

Description

Title of Invention: CONNECTION OF CONCRETE-FILLED STEEL TUBE COLUMN AND REINFORCED CONCRETE SLAB

Technical Field

[0001] This disclosure relates to connections of concrete-filled steel tube columns (hereinafter, "CFT columns" ("CFT" is an abbreviation for "Concrete Filled steel Tube")) and reinforced concrete slabs (hereinafter, "RC slabs" or "RC slab"). In particular, the disclosure relates to connections of RC slabs as flat slabs and CFT columns penetrating through the slabs.

Background

[0002] Flat slab structures have been used in architectural structures such as office/residential buildings or warehouses with many external walls, basements, and the like, making use of their advantages in formwork saving, floor height reduction, and so on. Such flat slab structures are generally formed by reinforced concrete columns (RC columns) and RC slabs. This arrangement, however, requires a structural component called a capital part, which is used for transferring vertical loads on an RC slab to the columns, causing the problems of reduction in ceiling height around the columns and deterioration of construction workability.

[0003] Therefore, as structures that allow omitting capital parts, various connections of CFT columns and RC slabs have been proposed. Referring to FIGs. 9 and 10, JPH8109695A (PTL 1) describes a connection comprising: a steel tube column 61; an RC slab 64; four ribs 63 welded to the steel tube column 61 through slits cut in the steel tube column 61, each of the ribs 63 having two parts, one part being located inside the steel tube column 61 and the other part being located inside the RC slab 64; and a horizontal bearing steel plate 62 welded to the steel tube column 61 and having the RC slab 64 mounted thereon.

[0004] Referring to FIGs. 11 and 12, JP2000160685A (PTL 2) describes a connection capable of resisting horizontal loads comprising: a CFT column 71; an RC slab 72; and bearing steel plates 73, 74 joined to the CFT column 71 at positions corresponding to the bottom and top surfaces of the RC slab 72, respectively, so as to surround the CFT column 71.

[0005] Referring to FIGs. 13(A) and 13(B), JP2008088639A (PTL 3) describes a connection capable of resisting vertical loads on an RC slab, the connection comprising: a plurality of perforated dowels 82 fixed to the outer circumferential surface of a steel tube column 81, at positions between top and bottom reinforcements 86, 87 constituting slab reinforcements of an RC slab 84, each of the perforated dowels 82 having a largest

plane coinciding with a vertical plane; and auxiliary reinforcing bars 83 provided independently from the slab reinforcements 86, 87 and threaded through the perforations 82a in the dowels.

Citation List

Patent Literature

- [0006] PTL 1: JPH8109695A
- PTL 2: JP2000160685A
- PTL 3: JP2008088639A

Summary

Technical Problem

- [0007] However, the techniques described in PTL 1 to PTL 3 all require further improvement in terms of resistance to vertical loads on RC slabs.
- [0008] Specifically, the connection described in PTL 1 has ribs interfering with slab reinforcements, which prevents sufficient fixation of slab reinforcements at the joining parts. In addition, the extent to which ribs protrude into a steel tube column is so small that vertical loads imposed on the RC slab cannot be sufficiently transferred to the infilled concrete.
- [0009] The connection described in PTL 2 is a structure that is designed focusing on ways to resist horizontal loads, and is thus not able to sufficiently transfer vertical loads imposed on an RC slab to the infilled concrete.
- [0010] The connection described in PTL 3 is designed to transfer vertical loads imposed on an RC slab to the infilled concrete in a steel tube column merely by the bond of the steel tube column to the infilled concrete alone, and is thus not able to sufficiently transfer vertical loads imposed on RC slabs to the infilled concrete. Additionally, with the connection described in PTL 3, when large vertical loads are applied to an RC slab and when the plate thickness of the steel pipe or tube is small, plasticization can locally develop in the steel tube column, leading to premature failure of the column.
- [0011] It could thus be helpful to provide such a connection of a CFT column and an RC slab that can resist larger vertical loads imposed on the RC slab.

Solution to Problem

- [0012] We thus provide:
 - (1) A connection of a steel tube column infilled with concrete and an RC slab, wherein
 - a plurality of ribs are connected to the steel tube column through slits provided in the steel tube column, such that the largest planes of the ribs coincide with a substantially vertical plane, each of the ribs having two parts, one part being located inside the steel tube column and the other part being located inside the RC slab,

a bearing steel plate is connected to the outer circumferential surface of the steel tube column and to the lower ends of the plurality of ribs, such that the largest plane of the bearing steel plate coincides with a substantially horizontal plane, the RC slab is mounted on the bearing steel plate, and each of the ribs has at least one first through-hole in the one part located inside the steel tube column.

- [0013] (2) The connection according to aspect (1), wherein each of the ribs has a plurality of the first through-holes along a substantially vertical direction.
- [0014] (3) The connection according to aspect (1) or (2), wherein each of the ribs has at least one second through-hole in the other part located inside the RC slab, an auxiliary reinforcing bar threaded through the second through-hole is arranged inside the RC slab, and at least some of slab reinforcements are U-shaped reinforcing bars, as viewed in a vertical plane, which are arranged such that their U-shaped portions catch and hold the auxiliary reinforcing bar.
- [0015] (4) The connection according to aspect (3), wherein each of the ribs has a plurality of the second through-holes along a substantially vertical direction.
- [0016] (5) The connection according to aspect (3) or (4), wherein the auxiliary reinforcing bar(s) are ring-shaped reinforcing bar(s) threaded through the second through-hole(s) in each of the ribs and extending to surround, as viewed in a horizontal plane, the steel tube column.
- [0017] (6) The connection according to aspect (3) or (4), wherein the auxiliary reinforcing bars are at least four linear reinforcing bars arranged to surround, as viewed in a horizontal plane, the steel tube column.
- [0018] (7) The connection according to any one of aspects (1) to (6), wherein the connecting of the plurality of ribs to the steel tube column and/or the connecting of the bearing steel plate to the outer circumferential surface of the steel tube column and to the lower ends of the plurality of ribs are performed by fillet welding.
- [0019] (8) The connection according to any one of aspects (1) to (7), wherein an auxiliary steel plate is connected to the outer circumferential surface of the steel tube column and to the upper ends of the plurality of ribs, such that the largest plane of the auxiliary steel plate coincides with a substantially horizontal plane.

Advantageous Effect

- [0020] The connection of a CFT column and an RC slab disclosed herein may resist larger vertical loads imposed on the RC slab.

Brief Description of Drawings

[0021] In the accompanying drawings:

[fig.1]FIG. 1 illustrates a connection 100 according to a first one of the disclosed embodiments, (A) is a vertical cross-sectional view and (B) is a horizontal cross-sectional view;

[fig.2]FIG. 2 is a diagram illustrating the positions at which slits 14 are provided in the steel tube column 10 in the connection 100 presented in FIG. 1;

[fig.3]FIG. 3 is a diagram illustrating a failure mode of a slab 20 when placed under punching shear force;

[fig.4]FIG. 4 is a vertical cross-sectional view of a connection 200 according to a second embodiment;

[fig.5]FIG. 5 is a horizontal cross-sectional view of a connection 300 according to a third embodiment;

[fig.6]FIG. 6 illustrates a connection 400 according to a fourth embodiment, (A) is a vertical cross-sectional view and (B) is a horizontal cross-sectional view;

[fig.7]FIG. 7 illustrates a connection 500 according to a fifth embodiment, (A) is a vertical cross-sectional view and (B) is a horizontal cross-sectional view;

[fig.8]FIG. 8 is a horizontal cross-sectional view of a connection 600 according to a sixth embodiment;

[fig.9]FIG. 9 is a top view of a connection described in PTL 1;

[fig.10]FIG. 10 is an A-A cross-sectional view of FIG. 9;

[fig.11]FIG. 11 is a vertical cross-sectional view of a connection described in PTL 2;

[fig.12]FIG. 12 is a perspective view of the connection described in PTL 2;

[fig.13]FIG. 13(A) is a top view of a connection described in PTL 3; and FIG. 13(B) is an A-A cross-sectional view of FIG. 13(A).

DETAILED DESCRIPTION

[0022] Embodiments of the connection disclosed herein will be described in detail below with reference to the drawings. It is noted that similar members are referred to by the same reference numerals throughout the embodiments.

[0023] (First Embodiment)

With reference to FIGS. 1 to 3, a connection 100 of a CFT column and an RC slab according to a first embodiment is described below. In this embodiment, a steel tube column 10 (a steel pipe column) is installed to penetrate through an RC slab 20, which makes it possible to reduce the welding work as well as the time and cost for construction, as compared to the case where the steel tube column is divided into sections. The RC slab may be a prestressed concrete slab (PC slab).

[0024] That is, with reference to FIGS. 1 and 2, a plurality of (in this embodiment, eight) slits 14 are provided in the steel tube column 10 infilled with concrete 12. A rib 30, which will be discussed below, is inserted through each slit 14. While the steel tube

column 10 is illustrated in FIG. 1 as being a circular steel pipe or tube, it is not so limited and may thus be a square or rectangular steel pipe or tube.

- [0025] Referring first to FIG. 1, a plurality of (in this embodiment, eight) ribs 30 are connected to the steel tube column 10 through the respective slits 14 provided in the column, such that the largest planes of the ribs coincide with a substantially vertical plane. Each of the ribs 30 has two parts, one part being located inside the steel tube column 10 and the other part being located inside the RC slab 20. It should be noted that the phrase "the largest planes of the ribs coincide with a substantially vertical plane" is intended to cover the case where the largest planes of the ribs coincide with the vertical plane, as well as the case where the largest planes of the ribs are at an inclination of 5° or less with respect to the vertical plane. Since these ribs 30 extend both inside and outside the steel tube column 10, it is possible to reduce out-of-plane bending of the skin plate of the steel tube column 10 and prevent premature plastification of the skin plate of the steel tube column 10, compared to installing ribs only outside the steel tube column.
- [0026] In addition, a bearing steel plate 40 is connected to the outer circumferential surface of the steel tube column 10 and to the lower ends of the plurality of ribs 30, such that the largest plane of the bearing steel plate coincides with a substantially horizontal plane. Then, the RC slab 20 is mounted on the bearing steel plate 40. It should be noted that the phrase "the largest plane of the bearing steel plate coincides with a substantially horizontal plane" is intended to cover the case where the largest plane of the bearing steel plate coincides with the horizontal plane as well as the case where the largest plane of the bearing steel plate is at an inclination of 5° or less with respect to the horizontal plane.
- [0027] In this embodiment, each rib 30 has first through-holes 32 penetrating through its surface at positions inside the steel tube column 10. Consequently, the area of contact between the ribs 30 and the infilled concrete 12 increases, with the result that vertical loads transferred from the RC slab 20 may be transferred to the infilled concrete 12 in the steel tube column 10, by means of the bond strength between the ribs 30 and the infilled concrete 12 as well as the bearing capacity of the first through-holes 32 and the lower ends of the ribs 30 and the infilled concrete 12. Thus, the connection 100 according to this embodiment may resist larger vertical loads imposed on the RC slab 20.
- [0028] In this embodiment, as illustrated in FIG. 1(B), a total of eight ribs are arranged in four directions at 90° angles from the steel tube column 10, two ribs for each direction, as viewed in a horizontal plane. This configuration easily avoids interference of ribs with slab reinforcements 22 inside the RC slab 20. The number of ribs is not limited to eight and, for example, a total of four ribs (instead of eight ribs) may be arranged in the

four directions, one for each direction.

- [0029] The ribs 30 are made of steel sheets. The thickness of each rib 30 is not particularly limited, yet, for example, the lower limit may be 6 mm and, considering the skin plate thickness (up to 28 mm) for a circular steel tube column, the upper limit may be 32 mm. This is not so limited for a square or rectangular steel pipe or tube. The shape of each rib 30 is not particularly limited, yet the largest plane preferably has a rectangular shape, as illustrated in FIG. 1(A). To guarantee a sufficient thickness of cover concrete, each rib 30 preferably has a vertical length L_v that is 70 % to 90 % of the slab thickness. In addition, the part of each rib 30 located outside the steel tube column 10 preferably has a horizontal length that is 50 % to 200 % of the slab thickness. On the other hand, the part of each rib 30 located inside the steel tube column 10 preferably has a horizontal length that is 15 % to 30 % of the diameter of the steel tube column 10, from the perspective of ensuring transfer of vertical loads to the infilled concrete 12.
- [0030] No particular limitation is placed on the number, shape, or dimensions of the first through-holes 32 in each rib 30. From the perspective of facilitating concrete flow into the first through-holes, however, the first through-holes 32 preferably have a circular shape. In addition, from the viewpoint of increasing the area of contact between the ribs 30 and the infilled concrete 12, it is more preferable to provide multiple holes with suitable dimensions than to provide a single, large hole. Accordingly, each rib 30 preferably has a plurality of first through-holes 32 along a substantially vertical direction. In this embodiment, each rib 30 has three first through-holes 32. This allows more reliable transfer of vertical loads to the infilled concrete 12. As used herein, the phrase "along a substantially vertical direction" is intended to mean a state in which adjacent first through-holes at least partially overlap one another in the vertical direction.
- [0031] In this embodiment, as illustrated in FIG. 1(B), the bearing steel plate 40 is a ring-shaped steel sheet which extends to surround the steel tube column 10. In this case, the bearing steel plate 40 is preferably formed by joining two equal parts together by welding or the like. However, no particular limitation is placed on the shape of the bearing steel plate 40, insofar as the bearing steel plate 40 extends immediately below all ribs and is large enough to support the RC slab 20. The bearing steel plate 40 preferably has a plate thickness that is approximately 10 % to 20 % of the slab thickness. Embodiments in which the bearing steel plate 40 has different shapes will be discussed later.
- [0032] Then, the arrangement of reinforcing bars inside the RC slab 20 will be described. As illustrated in FIG. 3, in an ultimate state in which the slab 20 fails under punching shear force, a failure surface A that forms a part of the lateral surface of a circular cone

pointing upward at 45° from the top surface of the bearing steel plate 40 is assumed. To resist such a failure, it is necessary to have reinforcing bars of sufficient length extending continuously across the failure surface A. Based on normal bar arrangement methods, however, it is difficult to arrange reinforcing bars of sufficient length between the failure surface A and the steel tube column 10.

- [0033] As such, in this embodiment, reinforcing bars are arranged inside the RC slab 20 as illustrated in FIGS. 1(A) and 3. Firstly, each rib 30 has three second through-holes 34 arranged along the vertical direction and penetrating through its surface at positions inside the RC slab 20. Three ring-shaped auxiliary reinforcing bars 28 are arranged inside the RC slab 20 such that they are threaded through respective second through-holes positioned at the same heights in each rib 30 and extend to surround, as viewed in a horizontal plane, the steel tube column 10. Additionally, some of the slab reinforcements 22 arranged in a matrix form, as viewed in a horizontal plane, are U-shaped reinforcing bars 24, as viewed in a vertical plane, which are arranged such that their U-shaped portions catch and hold (hook) auxiliary reinforcing bars 28. With this configuration, the U-shaped reinforcing bars 24 can resist any tension applied to the failure surface A, allowing the RC slab 20 to resist larger punching shear force. In other words, the above configuration may ensure fixation of the slab reinforcements 22 and achieve reinforcement of the RC slab in the periphery of the joining parts.
- [0034] Among the slab reinforcements 22, those reinforcing bars 26 that do not catch and hold any auxiliary reinforcing bars 28 may be common slab reinforcements, i.e., top reinforcements and bottom reinforcements, or U-shaped reinforcing bars, each formed by connecting distal ends of a pair of a top reinforcement and a bottom reinforcement overlapping in the vertical direction.
- [0035] In the case where each rib 30 has a plurality of second through-holes 34, the through-holes are preferably arranged along a substantially vertical direction. As used herein, the phrase "along a substantially vertical direction" is intended to mean a state in which adjacent second through-holes at least partially overlap one another in the vertical direction.
- [0036] As illustrated in FIG. 1(A), when the bottom surface of the bearing steel plate 40 is flush with the bottom surface of the RC slab 20, this may facilitate concrete formwork and improve finished appearance. In addition, the fire proof time and expense can be significantly simplified due to the flatness of the whole ceiling surface and the smallest area exposed to fire of the bearing steel plate. Besides, the heat transfer to the bearing steel plate in fire is also minimized because the bearing steel plate is embedded in the reinforced concrete slab. Alternatively, when the top surface of the bearing steel plate 40 is flush with the bottom surface of the RC slab 20, the effective depth of the RC slab increases by the plate thickness of the bearing steel plate 40 accordingly, allowing

the RC slab to resist larger punching shear force.

[0037] In addition, the connecting of the plurality of ribs 30 to the steel tube column 10 and/or the connecting of the bearing steel plate 40 to the outer circumferential surface of the steel tube column 10 and to the lower ends of the plurality of ribs 30 are preferably performed by fillet welding. Such connecting operation by fillet welding may reduce the time and cost for construction as compared to performing connecting operation by full penetration welding.

[0038] (Second Embodiment)

With reference to FIG. 4, a connection 200 of a CFT column and an RC slab according to a second embodiment is described below. The connection 200 according to this embodiment is similar to the connection 100 according to the first embodiment, except for the shape of each rib 30 and the number of first through-holes 32.

[0039] In this embodiment, the maximum vertical length of one part of each rib 30 located inside the steel tube column 10 is larger than the vertical length of the other part of the rib 30 located inside the RC slab 20. This configuration allows larger vertical loads to be transferred to the infilled concrete 12 in the steel tube column 10. In addition, with ribs having such shape, as illustrated in FIG. 4, it is easy to increase the number of first through-holes. In this embodiment, four first through-holes 32 are provided along the vertical direction.

[0040] (Third Embodiment)

With reference to FIG. 5, a connection 300 of a CFT column and an RC slab according to a third embodiment is described below. The connection 300 according to this embodiment is similar to the connection 100 according to the first embodiment, except for the arrangement of auxiliary reinforcing bars 28. As the connection 300 according to this embodiment has a vertical cross-section similar to that illustrated in FIG. 1(A), further illustration is omitted.

[0041] In this embodiment, as illustrated in FIG. 5, three linear auxiliary reinforcing bars 28A, three linear auxiliary reinforcing bars 28B, three linear auxiliary reinforcing bars 28C, and three linear auxiliary reinforcing bars 28D are arranged to surround, as viewed in a horizontal plane, the steel tube column 10. The three auxiliary reinforcing bars 28A are threaded through respective second through-holes 34 positioned at the same heights in two ribs 30. The three auxiliary reinforcing bars 28B are threaded through respective second through-holes 34 positioned at the same heights in another two ribs. The three auxiliary reinforcing bars 28C are threaded through respective second through-holes 34 positioned at the same heights in yet another two ribs 30. The three auxiliary reinforcing bars 28D are threaded through respective second through-holes 34 positioned at the same heights in the remaining two ribs 30. U-shaped reinforcing bars 24 are arranged such that their U-shaped portions catch and hold (hook)

the auxiliary reinforcing bars 28A, 28B, 28C, 28D.

[0042] (Fourth Embodiment)

With reference to FIG. 6, a connection 400 of a CFT column and an RC slab according to a fourth embodiment is described below. The connection 400 according to this embodiment is similar to the connection 100 according to the first embodiment, except that it has an auxiliary steel plate 50.

[0043] The RC slab 20 is mounted on the bearing steel plate 40, and shearing force is applied to the skin plate of the steel tube column 10 and out-of-plane bending occurs. In a CFT column, a steel pipe or tube with a small plate thickness may be used, which poses a concern for stress concentration on the skin plate, particularly, at positions above ribs 30, leading to a premature plasticization. Therefore, in this embodiment, a ring-shaped auxiliary steel plate 50 is connected to the outer circumferential surface of the steel tube column 10 and to the upper ends of the ribs 30, such that the largest plane of the auxiliary steel plate coincides with a substantially horizontal plane. This configuration eliminates the aforementioned concern even when a steel pipe or tube with a small plate thickness is used. The connecting operation is preferably performed by fillet welding.

[0044] (Fifth Embodiment)

With reference to FIG. 7, a connection 500 of a CFT column and an RC slab according to a fifth embodiment is described below. The connection 500 according to this embodiment is similar to the connection 100 according to the first embodiment, except that it has bearing steel plates 40 with a different shape.

[0045] In this embodiment, a total of four bearing steel plates 40 are provided, each being arranged immediately below two ribs 30, respectively. With this configuration, bearing steel plates are provided only below ribs to reduce the amount of steel material used. Also, the bearing steel plates have a substantially rectangular shape, which reduces waste in material processing.

[0046] (Sixth Embodiment)

With reference to FIG. 8, a connection 600 of a CFT column and an RC slab according to a sixth embodiment is described below. The connection 600 according to this embodiment is similar to the connection 100 according to the first embodiment, except that the auxiliary reinforcing bars 28 are arranged as described above for the third embodiment and the shape of the bearing steel plates 40 is as described above for the fifth embodiment.

[0047] (Other Embodiments)

The aforementioned first to sixth embodiments are merely representative of the disclosed connection and should not be taken as limiting the scope of the claims. Other configurations are also possible, including, for example, a connection obtained by

combining at least two of the first to sixth embodiments as appropriate.

Reference Signs List

- [0048] 100, 200, 300, 400, 500, 600 Connection
- 10 Steel tube column
 - 12 Infilled concrete
 - 14 Slit
 - 20 Reinforced concrete slab (RC slab)
 - 22 Slab reinforcement
 - 24 U-shape reinforcing bar
 - 26 Other slab reinforcement
 - 28 Auxiliary reinforcing bar
 - 30 Rib
 - 32 First through-hole
 - 34 Second through-hole
 - 40 Bearing steel plate
 - 50 Auxiliary steel plate

Claims

- [Claim 1] A connection of a steel tube column infilled with concrete and a reinforced concrete slab, wherein
a plurality of ribs are connected to the steel tube column through slits provided in the steel tube column, such that the largest planes of the ribs coincide with a substantially vertical plane, each of the ribs having two parts, one part being located inside the steel tube column and the other part being located inside the reinforced concrete slab,
a bearing steel plate is connected to the outer circumferential surface of the steel tube column and to the lower ends of the plurality of ribs, such that the largest plane of the bearing steel plate coincides with a substantially horizontal plane,
the reinforced concrete slab is mounted on the bearing steel plate, and each of the ribs has at least one first through-hole in the one part located inside the steel tube column.
- [Claim 2] The connection according to claim 1, wherein each of the ribs has a plurality of the first through-holes along a substantially vertical direction.
- [Claim 3] The connection according to claim 1 or 2, wherein
each of the ribs has at least one second through-hole in the other part located inside the reinforced concrete slab,
an auxiliary reinforcing bar threaded through the second through-hole is arranged inside the reinforced concrete slab, and
at least some of slab reinforcements are U-shaped reinforcing bars, as viewed in a vertical plane, which are arranged such that their U-shaped portions catch and hold the auxiliary reinforcing bar.
- [Claim 4] The connection according to claim 3, wherein each of the ribs has a plurality of the second through-holes along a substantially vertical direction.
- [Claim 5] The connection according to claim 3 or 4, wherein the auxiliary reinforcing bar(s) are ring-shaped reinforcing bar(s) threaded through the second through-hole(s) in each of the ribs and extending to surround, as viewed in a horizontal plane, the steel tube column.
- [Claim 6] The connection according to claim 3 or 4, wherein the auxiliary reinforcing bars are at least four linear reinforcing bars arranged to surround, as viewed in a horizontal plane, the steel tube column.
- [Claim 7] The connection according to any one of claims 1 to 6, wherein the

connecting of the plurality of ribs to the steel tube column and/or the connecting of the bearing steel plate to the outer circumferential surface of the steel tube column and to the lower ends of the plurality of ribs are performed by fillet welding.

[Claim 8]

The connection according to any one of claims 1 to 7, wherein an auxiliary steel plate is connected to the outer circumferential surface of the steel tube column and to the upper ends of the plurality of ribs, such that the largest plane of the auxiliary steel plate coincides with a substantially horizontal plane.