

5 **[0001]** The present disclosure relates to a connection of a steel tube column (steel pipe column) filled with concrete (hereinafter referred to as a "CFT column") and either a beam formed from an H-shaped steel or a reinforced concrete slab (hereinafter referred to as an "RC slab").

[0002] In a connection using concrete filled steel tube (CFT) columns, when the load bearing ratio of the steel tubes used is large, that is, when the steel tubes have a small diameter ratio (which is the ratio of the diameter to the thickness of the steel tube), i.e., a large thickness with respect to diameter, the self weight of the building is almost borne by the steel tubes. From this follows that the connection can be established as a stable structure as long as the load in the vertical direction applied to the floor (i.e., floor load) is transmitted to the steel tubes.

[0004] In joining CFT columns and beams, it is common to use diaphragms. Diaphragm is a steel plate arranged to transmit a bending stress from a column to a beam, and as illustrated in FIGS. 4A to 4C, three types of diaphragm, i.e., through diaphragm, inner diaphragm, and outer diaphragm are known. As illustrated in FIG. 4A, through diaphragms cut into a steel tube and are arranged inside and outside thereof. Accordingly, in a connection using through diaphragms, the through diaphragms can function as shear keys for transmitting the floor load to the filled concrete, and a stable structure is naturally established.

[0005] However, in a construction in which through diaphragms are welded to steel tubes, as illustrated in FIG. 4A, two welding lines are required for each through diaphragm (thus, four welding lines are required for welding upper and lower pairs of through diaphragms), and the welding amount is large. As such, automatic welding is generally performed by a welding robot having two
5 torches. In an environment without such a welding robot, it is necessary to perform welding requiring much time and labor to manufacture.

[0006] On the other hand, in a column-beam connection using an inner diaphragm as illustrated in FIG. 4B or an outer diaphragm as illustrated in FIG.
10 4C, cutting of steel tubes is unnecessary. Also, since only one weld line is required for each diaphragm, the welding amount is reduced to about half of the through diaphragm case. However, since the inner diaphragm is attached to the inner peripheral surface of the steel tube and the outer diaphragm is to the outer peripheral surface of the steel tube, unlike the through diaphragm,
15 they are not expected to function as a shear key that transmits the floor load to the filled concrete. Therefore, as disclosed in JP3168837B (PTL 1) disclosing a technique relating to outer diaphragms, it is necessary to provide a mechanism for transmitting the floor load to the filled concrete by separately welding a ring-shaped shear connector to the inner surface of the
20 steel tube, and construction could not be simplified.

CITATION LIST

Patent Literature

[0007] PTL 1: JP3168837B
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SUMMARY

(Technical Problem)

[0008] It would thus be helpful to provide a connection using a CFT column that can more effectively transmit a floor load to the filled concrete and withstand a larger floor load even when outer diaphragms are used, and a
30 method of producing a connection using CFT columns that can provide such a connection in a simpler way.

(Solution to Problem)

[0009] In order to provide a connection capable of efficiently transferring a
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floor load to the filled concrete by simple construction, we first conceived of using a internally-ribbed steel tube with a plurality of ribs extending spirally at intervals on the inner surface. However, since an internally-ribbed steel tube involves producing a steel strip with ribs formed by rolling thereon through a spiral tube manufacturing method, we recognized that one convex bead extending in a spiral pattern is formed on the outer surface due to seam welding, causing the problems as stated below.

[0010] In a steel sheet-rolled tube (pipe) or a UOE steel tube (pipe), a convex bead extends in the axial direction. Thus, in attaching an outer diaphragm to the outer surface of a steel tube, as illustrated in FIG. 5A, a notch is provided at the inner periphery of a ring-shaped outer diaphragm, the outer diaphragm can be easily attached to the steel tube by moving the outer diaphragm from the end of the steel tube so as to fit into the steel tube with the notch aligned with the convex bead. However, in the case of an internally-ribbed steel tube in which a convex bead extends in a spiral pattern, when attempting to attach a ring-shaped outer diaphragm to a steel tube in the same way, as illustrated in FIG. 5B, it is necessary to move the outer diaphragm to a predetermined position while turning it. In consideration of manufacturing tolerances such as variations in steel tube diameter and bending, moving the outer diaphragm to a predetermined position while turning is extremely complicated, difficult, and laborious in terms of production. In addition, when the outer diaphragm is not point-symmetrical, it is necessary for the orientation of the outer diaphragm to correspond exactly to the positional relationship designated by design specifications as a design requirement. This requires extremely accurate trial calculation and processing, in which the position of the convex bead corresponding to the attachment position should be precisely identified on three dimensions and the notch corresponding to the convex bead position be provided by machining in advance on the outer diaphragm. It is thus difficult to perform positioning with high precision.

[0011] Then, instead of fitting a ring-shaped outer diaphragm to a steel tube from an end, we conceived of cutting off beforehand a convex bead from an internally-ribbed steel tube at the position where outer diaphragms are to be attached, binding together outer diaphragm pieces at the portion from which the convex bead has been removed, and welding them to the steel tube. As a

result, it was discovered that there is no need to position a notch in advance with respect to the convex bead, and it is unnecessary to perform a work that is extremely complicated, difficult, and laborious in terms of manufacturing.

[0012] In this way, an outer diaphragm can be attached to an internally-ribbed steel tube. The application of the internally-ribbed steel tube can ensure the load transfer function by internal ribs that are molded integrally by factory rolling, without relying on the load transfer function of a ring-shaped shear connector on the inner surface of the steel tube as explained in the conventional method. This configuration enables reliable transmission of the floor load to the filled concrete.

[0013] The present disclosure was completed on the basis of the above findings and the primary features thereof are as follows.

(1) A connection comprising: a steel tube column filled with concrete; a pair of outer diaphragms formed from an upper diaphragm and a lower diaphragm and arranged in contact with an outer surface of the steel tube column so as to surround an outer periphery of the steel tube column such that the pair of outer diaphragms have largest planes coincident with a horizontal plane; and at least one of a beam formed from an H-shaped steel or a reinforced concrete slab connected to the pair of outer diaphragms, wherein the steel tube column is formed from an internally-ribbed steel tube that comprises a plurality of ribs extending spirally at intervals on its inner surface and a convex bead extending spirally on its outer surface, the convex bead is discontinued at an interval at a position where the pair of outer diaphragms are to be arranged on the outer surface of the steel tube column, wherein the interval is equal to or greater than a thickness of each outer diaphragm, and the pair of outer diaphragms are arranged so as to be fitted into a portion where the convex bead is discontinued.

[0014] (2) The connection according to (1), wherein the upper diaphragm and the lower diaphragm are respectively joined to an upper flange and a lower flange of the H-shaped steel.

[0015] (3) The connection according to (1), wherein the upper diaphragm and the lower diaphragm are respectively connected to a top reinforcement and a bottom reinforcement in the reinforced concrete slab.

[0016] (4) The connection according to (3), wherein at least one of the

upper diaphragm or the lower diaphragm is provided with a through-hole penetrating in the thickness direction thereof, and at least one of the top reinforcement or the bottom reinforcement has a U-shaped portion bent through the through-hole.

- 5 **[0017]** (5) The connection according to (3), wherein at least one of the top reinforcement or the bottom reinforcement comprises a lap joint having a distal end welded to at least one of the upper diaphragm or the lower diaphragm.

- 10 **[0018]** (6) A method of producing a connection, the method comprising: a first step of preparing a steel tube column, the steel tube column being formed from an internally-ribbed steel tube that comprises a plurality of ribs extending spirally at intervals on its inner surface and a convex bead extending spirally on its outer surface; a second step of welding a pair of outer diaphragms formed from an upper diaphragm and a lower diaphragm to an
15 outer surface of the steel tube column such that the pair of outer diaphragms are arranged so as to surround an outer periphery of the steel tube column and to have largest planes coincident with a horizontal plane; a third step of connecting at least one of a beam formed from an H-shaped steel or a reinforced concrete slab to the pair of outer diaphragms; and a fourth step of
20 filling the steel tube column with concrete, wherein after the first step and before the second step, the convex bead is partially removed by cutting such that the convex bead is discontinued at an interval at a position where the pair of outer diaphragms are to be arranged on the outer surface of the steel tube column, wherein the interval is equal to or greater than a thickness of each
25 outer diaphragm, and in the second step, the pair of outer diaphragms are arranged so as to be fitted into a portion where the convex bead is discontinued to thereby obtain the connection according to (1).

(Advantageous Effect)

- 30 **[0019]** The connection using CFT columns according to the present disclosure can more effectively transmit the floor load to the filled concrete and withstand a larger floor load even when outer diaphragms are used. Further, according to the production method disclosed herein, it is possible to obtain the above-described connection in a simpler way.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] In the accompanying drawings:

FIGS. 1A to 1C illustrate a bonding structure 100 according to a first embodiment of the present disclosure, where FIG. 1A is a vertical sectional view, FIG. 1B is a horizontal sectional view, and FIG. 1C is a side view;

FIG. 2A illustrates a convex bead present on the surface of a steel tube column 10 used in the present disclosure and a cutting position thereof; FIG. 2B illustrates the step of welding an upper diaphragm 20 to the steel tube column 10 after the cutting of the convex bead; and FIG. 2C illustrates a state after the welding;

FIGS. 3A and 3B illustrate a connection 200 according to a second embodiment of the present disclosure, where FIG. 3A is a vertical cross-sectional view and FIG. 3B is a horizontal cross-sectional view;

FIGS. 4A to 4C are vertical sectional views illustrating a connection of a CFT column and a beam using a general diaphragm, where FIG. 4A illustrates a through diaphragm, FIG. 4B illustrates an inner diaphragm, and FIG. 4C illustrates an outer diaphragm; and

FIG. 5A is a view illustrating how a ring-shaped outer diaphragm is attached to a steel sheet-rolled tube, and FIG. 5B illustrates how a ring-shaped outer diaphragm is attached to an internally-ribbed steel tube.

DETAILED DESCRIPTION

[0021] 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.

[0022] (First Embodiment)

With reference to FIGS. 1A-1C and FIGS. 2A-2C, a connection 100 according to a first embodiment of the present disclosure is described below. This embodiment relates to a connection in which a CFT column and a beam formed from an H-shaped steel are joined via outer diaphragms.

[0023] With reference to FIGS. 1A-1C, the connection 100 comprises: a steel tube column (CFT column) 10 filled with concrete 12 and extending in the vertical direction; a pair of outer diaphragms formed from an upper diaphragm 20 and a lower diaphragm 30 and arranged in contact with an outer surface of

the steel tube column 10 so as to surround an outer periphery of the steel tube column 10 such that the pair of outer diaphragms have largest planes coincident with a horizontal plane; and a beam 40 formed from an H-shaped steel connected to the pair of outer diaphragms.

5 **[0024]** The steel tube column 10 is formed from an internally-ribbed steel tube that comprises a plurality of ribs (protrusions) 14 extending spirally at intervals on its inner surface and a convex bead 16 extending spirally on its outer surface. Each rib 14 is a protrusion that is rolled and molded integrally with the steel tube on the inner surface thereof so as to extend in a linear
10 manner (spirally in the form of a steel tube). The convex bead 16 is formed due to seam welding from the outer surface in the process of producing an internally-ribbed steel tube, and its width is generally about 20 mm to about 40 mm. Here, the sliding resistance (τ_b) provided by the ribs at the contact surface between the steel tube and the concrete depends on the local yield
15 strength (σ_c) of the concrete around the ribs. From this follows that the resistance force tends to increase as the number of ribs per unit length increases. On the other hand, when the number of ribs exceeds a certain threshold, the concrete sandwiched between the ribs becomes relatively small, and consequently the concrete between the ribs causes a shear failure (b) prior
20 to a local fracture. As a result, the sliding resistance force tends to peak. A known or arbitrary internally-ribbed steel tube may be used, yet in order to effectively guarantee the above-described sliding resistance, the rib width (protrusion width) is preferably about 4 mm to about 20 mm, the rib height is preferably about 2.5 mm to about 10 mm, and the rib interval is preferably
25 about 30 mm to 40 mm.

[0025] The outer diaphragms 20 and 30 are steel plates that are welded to the outer peripheral surface of the steel tube column 10 and have a function of transmitting a floor load from the beam 40 to the steel tube column 10. The method of welding the outer diaphragms 20, 30 to the outer peripheral surface
30 of the steel tube column 10 is preferably complete penetration welding. It is preferable that the thickness of the outer diaphragms 20, 30 be equal to or greater than the thickness of the flanges of the beams to be connected so that the existing stress of the flanges of the beams can be reliably transmitted to the steel tube columns 10. The shape of the outer diaphragms 20, 30 is not

particularly limited and may be appropriately determined depending on the number of connected beams and the tip shape. In the present embodiment, however, as illustrated in FIG. 1B, the outer diaphragms 20, 30 have an octagonal outer peripheral shape as viewed in a horizontal plane.

5 **[0026]** As illustrated in FIG. 1C, a typical H-shaped steel formed from an upper flange 42, a lower flange 44, and a web 46 connecting the both may be used for the beam 40. In the present embodiment, the upper diaphragm 20 and the lower diaphragm 30 are respectively joined to the upper flange 42 and the lower flange 44 of the H-shaped steel. In this case, it is preferable to use
10 complete penetration welding.

[0027] In this embodiment, since the internally-ribbed steel tube is used as the steel tube column 10, the floor load is applied from the beam 40 through the outer diaphragms 20, 30 to the steel tube column 10, and further transmitted via the ribs 14 inside thereof to the filled concrete 12, without
15 applying through diaphragms even if a separate member such as a shear connector is not welded into the steel tube column. Therefore, it is possible to simplify the processing of the steel tube column, compared to a method that involves welding of a separate slip stopper or the like into a steel tube column or applying through diaphragms.

20 **[0028]** In the present embodiment, as illustrated in FIG. 1C, it is important that the convex bead 16 present on the outer surface of the steel tube column is discontinued, that is, does not exist, at an interval at a position where the outer diaphragms 20, 30 are to be arranged on the outer surface of the steel tube column 10, wherein the interval is equal to or greater than a thickness of
25 each outer diaphragm, and that the pair of outer diaphragms 20 and 30 are arranged to be fitted into a portion where the convex bead is discontinued. Specifically, as illustrated in FIG. 2A, the convex bead 16 is partially removed by cutting such that it is discontinued at an interval at a position where the outer diaphragms 20, 30 are to be arranged on the outer surface of the steel
30 tube column, wherein the interval is equal to or greater than a thickness of each outer diaphragm. That is, the cutting width (length in the vertical direction) of the convex bead is set to be equal to or larger than the thickness of the outer diaphragms 20, 30, and it is preferably larger than the thickness of the outer diaphragms 20, 30 by 5 mm or more, and more preferably by 10 mm

or more. By being larger by 5 mm or more, it is not difficult to fit the outer diaphragms 20, 30 into the portion where the convex bead is discontinued. By being larger by 10 mm or more, it is not difficult to weld the outer diaphragms to the steel tube. Further, by setting the cutting width to around
5 20 mm, it becomes possible to provide a gap of 10 mm on the upper and lower surfaces of the diaphragms, respectively, and welding can be performed from both upper and lower surfaces without difficulty. For this reason, the cutting width of the bead is preferably larger than the diaphragm thickness by at least 10 mm to 20 mm (5 mm to 10 mm in the upper and lower directions
10 respectively).

[0029] After the cutting, as illustrated in FIG. 2B, the outer diaphragm 20 divided into parts is arranged so as to be fitted into the portion where the convex bead is discontinued, and welded to the steel tube column 10 by complete penetration welding such that a state as illustrated in FIG. 2C is
15 achieved. Here, since the convex bead 16 does not exist at the position where the outer diaphragms 20, 30 are to be arranged, it is unnecessary to provide a notch corresponding to the convex bead at the contact portion between the outer diaphragms 20, 30 and the steel tube column 10. In this embodiment, as illustrated in FIG. 2B, the outer diaphragm 20 is formed by
20 welding divided outer diaphragm members 20A and 20B to the steel tube column 10. The present disclosure is, however, not limited to such configuration and may be configured otherwise as long as the outer diaphragms can be arranged so as to surround the outer periphery of the steel tube column.

[0030] After the pair of outer diaphragms 20, 30 are thus welded to the steel tube column 10, the beam 40 is connected to the pair of outer diaphragms 20, 30, and then the steel tube column 10 can be filled with concrete.

[0031] In this way, in the present embodiment, it is not necessary to position a notch in advance with respect to the convex bead, and it is unnecessary to
30 perform a work that is extremely complicated, difficult, and laborious in terms of production. In the present disclosure the work of cutting is necessary, yet it is the construction on the outer surface of the steel tube, and in the attachment of the outer diaphragms, it is possible to proceed the work of cutting according to the position of the outer diaphragms in the height

direction, which is clear from the design specification, and construction workability cannot be impaired. Therefore, the connection 100 can be obtained by a simple method. Further, since the efficiency of transmitting the floor load to the filled concrete is higher than the conventional structure having a ring-shaped shear connector provided on the inner surface of the steel tube, the connection disclosed herein can transmit the floor load to the filled concrete in a more efficient manner and withstand larger floor loads even if the outer diaphragms are used.

[0032] The internally-ribbed steel tube is effective in the function of transmitting the stress from the beam to the column. Thus, the present disclosure is not limited to the use of an internally-ribbed steel tube as the steel tube column 10 as a whole, yet an internally-ribbed steel tube may be used in a limited way at a joint portion with the beam (the portion to which the pair of outer diaphragms 20, 30 are attached). In this case, the column-beam connection member has a relatively small size, and it is possible to weld the outer diaphragms 20, 30 by downward welding with the steel tube column (internally-ribbed steel tube) placed in a vertical position, and construction work is also easy.

[0033] (Second Embodiment)

With reference to FIG. 3, a connection 200 of according to a second embodiment of the present disclosure is described below. This embodiment relates to a connection in which a CFT column and an RC slab are joined via an outer diaphragm, and more particularly to a connection of a type in which a CFT column passes through an RC slab as a flat slab. The connection 200 is the same as the first embodiment except that the RC slab 50, instead of the beam, is joined to the steel tube column 10. Thus the explanation of the same points as those of the first embodiment will be omitted, and the configuration of the RC slab 50 and the joining of the outer diaphragms 20, 30 and the slab arrangements in the RC slab 50 will be described below.

[0034] As illustrated in FIG. 3A, in the present embodiment, the upper diaphragm 20 and the lower diaphragm 30 are connected to a top reinforcement 52 and a bottom reinforcement 54 which are slab arrangements in the RC slab, respectively. Specific connection modes include one on the left side and the other on the right side of FIG. 3A. FIGS. 3A and 3B

illustrate both connection modes in one figure only for the sake of convenience.

[0035] In the connection mode on the left side of FIGS. 3A and 3B, the upper diaphragm 20 and the lower diaphragm 30 are provided with a first through-hole 22 and a second through-hole 32 respectively penetrating in the thickness direction thereof. The top reinforcement 52 has a U-shaped portion 56 bent through the first through-hole 22. The lower end reinforcing bar 54 also has a U-shaped portion 56 bent through the second through-hole 32.

[0036] In the connection mode on the right side of FIGS. 3A and 3B, the top reinforcement 52 and the bottom reinforcement 54 have a lap joint 58, and the tips thereof are flare-welded to the upper diaphragm 20 and the lower diaphragm 30, respectively.

[0037] According to these connection modes, since the top reinforcement 52 and the bottom reinforcement 54, which are slab arrangements in the RC slab, are firmly bonded to the upper diaphragm 20 and the lower diaphragm 30, respectively, the loads applied to the RC slab 50 are efficiently transmitted to the outer diaphragms 20, 30. The floor load is then transferred to the steel tube column 10, and further to the filled concrete 12 via the ribs 14 inside the steel tube column 10.

[0038] (Other Embodiments)

The above embodiments are merely illustrative of the connection according to the present disclosure, and the present disclosure is not limited to the disclosed embodiments. For example, a possible connection may combine the elements in the above embodiments as deemed appropriate.

REFERENCE SIGNS LIST

[0039]	100, 200	Connection
	10	Steel tube column (internally-ribbed steel tube)
	12	Filled concrete
	14	Rib
	16	Convex bead
	20	Upper diaphragm (outer diaphragm)
	22	First through-hole

	30	Lower diaphragm (outer diaphragm)
	32	Second through-hole
	40	Beam of H-shaped steel
	42	Upper flange
5	44	Lower flange
	46	Web
	50	Reinforced concrete slab (RC slab)
	52	Top reinforcement
	54	Bottom reinforcement
10	56	U-shaped portion
	58	Lap joint

CLAIMS

1. A connection comprising:
a steel tube column filled with concrete;
5 a pair of outer diaphragms formed from an upper diaphragm and a lower diaphragm and arranged in contact with an outer surface of the steel tube column so as to surround an outer periphery of the steel tube column such that the pair of outer diaphragms have largest planes coincident with a horizontal plane; and
10 at least one of a beam formed from an H-shaped steel or a reinforced concrete slab connected to the pair of outer diaphragms, wherein
the steel tube column is formed from an internally-ribbed steel tube that comprises a plurality of ribs extending spirally at intervals on its inner surface and a convex bead extending spirally on its outer surface,
15 the convex bead is discontinued at an interval at a position where the pair of outer diaphragms are to be arranged on the outer surface of the steel tube column, wherein the interval is equal to or greater than a thickness of each outer diaphragm, and
the pair of outer diaphragms are arranged so as to be fitted into a
20 portion where the convex bead is discontinued.
2. The connection according to claim 1, wherein the upper diaphragm and the lower diaphragm are respectively joined to an upper flange and a lower flange of the H-shaped steel.
- 25 3. The connection according to claim 1, wherein the upper diaphragm and the lower diaphragm are respectively connected to a top reinforcement and a bottom reinforcement in the reinforced concrete slab.
- 30 4. The connection according to claim 3, wherein at least one of the upper diaphragm or the lower diaphragm is provided with a through-hole penetrating in the thickness direction thereof, and at least one of the top reinforcement or the bottom reinforcement has a U-shaped portion bent through the through-hole.

5. The connection according to claim 3, wherein at least one of the top reinforcement or the bottom reinforcement comprises a lap joint having a distal end welded to at least one of the upper diaphragm or the lower diaphragm.

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6. A method of producing a connection, the method comprising:

a first step of preparing a steel tube column, the steel tube column being formed from an internally-ribbed steel tube that comprises a plurality of ribs extending spirally at intervals on its inner surface and a convex bead extending spirally on its outer surface;

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a second step of welding a pair of outer diaphragms formed from an upper diaphragm and a lower diaphragm to an outer surface of the steel tube column such that the pair of outer diaphragms are arranged so as to surround an outer periphery of the steel tube column and to have largest planes coincident with a horizontal plane;

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a third step of connecting at least one of a beam formed from an H-shaped steel or a reinforced concrete slab to the pair of outer diaphragms; and

a fourth step of filling the steel tube column with concrete, wherein after the first step and before the second step, the convex bead is partially removed by cutting such that the convex bead is discontinued at an interval at a position where the pair of outer diaphragms are to be arranged on the outer surface of the steel tube column, wherein the interval is equal to or greater than a thickness of each outer diaphragm, and

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in the second step, the pair of outer diaphragms are arranged so as to be fitted into a portion where the convex bead is discontinued to thereby obtain the connection according to claim 1.

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