invention.

20 Fig. 7 is the diagram showing a cross-sectional strength determination position
 of a joint end point of the RC member joining structure according to one embodiment of
 the present invention.

Fig. 8 is the diagram showing a stress block method according to American

Concrete Institute (ACI) 318.

Fig. 9 is the diagram showing the dimensional shape and the state of the arranged reinforcement of a test specimen.

[Description of Embodiments]

5 [0041]

Hereinafter, an RC member joining structure according to one embodiment of the present invention will be described with reference to Figs. 1 to 9.

[0042]

First, in this embodiment, as shown in Figs. 1 to 4, on a stub 1 consisting of one
10 RC member, a PCa column 2 of the other RC member is installed, and the stub 1 and the PCa column 2 are joined together to erect the PCa column 2.

[0043]

The stub 1 is formed with a plurality of main reinforcement 3 sticking out of an upper end face (joining end face) thereof to the upper side by a predetermined length.

15 [0044]

On the bottom end portion of the PCa column 2, a plurality of sheath pipes 4 having an approximately bottomed cylinder shape are integrally buried in a vertical direction along the axis, and a grouting gap is installed as joining end face. In addition, the PCa column 2 according to this embodiment includes a squeezing part 6 bending
20 portions near the lower end portion of the plurality of main reinforcement 5 at a gradient angle of $1/6$ to be near the center, the main reinforcement 5 is set so as to approach the sheath pipes 4 by this squeezing part 6, and one pair of sheath pipes 4 and the main reinforcement 5 are buried in concrete in parallel with a predetermined gap therebetween.

[0045]

25 In an RC member joining structure A according to this embodiment, inside the

sheath pipe 4 of the PCa column 2, the main reinforcement 3 projecting to the lower side of the stub 1 is plugged to have a gap with the main reinforcement 5 of the PCa column 2 in the horizontal direction, and a grout material is injected into the inside of each sheath pipe 4 and the joint portion 7. Accordingly, the main reinforcement 3 and 5 of the stub 1 and the PCa column 2 are connected by a non-contact lap splice 8 through the sheath pipes 4, and the stub 1 and the PCa column 2 are integrally jointed together.

[0046]

Here, a design method of a case in which the main reinforcement 2 and 5 of the stub 1 and the joining portion of the PCa column 2 are configured as the non-contact lap splice 8 as described above will be described.

[0047]

In addition, a joining portion targeted by this design method, for example, is preferably applied to a building that is constructed in an earthquake region (regions corresponding to Seismic zones 2 to 4 in U.S. UBC 1997 section 1653) and satisfies the following conditions.

[0048]

(Restriction on column to be applied)

1-1) The axial force N_U at the ultimate state is $A_g \cdot f_c / 10$ or less.

1-2) The shear span ratio $M_U / (Q_U \cdot D)$ at the ultimate state is 5.0 or more.

1-3) The designed limit member angle of the column at the ultimate state with plastic deformation considered is 2.0% or less.

[0049]

Here, D is the depth (mm) of the column, N_U is the axial force (kN) exerted in the column at the ultimate state, M_U is the bending moment (kNm) exerted in the column at the ultimate state, Q_U is the shear force (kN) exerted in the column at the ultimate

state, A_g is the cross-sectional area (mm^2) of the column, and f_c is the compressive strength (N/mm^2) of cylinders.

[0050]

(Frame system)

- 5 The frame system is a frame structure or a frame structure used also as a bearing wall.

[0051]

(Basic items)

Other basic items are as follows.

- 10 2-1) The seismic load is according to standards applied in the country or the region.
- 2-2) The calculation of the cross-section for the axial-direction force, the bending and the shear forces is performed on the basis of “Steel reinforcement concrete structure calculation standard and commentary” edited by the Architectural Institute of Japan” (hereinafter, referred to as the RC standard) or ACI 318 for a stress analysis. The
- 15 calculation thereof may be acquired on the basis of standards applied in the corresponding country or region.
- 2-3) The design of the joint is performed on a basis that will be described later (Design of joint).

[0052]

- 20 (Used materials)

(Concrete)

3-1) The concrete used is normal concrete.

3-2) The specified strength is $f_c = 21$ to 30 N/mm^2 (cylinder strength), or $f_{cu} = 25$ to 40 N/mm^2 (cube strength) or more and is converted into a cylinder strength using $f_c = 0.8$

- 25 f_{cu} . The conversion factor may be a numerical value according to the applied standard.

[0053]

(Steel)

4-1) The steel reinforcement is a deformed bar having a diameter of 25 mm or less.

4-2) The specified yield strength of the main reinforcement is 500 N/mm² or less.

5 [0054]

(Sheath pipe)

A Japanese Industrial Standard (JIS) G3302 hot-dip galvanized steel sheet or a steel bar or a material equivalent thereto is used.

[0055]

10 (Grout material)

5-1) The grout material is applied to the inside of the sheath pipe and a PCa pedestal.

5-2) The compressive strength is 60 N/mm² or more (cylinder strength).

[0056]

(Design of PCa column)

15 Next, the design of a PCa column will be described.

[0057]

(Calculation of axial-direction force and bending moment)

First, for the axial-direction force and the bending moment, the followings are applied.

20 6-1) The stress intensity of the inside of the cross-section is calculated on the basis of the RC standard or the ACI 318, and an allowable bending moment or an ultimate bending moment is acquired. Here, the calculation may be on the basis of standards applied to the corresponding country or region.

25 6-2) A minimum main reinforcement amount of the column follows the rules of the design reference to be applied.

[0058]

(Calculation of shear strength)

The calculation of the shearing is performed as bellows.

7-1) An allowable shear strength or an ultimate shear strength is acquired on the basis of
 5 the RC standard or ACI 318. In addition, those may be acquired on the basis of
 standards applied to the corresponding country or region.

7-2) The minimum shear reinforcement ratio follows the rules of the applied design
 standard.

7-3) The shear force is calculated at the pedestal and a joint end point.

10 7-4) At a small gap of the pedestal, the shear friction strength for grout is reviewed.

[0059]

(Design of Joint)

Next, the joint (lap splice) of the pedestal portion is designed in accordance with
 the following sequences (a) to (c).

15 (a) A lap splice length L_d according to attachment is calculated.

(b) Next, it is checked that bending yield does not occur at the cross-section of the joint
 end point.

(c) Then, the required transverse reinforcement amount p_{wd} of the joint section is
 calculated.

20 [0060]

(a) Calculation of lap splice length L_d according to attachment

The required lap splice length L_d of the lap splice portion is calculated using the
 following Equations (18) to (23). In addition, please refer to Fig. 5 for symbols
 included in the equations

25 [0061]

[Formula 18]

$$L_d \geq \max(L_{d1}, L_{d2}) \quad (18)$$

[0062]

[Formula 19]

$$L_{d1} = \left\{ \frac{\frac{L_b - h_b}{d_b} \cdot \tau_{b \max} + \frac{1}{4} \cdot \sigma_y \cdot \left(1 - \frac{h_b}{H}\right)}{\tau_{b \max} + \frac{d_b}{4H} \cdot \sigma_y} \right\} \cdot \frac{1}{1 - \gamma_t} \cdot d_b \quad (19)$$

5

[0063]

[Formula 20]

$$L_{d2} = \left(\frac{1}{4} \cdot \frac{\sigma_y}{\tau_{sb \max}} \cdot \frac{d_b}{D_s} + \frac{L_b - h_b}{d_b} \right) \cdot \frac{1}{1 - \gamma_t} \cdot d_b \quad (20)$$

[0064]

10 [Formula 21]

$$L_b = 0.26(R_d - R_y) \cdot d_{cy} \quad (21)$$

[0065]

[Formula 22]

$$\tau_{b \max} = \alpha \cdot 0.658 \sqrt{f_c} \quad (22)$$

15 [0066]

[Formula 23]

$$\tau_{sb \max} = \alpha \cdot 0.366 \sqrt{f_c} \quad (23)$$

[0067]

Here, L_d is a lap splice length (mm), d_b is the nominal diameter (mm) of the main reinforcement of the column. L_b is the joint lower ineffective length (mm) and is
 5 acquired by Equation (21). σ_{yf} is the yield strength (N/mm²) of the main reinforcement of the column and is 1.1 times the specified yield strength.

[0068]

H is the shear span (mm) of the column. h_b is the grout thickness at the precast joint (mm), and it is assumed that $h_b = 0$ in the review for safety. D_s is the sheath pipe
 10 outer diameter (mm). $\tau_{b \max}$ is the bond strength (N/mm²) of the column main reinforcement and is acquired by Equation (22). $\tau_{sb \max}$ is the bond strength (N/mm²) of the sheath pipe and is acquired by Equation (23).

[0069]

γ_t is the ratio of the joint upper ineffective length to the lap splice length and is
 15 0.13. R_d is the design limit member angle (%) and is 2.0%. R_y is the yield member angle (%) and is 0.75%. d_{cy} is the effective depth (mm) of the column and is the distance from the compressive fiber stress of the cross-section of the pedestal portion to the centroid of the steel reinforcement (joint reinforcement) in tension.

[0070]

20 α is the bond reduction coefficient and is assumed to be 0.8 when the column is manufactured through concrete laying down casting and is assumed to be 1.0 otherwise. f_c is the concrete design reference strength (N/mm²).

[0071]

(b) Checking no yield at the cross-section of the joint end point

It is checked that the yield moment M_Y based on the PCa column main reinforcement arranged on the inner side of the sheath pipe is above an acting bending moment M_{LE} at the joint end point using the following Equation (24). In a case where Equation (24) is not satisfied, it is predicted that a crack is expected to initiate at the joint end point, and accordingly, the required lap splice length L_d is increased so as to satisfy Equation (24).

[0072]

Here, M_Y is the yield moment (kNm) at the cross-section according to the column main reinforcement at the joint end point and is acquired by Equation (25) below. M_{LE} is the moment (kNm) acting on the joint end point. M_{cy} is the yield moment strength (kNm) at the cross-section of the pedestal and is acquired by Equation (26) below. As described above, H is the shear span length (mm) of the column. h_b is the grout thickness at the joint portion (mm) and is assumed to be $h_b = 0$ in reviewing the safety. L_d is the lap splice length (mm). L_b is the joint lower ineffective length (mm) and is acquired by Equation (21). ϕ_e is the coefficient of the bending moment and is assumed to be 1.0.

[0073]

In addition, A_s is the cross-sectional area (mm^2) of the steel reinforcement in tension. d_Y is the effective depth (mm) of the column and is the distance from the compressive fiber stress of the joint end point cross-section to the centroid position of the steel reinforcement in tension. d_{cy} is the effective depth (mm) of the column and is the distance from the compressive fiber stress of the cross-section of the pedestal up to the centroid of the steel reinforcement (joint reinforcement) in tension. a is the stress block depth (mm) of concrete and is calculated by Equation (27) from the balance of the

cross-section. F_c is the concrete specified strength (N/mm²), f_y is the specified yield strength (N/mm²) of the main reinforcement of the column, and b is the member width (mm).

[0074]

5 [Formula 24]

$$M_{LE} = \phi_e \cdot M_{cy} \cdot \frac{H - L_d - h_b}{H - L_b} < M_Y \quad (24)$$

[0075]

[Formula 25]

$$M_Y = A_s \cdot f_y \cdot (d_Y - 0.5 \times a) \cdot 10^{-6} \quad (25)$$

10 [0076]

[Formula 26]

$$M_{cy} = A_s \cdot f_y \cdot (d_{cy} - 0.5 \times a) \cdot 10^{-6} \quad (26)$$

[0077]

[Formula 27]

$$a = \frac{A_s \cdot f_y}{0.85 \cdot f_c \cdot b} \quad (27)$$

15

[0078]

(c) Calculation of the required transverse reinforcement amount p_{wd} at the joint section

The required transverse reinforcement amount p_{wd} is calculated by the following

Equations (28) and (29).

[0079]

Here, C_s is the smaller value of a gap (mm) between sheath pipes and twice the minimum covering thickness (mm) of the sheath pipe. D_s is the sheath pipe outer diameter (mm), and p_{wd} is the required transverse reinforcement ratio. f_{wy} is a specified yield strength (N/mm²) of the transverse reinforcement and is 390 N/mm² or less.

[0080]

σ_{td} is the design splitting stress intensity (N/mm²). σ_{t0} is the reference splitting strength (N/mm²) and is assumed to be 1.0. σ_{tav} is the average stress intensity (N/mm²) acting on the splitting face when concrete is failed in splitting and is acquired by Equation (30).

[0081]

α is the bond reduction coefficient and is assumed to be 0.8 when manufacturing the column through concrete laying down casting and is assumed to be 1.0 otherwise. τ_b is the working bond stress (N/mm²) of the main reinforcement of the column and is acquired by Equation (31) below. τ_{sb} is the working bond stress (N/mm²) of the sheath pipe and is acquired by Equation (32) below.

[0082]

d_b is the nominal diameter (mm) of the main reinforcement of the column. σ_y is the yield strength (N/mm²) of the main reinforcement of the column and is 1.1 times the specified yield strength. H is the shear span (mm) of the column. h_b is the grout thickness at the joint portion (mm) and is assumed to be $h_b = 0$ in reviewing the safety. L_d is the lap splice length (mm). L_t is the joint upper ineffective length (mm) and is acquired by Equation (33) below.

As described above, L_b is the joint lower ineffective length (mm) and is acquired

by Equation (21). D_s is the sheath pipe outer diameter (mm), and f_c is the concrete specified strength (N/mm²). f_t is the splitting strength (N/mm²) of concrete and is acquired by Equation (34) below.

[0083]

5 [Formula 28]

$$p_{wd} \geq \frac{C_s}{C_s + D_s} \cdot \frac{\sigma_{td}}{f_{wy}} \quad (28)$$

[0084]

[Formula 29]

$$\sigma_{td} = \frac{1}{\alpha} \max \left(0.78 \cdot \tau_b / \sigma_{td}, 1.6 \cdot \tau_{sb} / \sigma_{t0} \right) \times \sigma_{tav} \quad (29)$$

10 [0085]

[Formula 30]

$$\sigma_{tav} = \frac{\left(\frac{C_s}{D_s} + 2 \right) \cdot f_t}{\left(\frac{C_s}{D_s} + 1 \right)^2 + 1 + \left\{ \left(\frac{C_s}{D_s} + 1 \right)^2 - 1 \right\} \cdot \frac{f_t}{f_c}} \quad (30)$$

[0086]

[Formula 31]

$$\tau_b = \frac{d_b}{4} \cdot \frac{\sigma_y}{L_d + h_b - L_t - L_b} \left(1 - \frac{L_d + h_b - L_t}{H} \right) \quad (31)$$

15

[0087]

[Formula 32]

$$\tau_{sb} = \frac{d_b^2}{4D_s} \cdot \frac{\sigma_y}{L_d + h_b - L_t - L_b} \quad (32)$$

[0088]

[Formula 33]

$$L_t = 0.13 \times L_d \quad (33)$$

5

[0089]

[Formula 34]

$$f_t = 0.56 \cdot \sqrt{f_c} \quad (34)$$

[0090]

10 The design method described above is applied under the following conditions 8-1) to 8-9).

8-1) The diameters, the numbers, and the materials of the main reinforcement of the column inside the sheath pipe and the main reinforcement of the column inside the PCa are assumed to be the same.

15 8-2) A slope of the inclined main reinforcement in the squeezing part of PCa column is 1/6 or less. At a bending point of the main reinforcement of the column, an additional transverse reinforcement is arranged to bear a transverse component of a force.

8-3) The minimum lap splice length is 40 times the diameter of the main reinforcement or more.

8-4) The lap splice length is set in consideration of a construction error together with the calculated required length.

8-5) The diameter of the transverse reinforcement of the joint section is 10 mm or more, and the gap is 100 mm or less.

5 The transverse reinforcement of the upper portion of the joint section follows the rules of the design standard to be applied.

8-6) In order to prevent splitting failure, all the the sheath pipes are constrained by the transverse reinforcement (core reinforcement).

8-7) Hooks of the hoop and the core reinforcement are 135 degrees or 180 degrees with
10 an additional length of 6d or more.

8-8) Clearance of the sheath pipe and the main reinforcement in the column except for a combination of the sheath pipe and the main reinforcement of the column forming the joint is $\frac{4}{3}$ times the coarse aggregate and is the diameter of the main reinforcement or more.

15 8-9) A gap between the main reinforcement of the stub and the main reinforcement of the PCa column at the non-contact lap splice is defined to be $\frac{1}{5}$ or the non-contact lap splice length and is 150 mm or less.

[0091]

(Stress state assumed in this design)

20 As the stress state assumed in this design, the stress state of the steel reinforcement of the joining portion when the bending yield moment is reduced at the end portion of the column is assumed to be that shown in Fig. 5.

In addition, the split line at the bond splitting failure and various dimensions are assumed to be those shown in Fig. 6. In order to check that the joint end point does not
25 yield in flexure, a distribution of bending moments shown in Fig. 7 is assumed. In

addition, when the cross-section of the joint end point yields in flexure, the upper joint ineffective length L_t shown in Fig. 5 becomes longer than the assumed length, and, as a result, the effective lap splice length becomes shorter than the assumed length, and then it is predicted that slipping-out of the main reinforcement of the column from the joining portion occurs. For this reason, the cross-section of the end point of the joint is planned not so as to yield in flexure.

[0092]

(Setting of design limit member angle R_d)

The design limit member angle R_d used for calculating the joint lower ineffective length L_b is set on the basis of a story drift angle determination condition 2.0% of a general building in US ASCE 7-05.

In this design, a design equation based on the concept that the joining portion may not be failed up to the design limit member angle R_d in advance is formed. Based on the appropriate evaluation in accordance with the design policy of a building, the numerical value of R_d can be appropriately changed. Here, the upper limit value of R_d is 2.5%, a value that has been determined through experiment. When the numerical value of R_d is decreased, the joint lower ineffective length L_b increases, and the required lap splice length L_b decreases in accordance with Equation (18).

[0093]

(Yield strength for reviewing no yield at the joint end point)

The yield moment M_y at the cross-section of the joint end point and the yield moment M_{cy} at the cross-section of the pedestal are calculated on the basis of the following Equations (35) and (36) acquiring an ultimate strength using the concrete stress block method (Fig. 8) represented in ACI 318. Since a technique for acquiring a yield strength in simplified calculation is not represented in ACI 318, here, based on these

equations, Equations (25) and (26) having a strength reduction coefficient ϕ of 1.0 are used for the yield strength for reviewing no yield at the cross-section of the joint end point.

[0094]

- 5 Here, A_s is the cross-sectional area (mm^2) of the steel reinforcement in tension, f_y is the specified yield strength (N/mm^2), d is the effective depth of the column (a distance (mm) from the compressive fiber stress to the centroid of the steel reinforcement in tension), and a is the stress block depth (mm) of concrete and is acquired by Equation (36) from the balance in the cross-section. ϕ is the strength reduction coefficient and is assumed to be 0.9. f_c' is the design reference strength (N/mm^2) of concrete, and b is the member width (mm).

[0095]

[Formula 35]

$$\phi \cdot M_n = \phi \cdot A_s \cdot f_y \cdot (d - 0.5 \times a) \quad (35)$$

- 15 [0096]

[Formula 36]

$$a = \frac{A_s \cdot f_y}{0.85 \cdot f_c' \cdot b} \quad (36)$$

[0097]

(Collation with test result)

- 20 Here, by using the method of calculating the required lap splice length described above, the bond strength, and the required transverse reinforcement amount, it has been

checked whether or not a failure mode of column test specimens can be correctly determined.

Fig. 9 shows the dimension shape and the arrangement of reinforcement in test specimens and, and Tables 1 and 2 show results of the reviews. The positive side
5 represents the loading direction exerting compressive stress in upper side on casting concrete, and the negative side presents the loading direction exerting compressive stress in lower side on casting concrete.

[0098]

[Table 1]

Review result 1 of column member test

Design specification		No. 1			No. 2	
		Positive side	Negative side		Positive side	Negative side
Failure mode		Flexural yield + shear afterwards	Bond splitting		Flexural yield	Flexural yield
Designed lap splice length		50d _b	50d _b		50d _b	50d _b
Designed transverse reinforcement amount		0.0031	0.0031		0.0051	0.0051
Design limit deformation	R _d %	2.0	1.5		2.5	2.5
Clear span of column	H mm	3500				
Grout thickness at joint	h _b mm	30				
Effective depth of column	d mm	620				
Bond strength of column main reinforcement	τ_{bmax} N/mm ²	3.4	2.8		3.4	2.8
Bond strength of column main reinforcement	τ_{sbmax} N/mm ²	1.9	1.5		1.9	1.5
Required lap splice length	L _d d _b	36.4	39.3		40.1	47.1
Column main reinforcement side	L _{d1} d _b	36.1	38.3		39.1	44.4
Sheath pipe side	L _{d2} d _b	36.4	39.3		40.1	47.1
Joint upper ineffective length	L ₁ mm	163	163		163	163
Joint lower ineffective length	L _b mm	211	121		292	292
Check excess/insufficiency of lap splice length		OK	OK		OK	OK
Nominal diameter of steel reinforcement	d _b mm	25				
Yield strength of steel reinforcement	f _y N/mm ²	434				
Outer diameter of sheath pipe	D _s mm	58				
Equivalent covering thickness	C _s mm	77				
Yield strength of reinforcement	f _{wy} N/mm ²	443				
Bond strength reduction coefficient	α	1.0	0.80		1.0	0.80
Compressive intensity of concrete (1 axis)	f _c ' N/mm ²	27.4				
Splitting strength of concrete	f _t ' N/mm ²	2.09				
Safety coefficient of design slitting stress intensity	K _{exp2}	2.06	1.88		2.27	2.27

Working bond stress of column main reinforcement	τ_b		2.04	1.85	2.24	2.24
Working bond stress of sheath pipe	τ_{sb}	N/mm ²	1.29	1.17	1.42	1.42
Average splitting stress intensity	σ_{av}	N/mm ²	1.03	1.03	1.03	1.03
Design splitting stress intensity	σ_{dl}	N/mm ²	2.12	2.42	2.33	2.92
Required transverse reinforcement ratio	pwd	N/mm ²	0.00274	0.00311	0.00300	0.00375
Check excess/insufficiency of transverse reinforcement amount			OK	NG	OK	OK

[0099]

[Table 2]

Review result 2 of column member test

Design specification		No. 1		No. 2	
		Positive side	Negative side	Positive side	Negative side
Failure mode		pulling out of main reinforcement at joint end	pulling out of main reinforcement at joint end	pulling out of main reinforcement at joint end	pulling out of main reinforcement at joint end
Designed lap splice length		33d _b	33d _b	33d _b	33d _b
Designed transverse reinforcement amount		0.0031	0.0031	0.0051	0.0051
Design limit maximum deformation	R _d		1.0	2.5	
Clear span of column	H		3500		
Grout thickness at bottom of joint	h _b		30		
Effective depth of column	d		620		
Bond strength of column main reinforcement	τ_{bmax}		2.9	3.6	
Bond strength of column main reinforcement	τ_{sbmax}		1.6	2.0	
Required lap splice length	L _d		33.6	38.1	
Column main reinforcement side	L _{d1}		33.6	37.5	
Sheath pipe side	L _{d2}		33.2	38.1	
Joint upper ineffective length	L ₁		107	107	
Joint lower ineffective length	L _b		23	274	
Check excess/insufficiency of lap splice length			NG	NG	
Nominal diameter of steel reinforcement	d _b		25		

Yield strength of steel reinforcement	f_y	N/mm ²				434	
Outer diameter of sheath pipe	D_s	mm				58	
Equivalent covering thickness	C_s	mm				77	
Yield strength of reinforcement	f_{vy}	N/mm ²				443	
Bond strength reduction coefficient	α		1.0	0.80	1.0		0.80
Compressive intensity of concrete (1 axis)	fc'	N/mm ²				29.9	
Splitting strength of concrete	ft'	N/mm ²				2.38	
Safety coefficient of design slitting stress intensity	K_{exp2}		-	2.58	3.95		-
Working bond stress of column main reinforcement	τ_b		-	2.94	4.50		-
Working bond stress of sheath pipe	τ_{sb}	N/mm ²	-	1.61	2.47		-
Average splitting stress intensity	σ_{lav}	N/mm ²	-	1.17	1.17		-
Design splitting stress intensity	σ_{ld}	N/mm ²	-	3.77	4.62		-
Required transverse reinforcement ratio	ρ_{wd}	N/mm ²	-	0.00486	0.00595		-
Check excess/insufficiency of transverse reinforcement amount				NG	NG		

[0100]

In Test specimen No. 1, determination results are acquired in which the required lap splice length and the required transverse reinforcement amount are satisfied on the positive side, and the transverse reinforcement amount is insufficient on the negative side. The result of the test coincides with the occurrence of bond splitting failure on the negative side.

[0101]

In Test specimen No. 2, the required lap splice length and the required transverse reinforcement amount are satisfied, and, the result of the test coincides with the formation of a flexural toughness pattern having no decrease in the load.

[0102]

For Test specimens No. 3 and No. 4, determination results are acquired in which both the lap splice length and the transverse reinforcement amount are insufficient. In Test specimens No. 3 and No. 4, pulling out of discharge of the main reinforcement from the joining portion occurs, which coincides with the results of the tests.

[0103]

In this way, it has been checked that a failure modes acquired through the test can be correctly determined for any of the test specimens.

[0104]

Accordingly, in the RC member joining structure according to this embodiment, the structure of a joining portion having high reliabilities can be realized using a non-contact lap splice of which the design method has not been conventionally established.

[0105]

As above, while one embodiment of the RC member according to the present

invention has been described, the present invention is not limited to the one embodiment described above, and a change can be appropriately made in a range not departing from the concept thereof.

[0106]

- 5 One RC member according to the present invention may not necessarily need to be a stub and, for example, may be a column member. In addition, the other RC member may not be a PCa column but an RC column of cast-in-place.

[Industrial Applicability]

[0107]

- 10 According to an RC member joining structure according to the present invention, the structure of a joining portion having high reliabilities can be realized by using a non-contact lap splice of which a design method has not been conventionally established.

[Reference Signs List]

- 15 [0108]

1 Stub (one RC member)

2 PCa column (the other RC member/column)

3 Main reinforcement

4 Sheath pipe

- 20 5 Main reinforcement

6 Diaphragm portion

7 Joint portion

8 Non-contact lap splice

A RC member joining structure

[CLAIMS]

What is claimed is:

[Claim 1]

An RC member joining structure in which one RC member is formed by
 5 extending main reinforcement from a joining end face to the outer side, and the other RC
 member is a column and is formed by having sheath pipes buried to open to the joining
 end face in parallel with the main reinforcement,

wherein the main reinforcement of the one RC member is inserted into the
 sheath pipe, a grout material is filled inside the sheath pipe, and the main reinforcement
 10 of the one RC member and a main reinforcement of the other RC member are connected
 by a non-contact lap splice with each other, having a gap therebetween, and

wherein the required lap splice length L_b of the non-contact lap splice is set in
 accordance with Equations (1) to (6) below:

[Formula 1]

$$L_d \geq \max(L_{d1}, L_{d2}) \quad (1)$$

[Formula 2]

$$L_{d1} = \left\{ \frac{\frac{L_b - h_b}{d_b} \cdot \tau_{b\max} + \frac{1}{4} \cdot \sigma_y \cdot \left(1 - \frac{h_b}{H}\right)}{\tau_{b\max} + \frac{d_b}{4H} \cdot \sigma_y} \right\} \cdot \frac{1}{1 - \gamma_t} \cdot d_b \quad (2)$$

[Formula 3]

$$L_{d2} = \left(\frac{1}{4} \cdot \frac{\sigma_y}{\tau_{sb\max}} \cdot \frac{d_b}{D_s} + \frac{L_b - h_b}{d_b} \right) \cdot \frac{1}{1 - \gamma_t} \cdot d_b \quad (3)$$

[Formula 4]

$$L_b = 0.26(R_d - R_y) \cdot d_{cy} \quad (4)$$

[Formula 5]

$$\tau_{b\max} = \alpha \cdot 0.658 \sqrt{f_c} \quad (5)$$

5 [Formula 6]

$$\tau_{sb\max} = \alpha \cdot 0.366 \sqrt{f_c} \quad (6)$$

wherein L_d is the lap splice length (mm), d_b is the nominal diameter (mm) of the main reinforcement of the column, L_b is the joint lower ineffective length (mm) and is acquired by Equation (4), and σ_{yf} is the yield strength (N/mm²) of the main reinforcement
10 of the column;

wherein H is the shear span (mm) of the column, h_b is the grout thickness at bottom of joint (mm), D_s is the sheath pipe outer diameter (mm), $\tau_{b\max}$ is the bond strength (N/mm²) of the main reinforcement of the column and is acquired by Equation (5), and $\tau_{sb\max}$ is the bond strength (N/mm²) of the sheath pipe and is acquired by
15 Equation (6);

wherein γ_t is the ratio of the joint upper ineffective length to the lap splice length, R_d is the design limit member angle (%), R_y is the yield member angle (%), and d_{cy} is an effective depth (mm) of the column and is the distance from the compressive stress fiber at the cross-section of a pedestal portion to the centroid position of the steel

reinforcement (joint reinforcement) in tension; and

α is the bond reduction coefficient, and f_c is the concrete specified strength (N/mm²).

[Claim 2]

5 The RC member joining structure according to claim 1,

wherein a yield moment M_Y at the cross-section based on arrangement of main reinforcement of the other RC member arranged on the inner side of the sheath pipe is above an acting bending moment M_{LE} at the joint end point, and the required lap splice length L_d is set so as not to yield in failure at the cross-section of the joint end point of

10 the non-contact lap splice by satisfying a condition of Equation (7) below;

[Formula 7]

$$M_{LE} = \phi_e \cdot M_{cy} \cdot \frac{H - L_d - h_b}{H - L_b} < M_Y \quad (7)$$

wherein M_Y is the yield moment (kNm) at the cross-section according to the column main reinforcement at the joint end point and is acquired by Equation (8) below,

15 M_{LE} is the moment (kNm) acting on the joint end point, M_{cy} is the yield moment (kNm) at the cross-section of the pedestal and is acquired by Equation (9) below, and ϕ_e is the coefficient of bending moment and is 1.0; and

wherein A_s is the total cross-sectional area (mm²) of the steel reinforcement in tension, d_Y is the effective depth (mm) of the column and is the distance from the

20 compressive fiber stress of the joint end point cross-section to the centroid of the steel reinforcement in tension, a is the stress block depth (mm) of concrete and is calculated by Equation (10) from the balance at the cross-section, and F_c is the concrete specified strength (N/mm²), f_y is the specified yield strength (N/mm²) of the main reinforcement of

the column, and b is the member width (mm).

[Formula 8]

$$M_Y = A_s \cdot f_y \cdot (d_Y - 0.5 \times a) \cdot 10^{-6} \quad (8)$$

[Formula 9]

$$M_{cy} = A_s \cdot f_y \cdot (d_{cy} - 0.5 \times a) \cdot 10^{-6} \quad (9)$$

[Formula 10]

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

[Claim 3]

The RC member joining structure according to claim 1 or 2,

wherein the required transverse reinforcement amount p_{wd} in a lap splice section is set in accordance with Equation (11) and Equation (12);

[Formula 11]

$$p_{wd} \geq \frac{C_s}{C_s + D_s} \cdot \frac{\sigma_{td}}{f_{wy}} \quad (11)$$

[Formula 12]

$$\sigma_{td} = \frac{1}{\alpha} \max \left(0.78 \cdot \frac{\tau_b}{\sigma_{td}}, 1.6 \cdot \frac{\tau_{sb}}{\sigma_{t0}} \right) \times \sigma_{tav} \quad (12)$$

wherein C_s is the smaller value of a gap (mm) between sheath pipes and twice

the minimum covering thickness (mm) of the sheath pipe, D_s is the sheath pipe outer diameter (mm), and p_{wd} is the required transverse reinforcement ratio, and f_{wy} is the specified yield strength (N/mm²) of the transverse reinforcement;

wherein σ_{td} is the design splitting stress intensity (N/mm²), σ_{t0} is the reference splitting strength (N/mm²), and σ_{tav} is the average stress intensity (N/mm²) acting on a splitting face when concrete is failed in splitting and is acquired by Equation (13);

wherein α is the bond reduction coefficient, τ_b is the working bond stress (N/mm²) of the main reinforcement of the column and is acquired by Equation (14) below, and τ_{sb} is the working bond stress (N/mm²) of the sheath pipe and is acquired by Equation (15) below; and

wherein f_t is the splitting strength (N/mm²) of concrete and is acquired by Equation (17) below.

[Formula 13]

$$\sigma_{tav} = \frac{\left(\frac{C_s}{D_s} + 2\right) \cdot f_t}{\left(\frac{C_s}{D_s} + 1\right)^2 + 1 + \left\{\left(\frac{C_s}{D_s} + 1\right)^2 - 1\right\} \cdot \frac{f_t}{f_c}} \quad (13)$$

[Formula 14]

$$\tau_b = \frac{d_b}{4} \cdot \frac{\sigma_y}{L_d + h_b - L_t - L_b} \left(1 - \frac{L_d + h_b - L_t}{H}\right) \quad (14)$$

[Formula 15]

$$\tau_{sb} = \frac{d_b^2}{4D_s} \cdot \frac{\sigma_y}{L_d + h_b - L_t - L_b} \quad (15)$$

[Formula 16]

$$L_t = 0.13 \times L_d \quad (16)$$

[Formula 17]

$$f_t = 0.56 \cdot \sqrt{f_c} \quad (17)$$