

DESCRIPTION

[Title of Invention] CONNECTION STRUCTURE BETWEEN STEEL-
REINFORCED CONCRETE COLUMN AND STEEL BEAMS

[Technical Field]

[0001]

The present invention relates to a connection structure in which a steel-reinforced concrete column and steel beams are connected together.

[Background Art]

[0002]

A connection structure in which a steel-reinforced concrete column and steel beams are connected together is widely known.

[0003]

Non Patent Literature 1 discloses a beam-to-column connection structure for steel-reinforced concrete columns. The disclosed structure is a through-column type beam-column connection structure. Stiffeners are disposed at connection portions between the column and the beams for preventing deformation of sectional shape of the steel column. The form of installation of stiffeners includes a horizontal form and a vertical form.

[0004]

Fig. 14 is a perspective view of a connection structure at beam-to-column connection portions including horizontal

stiffeners. As illustrated in Fig. 14, a steel column 1 has a generally cruciform section. Steel beams 2 are attached to the steel column 1 in four directions. The steel column 1 includes four column webs 1a-1, 1a-2, 1a-3, and 1a-4, assembled into a cross shape, and column flanges 1b-1, 1b-2, 1b-3, and 1b-4 respectively connected to the ends of the column webs 1a-1, 1a-2, 1a-3, and 1a-4.

[0005]

The horizontal stiffeners 4 are disposed at four corners of the steel column 1. The horizontal stiffeners 4 are L-shaped steel plates. The flat surfaces of the horizontal stiffeners 4 are disposed perpendicular to the direction in which the steel column 1 extends. Each horizontal stiffener 4 is connected to two column webs of the column webs 1a-1 to 1a-4 of the steel column 1, adjacent to each other in the horizontal direction of the steel column 1, and two column flanges of the column flanges 1b-1 to 1b-4, adjacent to each other in the horizontal direction, at the protruding side of the steel plate. For example, in the case where a horizontal stiffener 4 at the front of Fig. 14 is taken as an example, the horizontal stiffener 4 is connected to the adjacent column webs 1a-3 and 1a-4 and the adjacent column flanges 1b-3 and 1b-4.

[0006]

In the horizontal stiffeners, stress of the beam

flanges 2a is transmitted to the inside of the column through the column webs 1a-1 to 1a-4 and the L-shaped horizontal stiffeners 4. In case of the horizontal stiffeners, each horizontal stiffener 4 is connected to two adjacent ones of the column webs 1a-1 to 1a-4 of the steel column 1 and two adjacent ones of the column flanges 1b-1 to 1b-4. Thus, the way how stress is transmitted is clearly understandable. For this reason, the horizontal stiffeners are widely used. However, the horizontal stiffeners have a disadvantage in that the horizontal stiffeners hinder concrete from being filled into a space under the lower surfaces of the horizontal stiffeners 4.

[0007]

Fig. 15 is a perspective view of a connection structure at beam-to-column connection portions that includes vertical stiffeners. As illustrated in Fig. 15, in the case of the vertical stiffeners, similarly board-shaped vertical stiffeners 3 are disposed at four corners of the steel column 1. The surfaces of the vertical stiffeners 3 are disposed parallel to the direction in which the steel column 1 extends. The vertical stiffeners 3 are connected to two adjacent ones of the column flanges 1b-1 to 1b-4.

[0008]

When the vertical stiffeners 3 are used for the steel column having a generally T-shaped section to which steel

beams 2 are connected in three directions, the vertical stiffeners are disposed in the same manner as those in the case of the steel column having a generally cruciform section illustrated in Fig. 15. Specifically, as in the case of the steel column having a generally cruciform section, each vertical stiffener is attached to adjacent column flanges at its lateral side surfaces so as to connect the adjacent column flanges together.

[0009]

Although the vertical stiffeners have an excellent capability of allowing concrete to be sufficiently filled, it has been pointed out that the stress transmission through the vertical stiffeners is questionable.

[0010]

To address such concern, Non Patent Literature 2 and Non Patent Literature 3 have evaluated the strength of the connection portions through experimental research. Non Patent Literature 2 and Non Patent Literature 3 have proposed methods for evaluating the strength of vertical stiffeners and concluded that the vertical stiffeners have a structure that has a practically usable strength.

[Citation List]

[Non Patent Literature]

[0011]

[NPL 1] "Standard for Structural Calculation of Steel

Reinforced Concrete Structures and Explanation for the Same", Architectural Institute of Japan, fifth edition, January 2001

[NPL 2] Morita and three others "STRUCTURAL BEHAVIORS OF STEEL-BEAM TO SRC-COLUMN CONNECTIONS REINFORCED WITH VERTICAL STIFFENING PLATES", Journal of Structural and Construction Engineering of Architectural Institute of Japan, No.413, July 1990, pp. 53 - 64

[NPL 3] Morita and three others "STRUCTURAL BEHAVIORS OF STEEL-BEAM TO SRC-COLUMN CONNECTIONS REINFORCED WITH VERTICAL STIFFENING PLATES", No.423, May 1991, pp. 69 - 78

[Summary of Invention]

[Technical Problem]

[0012]

Growing interest in measures against earthquakes in recent years requires further enhancement in connection-structure stiffness in a connection structure for a steel column having a standard section in which all column webs 1a-1 to 1a-4 have the same length, as illustrated in Fig. 15. However, the existing vertical stiffeners cannot efficiently transmit the stress to the inside of the column, since vertical stiffeners 3 are disposed at an angle with respect to the direction from which the vertical stiffeners 3 receive stress from the beam flange 2a.

[0013]

As illustrated in Fig. 16, the vertical stiffeners have another problem if the steel column 1 has an irregular section in which column webs 1a-1 to 1a-4 have different lengths. Specifically, as illustrated in Fig. 16, when a first column width H is larger than a second column width at a connection portion of the steel column 1 having a generally cruciform section, an angle α_2 formed by a vertical stiffener 3 and a short column web 1a-2 becomes large and exceeds 45 degrees. Thus, the stress of the beam flange applied to the short column web 1a-2 in the direction of arrow cannot be fully transmitted to the inside of the column (to a different column flange 1b-1).

[0014]

As illustrated in Fig. 17, if a steel column has a generally T-shaped section, another problem can occur such that the angle α_2 becomes large and thus the rotational deformation at the connection portion becomes large when the stress of the beam flange is applied to the column in the lateral direction of the column (in the direction of arrow). As illustrated in Fig. 18, the same problem can occur in a connection structure between steel beams and a steel column that has a section formed by cutting off one side of a steel column having a generally cruciform section.

[0015]

The present invention has been made to solve the above-

described problems and aims to provide a connection structure that allows stress of a beam flange to be efficiently transmitted to the inside of a column without hindering concrete from being sufficiently filled thereinto.

[Solution to Problem]

[0016]

In order to solve the above problems, the present invention includes the following characteristics.

[1] A connection structure between a steel-reinforced concrete column and a steel beam in which a steel beam is connected to a steel column of a steel-reinforced concrete column, comprising: a vertical stiffener that is disposed at the steel column including a plurality of column webs extending in different directions and column flanges disposed at ends of the respective column webs so as to be perpendicular to the column webs, the vertical stiffener including a first board portion and a second board portion, the first board portion being connected to a first one of adjacent ones of the column flanges of the steel column, the second board portion not being parallel to the first board portion, and the second board portion being connected to a second one of the adjacent column flanges, wherein the vertical stiffener is attached to the steel column at a position that at least partially includes a vertical position at which a beam flange of the steel beam is

connected to the steel column.

[2] The connection structure between a steel-reinforced concrete column and a steel beam according to the article [1], wherein the vertical stiffener has an L-shaped horizontal section formed by the first board portion and the second board portion perpendicular to the first board portion.

[3] The connection structure between a steel-reinforced concrete column and a steel beam according to the article [1] or [2], wherein the first board portion of the vertical stiffener is connected to one end of the first one of the adjacent column flanges whereas the second board portion of the vertical stiffener is connected to one end of the second one of the adjacent column flanges.

[4] The connection structure between a steel-reinforced concrete column and a steel beam according to any one of the articles [1] to [3], wherein the first board portion of the vertical stiffener is perpendicular to the first one of the adjacent column flanges whereas the second board portion of the vertical stiffener is perpendicular to the second one of the adjacent column flanges.

[5] The connection structure between a steel-reinforced concrete column and a steel beam according to any one of the articles [1] to [4], wherein the first board portion and the second board portion are connected to surfaces of

corresponding ones of the column flanges facing an inner side of the column.

[6] The connection structure between a steel-reinforced concrete column and a steel beam according to any one of the articles [1] to [5], wherein in the steel-reinforced concrete column, the steel column has a generally cruciform section or a generally T-shaped section.

[Advantageous Effects of Invention]

[0017]

The present invention can provide a connection structure that can sufficiently transmit stress of a beam flange to the inside of a column without hindering concrete from being sufficiently filled thereinto.

[Brief Description of Drawings]

[0018]

[Fig. 1] Fig. 1(a) is a vertical cross-sectional view of a connection structure according to a first embodiment of the present invention and Fig. 1(b) is a horizontal cross-sectional view of the connection structure.

[Fig. 2] Fig. 2 is an enlarged view of part of the horizontal cross-sectional view of the connection structure according to the first embodiment of the present invention.

[Fig. 3] Fig. 3(a) is a vertical cross-sectional view of a connection structure according to a second embodiment of the present invention and Fig. 3(b) is a horizontal

cross-sectional view of the connection structure.

[Fig. 4] Fig. 4 is an enlarged view of part of the horizontal cross-sectional view of the connection structure according to the second embodiment of the present invention.

[Fig. 5] Fig. 5(a) is a horizontal cross-sectional view of a test piece A of a steel-reinforced concrete column including a generally cruciform steel column and Fig. 5(b) is a vertical cross-sectional view of the test piece A.

[Fig. 6] Fig. 6 illustrates the relationship between the tensile load P [kN] and the local deformation Δ [mm] regarding the test piece A and a test piece B.

[Fig. 7] Fig. 7(a) is a horizontal cross-sectional view of a test piece C of a steel-reinforced concrete column including a generally T-shaped steel column and Fig. 7(b) is a vertical cross-sectional view of the test piece C.

[Fig. 8] Fig. 8 illustrates the relationship between the tensile load P [kN] and the local deformation Δ [mm] regarding the test piece C and a test piece D.

[Fig. 9] Fig. 9 illustrates the relationship between the tensile load P [kN] and the rotational deformation θ [rad.] regarding the connection structures of the test piece C and the test piece D.

[Fig. 10] Fig. 10 is a horizontal cross-section of a connection structure according to a first modified embodiment of the present invention.

[Fig. 11] Fig. 11 is a horizontal cross-section of a connection structure according to a second modified embodiment of the present invention.

[Fig. 12] Fig. 12 is a horizontal cross-section of a connection structure according to a third modified embodiment of the present invention.

[Fig. 13] Fig. 13 is a horizontal cross-section of a connection structure according to a fourth modified embodiment of the present invention.

[Fig. 14] Fig. 14 is a perspective view of a connection structure including existing horizontal stiffeners.

[Fig. 15] Fig. 15 is a perspective view of a connection structure including existing vertical stiffeners.

[Fig. 16] Fig. 16 is a horizontal cross-sectional view of a connection structure of a column including a steel column having a generally cruciform section, the structure including existing vertical stiffeners.

[Fig. 17] Fig. 17 is a horizontal cross-sectional view of a connection structure of a column including a steel column having a generally T-shaped section, the structure including existing vertical stiffeners.

[Fig. 18] Fig. 18 is a horizontal cross-sectional view of another connection structure of a column including a steel column having a generally cruciform section, the structure including existing vertical stiffeners.

[Description of Embodiments]

[0019]

Referring now to the appended drawings, embodiments of the present invention will be described below.

[First Embodiment]

[0020]

Fig. 1(a) is a vertical cross-sectional view of a connection structure according to a first embodiment of the present invention and Fig. 1(b) is a horizontal cross-sectional view of the connection structure. As illustrated in Figs. 1(a) and 1(b), steel beams 2 are attached to a steel-reinforced concrete column 10 from four directions. The steel beams 2 are connected to the steel-reinforced concrete column 10 by welding or using bolts.

[0021]

The steel-reinforced concrete column 10 includes a steel column 1. The steel column 1 includes four column webs 1a-1, 1a-2, 1a-3, and 1a-4, which extend in different directions, and column flanges 1b-1, 1b-2, 1b-3, and 1b-4, which are respectively disposed at the ends of the corresponding column webs 1a-1, 1a-2, 1a-3, and 1a-4 so as to be perpendicular to the column webs 1a-1, 1a-2, 1a-3, and 1a-4. In the first embodiment, the horizontal section of the steel column 1 is a generally cruciform section.

[0022]

The four column webs 1a-1 to 1a-4 have the same shape. The four column flanges 1b-1 to 1b-4 also have the same shape. As illustrated in Fig. 1(b), adjacent ones of the column webs 1a-1 to 1a-4 form an angle of 90° . Thus, adjacent ones of the column flanges 1b-1 to 1b-4 of the steel column 1 also form an angle of 90° .

[0023]

The steel-reinforced concrete column 10 is formed by joining reinforcing bars (main bars 6 and hoops 7) together around the periphery of the steel column 1 and by casting concrete 5. The steel-reinforced concrete column 10 includes vertical stiffeners 3 at four corners of the steel column 1. As illustrated in Fig. 1(b), the vertical stiffeners 3 are disposed between two adjacent ones of the column flanges 1b-1 to 1b-4. The vertical stiffeners 3 are formed by bending steel plates and have surfaces that are parallel to the direction in which the steel column 1 extends. Hereinbelow, for the purpose of illustration, a vertical stiffener 3 disposed between the column flanges 1b-1 and 1b-2 is described as an example.

[0024]

The vertical stiffener 3 includes a first board portion 3a and a second board portion 3b. The first board portion 3a is connected to the column flange 1b-1. The second board portion 3b is not parallel to the first board portion 3a and

is connected to the column flange 1b-2 adjacent to the column flange 1b-1. In the first embodiment, the vertical stiffener 3 is formed so as to have an L-shaped horizontal section. In other words, in the first embodiment, the first board portion 3a and the second board portion 3b are formed so as to be perpendicular to each other.

[0025]

The first board portion 3a is connected to one end of the column flange 1b-1 and the second board portion 3b is connected to one end of the column flange 1b-2. In the first embodiment, the protruding side of the L shape formed by the first board portion 3a and the second board portion 3b faces the center of the column and the recessed side of the L shape faces away from the column. The first board portion 3a of the vertical stiffener 3 is perpendicular to the adjacent column flange 1b-1. The second board portion 3b is perpendicular to the column flange 1b-2.

[0026]

In the first embodiment, the first board portion 3a and the second board portion 3b are formed so as to have the same length. The thickness of the vertical stiffener 3 is determined so as to be approximately the same as the thickness of the column flanges 1b-1 and 1b-2 to which the vertical stiffener 3 is connected. It is preferable that the vertical stiffener 3 be connected to surfaces of the

column flanges 1b-1 and 1b-2 facing the column center so that the vertical stiffener 3 can receive stress that the column flanges 1b-1 and 1b-2 receive from the beam flange 2a, from the side opposite to the side on which the stress is applied. However, the vertical stiffener 3 may be connected to any surfaces of the column flanges 1b-1 and 1b-2. The vertical stiffener 3 may be directly connected to the column flanges 1b-1 and 1b-2 or indirectly connected to the column flanges 1b-1 and 1b-2 using other members.

[0027]

As illustrated in Fig. 1(a), each vertical stiffener 3 is attached to the steel column 1 in a range that includes a vertical position at which a beam flange 2a of the steel beam 2 is connected to the steel column 1. The vertical stiffeners 3 are disposed between the steel column 1 and respective upper and lower beam flanges 2a of the steel beam 2. In Fig. 1(a), each vertical stiffener 3 is disposed in a range that includes the entirety of the vertical position at which a beam flange 2a is connected to the steel column 1. However, each vertical stiffener 3 only has to be disposed so as to overlap at least part of the vertical position at which a beam flange 2a is connected to the steel column 1.

[0028]

Fig. 2 is an enlarged view of part of the horizontal cross-sectional view of the connection structure according

to the first embodiment of the present invention. In Fig. 2, for the purpose of illustration, only one of the steel beams 2 connected to the steel column 1 is shown and the remaining three steel beams are not illustrated. When the stress toward the right side of Fig. 2 occurs in the steel beam 2, the stress (beam-flange stress) toward the right side of Fig. 2 also occurs in the beam flanges 2a of the steel beam 2. The steel column 1 is connected to the steel beam 2. Thus, the cross-sectional force of the column web 1a-2 toward the left side of Fig. 2 is exerted on the steel column 1 as a reaction force. Here, the second board portions 3b of two vertical stiffeners 3 are connected to the column flange 1b-2, which is integrated with the column web 1a-2. Thus, the cross-sectional force is exerted toward the left side of Fig. 2 from the two vertical stiffeners 3 disposed on both sides of the steel beam 2.

[0029]

The concrete 5 is casted into the steel beam 2. Thus, the bearing force of the concrete 5 occurs as a reaction force against the beam-flange stress and the bearing force acts on the first board portions 3a of the vertical stiffeners 3. Fig. 2 illustrates, as an example, the case where the stress is exerted on the steel column 1 to the right side of Fig. 2 from the steel beam 2. In the case where the stress is exerted on the steel column 1 to the

left side of Fig. 2 from the steel beam 2, the force opposite to the above-described force occurs.

[0030]

In this manner, in the connection structure according to the first embodiment of the present invention, the vertical stiffener 3 having an L-shaped horizontal section is disposed between the adjacent column flanges 1b-1 and 1b-2 of the steel column 1. Here, in the case where stress occurs in the steel beam 2 as illustrated in Fig. 2, the stress is applied to the column flange 1b-2 connected to the steel beam 2. The stress applied to the column flange 1b-2 is transmitted to the column web 1a-2 connected to the column flange 1b-2 and to the second board portions 3b of the vertical stiffeners 3 perpendicular to the column flange 1b-2. Specifically, in the first embodiment, the surfaces of the second board portions 3b of the vertical stiffeners 3 are disposed so as to be parallel to the stress that the second board portions 3b receive from the steel beam 2. Thus, the stress that has occurred in the steel beam 2 can be efficiently transmitted to the steel-reinforced concrete column 10 through the second board portions 3b of the vertical stiffeners 3 on both sides of the column flange 1b-2 (on upper and lower sides in Fig. 2).

[0031]

In the connection structure according to the first

embodiment, the first board portion 3a and the second board portion 3b form a predetermined angle. The vertical stiffener 3 is thus deformed so as to bend at a portion between the first board portion 3a and the second board portion 3b upon receipt of the stress from the beam flange 2a. This deformation can absorb part of the stress from the beam flange 2a.

[0032]

In the first embodiment, each vertical stiffener 3 is disposed at a vertical position that includes a portion to which the beam flange of the steel beam 2 is connected. The steel beam 2 includes beam flanges 2a at the top and the bottom of a beam web 2b. Vertical stiffeners 3 are thus disposed at vertical positions of the steel column 1 at which beam flanges 2a, which are subject to a large stress or bending moment when being bent, are connected to the steel column 1. Consequently, the stress or bending moment of the steel beam 2 can be efficiently transmitted to the inside of the column.

[0033]

As illustrated in Figs. 1 and 2, in the steel column 1 of the connection structure according to the first embodiment, a first column width and a second column width are equal to each other. The present invention is also applicable to a steel column in which a first column width

and a second column width are different. Specifically, in such a case, the first board portion 3a and the second board portion 3b may be connected to the respective column flanges after the lengths of the first board portion 3a and the second board portion 3b of each vertical stiffener 3 are appropriately adjusted so as to conform with the dimensions between the adjacent flanges of the steel column 1. In this manner, even a steel column having a generally cruciform section and in which a first column width is larger than a second column width can be effectively prevented from being deformed by the stress applied from the steel beam 2.

[Second Embodiment]

[0034]

Now, a connection structure according to a second embodiment of the present invention will be described. Fig. 3(a) is a vertical cross-sectional view of a connection structure according to a second embodiment of the present invention and Fig. 3(b) is a horizontal cross-sectional view of the connection structure. The second embodiment is a connection structure in which vertical stiffeners 3 are used in a column including a steel column having a T-shaped section.

[0035]

As illustrated in Fig. 3(b), the steel column 11 has a T-shaped horizontal section. The steel column 11 includes

three column webs 11a-1, 11a-2, and 11a-3 and column flanges 11b-1, 11b-2, and 11b-3 respectively connected to the column webs 11a-1, 11a-2, and 11a-3. Here, for the purpose of illustration, a vertical stiffener 3 between a column flange 11b-1 of a long column web 11a-1 and a column flange 11b-2 of a short column web 11a-2 is described as an example.

[0036]

Three steel beams 2 are connected to the steel column 11. As illustrated in Fig. 3(b), adjacent column webs 11a-1 and 11a-2 form an angle of 90° . Thus, the column flange 11b-1 and the column flange 11b-2, which are respectively perpendicular to the column webs 11a-1 and 11a-2, also form an angle of 90° .

[0037]

As in the case of the first embodiment, each vertical stiffener 3 has an L shape formed by a first board portion 3a and a second board portion 3b. Each vertical stiffener 3 is so disposed that the protruding side of the L shape faces the inner side of the column and the recessed side of the L shape faces away from the column. In the vertical stiffener 3 according to the second embodiment, the first board portion 3a and the second board portion 3b have different lengths. Specifically, the first board portion 3a is longer than the second board portion 3b.

[0038]

The end of the first board portion 3a is connected to one end of the column flange 11b-1 and the end of the second board portion 3b is connected to one end of the column flange 11b-2. Except for the ratio of the length of the first board portion 3a to the length of the second board portion 3b, the second embodiment is substantially similar to the first embodiment. Board-shaped vertical stiffeners 31 having a straight section are disposed between the column flanges 11b-2 and 11b-3 respectively disposed at ends of the short column webs 11a-2 and 11a-3.

[0039]

In this manner, in this invention, the ratio of the first board portion 3a to the second board portion 3b of the L-shaped vertical stiffener 3 can be appropriately determined in accordance with the shape of the steel column 11 to which the vertical stiffeners 3 are attached. In the second embodiment, even in the steel column 11 in which the column webs 11a-1 to 11a-3 have different lengths, a reaction force can be caused in the direction opposite to the direction in which the stress is applied from the beam flange 2a since the L-shaped vertical stiffener 3 are connected to the respective column flanges 11b-1 to 11b-3 at right angles.

[0040]

Fig. 4 is an enlarged view of part of the horizontal

cross-sectional view of the connection structure according to the second embodiment of the present invention. For the purpose of illustration, Fig. 4 illustrates an example in which only one steel beam 2 is connected to the steel column 11. In the second embodiment, as in the case of the first embodiment, when stress to the right side of Fig. 4 is applied to the steel beam 2, a cross-sectional force occurs in the column web 11a-2 to which the steel beam 2 to which the stress is applied is connected. Vertical stiffeners 3 are connected to the column flange 11b-2. Thus, the cross-sectional force also occurs in the vertical stiffeners 3.

[0041]

The concrete 5 is casted into the steel beam 2. Thus, the bearing force of the concrete 5 that has occurred as a reaction force against the beam-flange stress acts on the long side of the vertical stiffener 3 (first board portion 3a). In this manner, also in the second embodiment, disposing the L-shaped vertical stiffener 3 can enhance the stiffness of the connection portion. Fig. 4 illustrates, as an example, the case where the stress is exerted on the steel column 11 to the right of Fig. 4 from the steel beam 2. In the case where the stress is exerted on the steel column 11 to the left side of Fig. 4 from the steel beam 2, the force opposite to the above-described force occurs and the similar effects occur. In addition, rotational deformation

occurs in the arrow direction at the connection portion between the steel column 11 and the steel beam 2. The vertical stiffener 3 can also prevent the rotational deformation from occurring by enhancing the stiffness at the connection portion.

[0042]

In this manner, the present invention is also applicable to the steel-reinforced concrete column including a generally T-shaped steel column and can enhance the stiffness of the connection portion.

[First Modified Embodiment]

[0043]

Now, modified embodiments of the present invention will be described. The following describes a case where modified embodiments are used for a generally cruciform steel column. All the modified embodiments described below are also similarly applicable to a steel column having a generally T-shaped section. The modified embodiments are illustrated in cross-sectional views corresponding to Fig. 1(b) illustrating the connection structure according to the first embodiment. For the purpose of simplification of illustration, the drawings for the modified embodiments only illustrate steel columns and vertical stiffeners and exclude other components.

[0044]

Fig. 10 is a horizontal cross-sectional view of a connection structure according to a first modified embodiment of the present invention. In the first embodiment, the first board portion 3a of the vertical stiffener 3 is connected to one end of the column flange 1b-1 and the second board portion 3b is connected to the column flange 1b-2. In the first modified embodiment, a first board portion 3a is connected to a portion of a first column flange near the center and a second board portion 3b is connected to a portion of a second column flange near the center. In this manner, the vertical stiffener 3 may be connected to column flanges at any portions as long as it is connected to adjacent column flanges.

[Second Modified Embodiment]

[0045]

Fig. 11 is a horizontal cross-section of a connection structure according to a second modified embodiment of the present invention. In the first embodiment, the vertical stiffener 3 is formed into an L shape in such a manner that the first board portion 3a and the second board portion 3b are perpendicular to each other. In the second modified embodiment, the first board portion 3a and the second board portion 3b may be disposed so as to form any angle as long as they are not parallel to each other. For example, as illustrated in Fig. 11, the first board portion 3a and the

second board portion 3b can form an angle that is over 90° . Alternatively, the first board portion 3a and the second board portion 3b may form an angle that is below 90° (not illustrated).

[Third Modified Embodiment]

[0046]

Fig. 12 is a horizontal cross-section of a connection structure according to a third modified embodiment of the present invention. In the first embodiment, the vertical stiffener 3 is formed into an L shape by the first board portion 3a and the second board portion 3b. In the third modified embodiment, the vertical stiffener 3 may have any shape as long as it includes a first board portion 3a and a second board portion 3b that are not parallel to each other. For example, the vertical stiffener 3 may include a third side 3c between the first board portion 3a and the second board portion 3b.

[Fourth Modified Embodiment]

[0047]

Fig. 13 is a horizontal cross-section of a connection structure according to a fourth modified embodiment of the present invention. In the first embodiment, the mountain side of the L shape formed by the first board portion 3a and the second board portion 3b faces the center of the column while the valley side of the L shape faces the outer surface.

In the fourth modified embodiment, as illustrated in Fig. 13, the vertical stiffeners 3 may be disposed in such a manner that the recessed side of the L shape faces the center of the column while the protruding side of the L shape faces the outer surface.

[0048]

As described above, vertical stiffeners according to the present invention may be formed in any shape. Vertical stiffeners according to the present invention are usable for a steel column shaped in accordance with an existing technology as illustrated in Fig. 18.

[Examples]

[Example 1]

[0049]

The following describes experiments on partial models of a connection structure, conducted using test pieces. Fig. 5(a) is a horizontal cross-sectional view of a test piece A of a steel-reinforced concrete column including a generally cruciform steel column and Fig. 5(b) is a vertical cross-sectional view of the test piece A. The test piece A is an example made in accordance with the connection structure according to the first embodiment of the present invention. A frame element of the column of the test piece A is formed by welding an H-section steel (H - 400 x 200 x 9 x 12) and a T-shaped (cut T) steel (CT - 196 x 200 x 9 x 12) together.

The beam flange is a steel plate with a width of 200 mm and a thickness of 16 mm. The vertical stiffeners are formed by bending steel plates with a width of 80 mm and a thickness of 9 mm.

[0050]

A test piece B (not illustrated) used as a comparative example is formed by combining existing vertical stiffeners with the frame element of the column of the test piece A.

[0051]

Fig. 6 illustrates the relationship between the tensile load P and the local deformation Δ regarding the test piece A and the test piece B. Circles in Fig. 6 on the test pieces A and B indicate the full plastic strength of the test pieces A and B. The local deformation Δ is defined as a mean value of a deformation Δ_U at the upper end and a deformation Δ_L at the lower end. The test piece A to which the present invention is applied was confirmed that the test piece A has a higher stiffness than the test piece B according to the existing technology. In addition, it was confirmed that the full plastic strength was increased by approximately 30% and the maximum strength was increased by approximately 20%. Specifically, it was found that the application of the present invention successively enhanced the strength at the connection portion of the steel reinforced concrete.

[Example 2]

[0052]

Similarly, the following describes experiments on models of a connection structure according to the second embodiment of the present invention. Fig. 7(a) is a horizontal cross-sectional view of a test piece C of a steel-reinforced concrete column including a generally cruciform steel column and Fig. 7(b) is a vertical cross-sectional view of the test piece C. The test piece C is an example made in accordance with the connection structure according to the second embodiment of the present invention. The frame element of the column of the test piece C is formed by welding an H-section steel (H - 400 x 200 x 9 x 12) and a T-shaped (cut T) steel (CT - 296 x 200 x 9 x 12) together. The beam flange is a steel plate with a width of 200 mm and a thickness of 19 mm.

[0053]

A test piece D used as a comparative example is formed using existing vertical stiffeners. The vertical stiffeners of the test piece C are formed by bending steel plates with a width of 120 mm and a thickness of 12 mm.

[0054]

Fig. 8 illustrates the relationship between the tensile load P and the local deformation Δ regarding the test piece C and the test piece D. Circles in Fig. 8 on the test

pieces C and D indicate the full plastic strength of the test pieces C and D. The local deformation Δ is defined by the following expression (1), using a deformation Δ_U at the upper end and a deformation Δ_L at the lower end:

$$\Delta = \Delta_L + (\Delta_U - \Delta_L)W_1/W \dots (1)$$

Here, W denotes the length of the column of the test piece C in the longitudinal direction and W_1 denotes the distance from the upper end of the column of the test piece C to the connection point at which the three column webs meet.

[0055]

The test piece C to which the present invention is applied was confirmed that the test piece C has a higher stiffness than the test piece D according to the existing technology. In addition, it was confirmed that the full plastic strength was increased by approximately 25% and the maximum strength was increased by approximately 20%. That is, the application of the present invention successively enhanced the stiffness (strength) of the connection structure.

[0056]

Fig. 9 illustrates the relationship between the tensile load P and the rotational deformation angle θ regarding the connection structures of the test piece C and the test piece D. Here, the rotational deformation angle θ is defined by

the following expression (2):

$$\theta = 0.5 \cdot (\Delta_U - \Delta_L) / W \dots (2)$$

In the test piece C to which the present invention is thus applied, it was found that the rotational deformation angle θ was reduced further than the test piece D including an existing connection structure.

[0057]

The present invention is not limited to the above-described embodiments and can be appropriately modified within the range not departing from the gist of the present invention.

[Reference Signs List]

[0058]

1, 11 steel column

1a-1 to 1a-4, 11a-1 to 11a-4 column web

1b-1 to 1b-4, 11b-1 to 11b-3 column flange

2 steel beam

2a beam flange

2b beam web

3, 31 vertical stiffener

4 horizontal stiffener

5 concrete

6 main bar

7 hoop

10 steel-reinforced concrete column

CLAIMS

[Claim 1]

A connection structure between a steel-reinforced concrete column and a steel beam in which a steel beam is connected to a steel column of a steel-reinforced concrete column, comprising:

a vertical stiffener that is disposed at the steel column including a plurality of column webs extending in different directions and column flanges disposed at ends of the respective column webs so as to be perpendicular to the column webs, the vertical stiffener including a first board portion and a second board portion, the first board portion being connected to a first one of adjacent ones of the column flanges of the steel column, the second board portion not being parallel to the first board portion, and the second board portion being connected to a second one of the adjacent column flanges,

wherein the vertical stiffener is attached to the steel column at a position that at least partially includes a vertical position at which a beam flange of the steel beam is connected to the steel column.

[Claim 2]

The connection structure between a steel-reinforced concrete column and a steel beam according to Claim 1, wherein the vertical stiffener has an L-shaped horizontal

section formed by the first board portion and the second board portion perpendicular to the first board portion.

[Claim 3]

The connection structure between a steel-reinforced concrete column and a steel beam according to Claim 1 or 2, wherein the first board portion of the vertical stiffener is connected to one end of the first one of the adjacent column flanges whereas the second board portion of the vertical stiffener is connected to one end of the second one of the adjacent column flanges.

[Claim 4]

The connection structure between a steel-reinforced concrete column and a steel beam according to any one of Claims 1 to 3, wherein the first board portion of the vertical stiffener is perpendicular to the first one of the adjacent column flanges whereas the second board portion of the vertical stiffener is perpendicular to the second one of the adjacent column flanges.

[Claim 5]

The connection structure between a steel-reinforced concrete column and a steel beam according to any one of Claims 1 to 4, wherein the first board portion and the second board portion are connected to surfaces of corresponding ones of the column flanges facing an inner side of the column.

[Claim 6]

The connection structure between a steel-reinforced concrete column and a steel beam according to any one of Claims 1 to 5, wherein in the steel-reinforced concrete column, the steel column has a generally cruciform section or a generally T-shaped section.