

CONNECTION SYSTEM BETWEEN HOLLOW STRUCTURAL STEEL COLUMNS AND POST-TENSIONED CONCRETE SLABS.

Technical Field

5 This invention specifically relates to hollow structural steel gravity columns and their connection system between hollow structural steel columns and post-tensioned concrete slabs.

Background Art

10 Post-tensioned concrete slab is a combination of conventional reinforced concrete slab and additional high-strength PC strands (pre-stressed concrete steel strand), which are consequently subjected to tension after the concrete has set. Post-tensioned concrete slab is extensively used in infrastructure and building construction due to a number of advantages, including the ease of management and construction. Due to the application of high-strength steel tendons and post-tensioned process, thinner slab with long span structure can be achieved,
15 resulting in longer column-free spaces and light weight structure. Post-tensioned concrete slab is considered as a popular concrete slab system in various countries. This is because the post-tensioned concrete slab is lighter in weight as a result of thinner slab thickness than the weight of conventional cast-in-place concrete slab. It also provides wider spans for certain types of buildings, such as parking buildings, residential buildings or hotels, as the post-tensioned
20 concrete slabs do not need beams or girders in order to carry the floor load which would be conversely carried by PC strands (pre-stressed concrete steel strand). These PC strands are installed evenly along the columns line in both x and y axes, during the process of reinforcement installation before the concrete pouring sequence. After pouring concrete and the concrete has already hardened, PC strands are then stressed to strengthen and increase the load-carrying
25 capacity of post-tensioned concrete slabs.

 Hollow structural steel columns with the same load-carrying capacity comparing to conventional concrete columns require a smaller cross-sectional area, resulting in more spacious floor space allowing more flexibility in interior design. In addition, the installation of the steel columns can be done much quicker due to modular system characteristics. The types of steel
30 columns commonly used in building construction are H-beam structural steel columns, Hollow Steel Section (HSS) columns, etc.

The use of post-tensioned concrete slabs with hollow structural steel columns will greatly contribute more values to building construction projects. However, post-tensioned concrete slabs and steel columns have not been integratedly designed together due to the complexity of connection systems between them and the limitations of engineering knowledge regarding structural behaviors of the integrated composite system. These complexity and limitations are the concerns need to be further studied in detail, which can be stated as follows.

1. Prevention of punching shear of the post-tensioned concrete slab due to smaller size of hollow structural steel column (comparing to RC column) and the inhomogeneity between hollow structural steel columns and post-tensioned concrete slabs

2. Connection details between lower columns and upper columns so that the structural integrity of these columns can be achieved

3. Concrete slab reinforcement details to ensure the continuity of the post-tensioned concrete slab at the connecting area in order to maintain the performance of the post-tensioned slab

Objects of the Invention

An object of the present invention is to address the solution in response to the aforementioned problems by designing a connection system between hollow structural steel columns and post-tensioned concrete slabs at the top and base of the hollow structural steel columns, describing as a male connection and female connection respectively. The male connection is designed to provide punching shear resistance for post-tensioned concrete slab at the connecting area around the top of columns. On the other hand, the main function of female connection is to provide the continuity and integrity for post-tensioned concrete slabs at the connected area. To connect female connection and male connection together, this can be simply achieved by placing female connection on top of male connection of the lower column and tightening them with bolts or threaded shear studs with nuts which have been pre-installed on the male connection. Threaded shear studs or bolts are installed with leveling nuts to allow constructors to be able to adjust column elevation and plumpness of the upper column as desired.

The male connection consists of a steel cap plate welded to the top of the lower column, a group of guide plates, and a set of threaded shear studs or bolts and leveling nuts. The guide

plates will be installed on the cap plate where the upper column is centered and used as a guide to locate the center of the upper columns during the erection process.

The female connection comprises the triangular brackets, which are welded to the sides of the hollow structural steel column. An open end of the upper hollow structural steel column is to be placed where the guide plates of the male connection welded to the top of the upper lower column cap plate are located. Openings with additional steel reinforcement on the sides of the upper column base are provided as a passway of the concrete slab reinforcement to provide the continuity of the post-tensioned concrete slab at the area around the connection.

The main function of this invented connection system is to provide an integrated connection system between upper and lower hollow structural steel columns, while supporting post-tensioned concrete slabs. Furthermore, there is no limitation with respect to the different sizes of upper and lower columns due to the advantages of exploiting pre-fabrication process, which will facilitate the ease of installation and its accuracy.

Brief Description of the Drawings

Figure 1 Overall components of connection system.

Figure 2 The location of male connection and female connection on a hollow structural steel column.

Figure 3 Components of male connection (top view).

Figure 4 Components of male connection (bottom view).

Figure 5 Components of female connection (top view).

Figure 6 Components of female connection (bottom view).

Figure 7 Complete connection system.

Figure 8 Cross section of completed connection system.

Figure 9 Side view of completed connection system within post-tensioned concrete slab.

Description of the Preferred Embodiments

The connection system between hollow structural steel columns and post-tensioned concrete slabs according to a preferred embodiment of the present invention comprises a male connection (4), which is a square or rectangular steel plate, placed at the top of the lower column, and a female connection (5) comprising triangular brackets (12) welded at the base of the upper column sidewalls. The male and female connections will then be bolted to connect the upper column (1) and the lower column (2) together. The complete connection system provides a connection between the upper and lower hollow structural steel columns while supporting post-tensioned concrete slabs (3) at the same time (Figure 1).

Figure 2 illustrates that the male connection (4) is located at the top of the lower column, and the female connection (5) is located at the base of the upper column.

Figures 3 and 4 illustrate the component of male connection, which consists of a steel cap plate (6) welded at the top of the lower column (4). The cap plate is wider than the width of steel columns and is mainly responsible for carrying the post-tensioned concrete slab carrying designed dead load and floor live load. At the top center of the cap plate (6), there is a group of guide plates (10) made of steel plates welded on top of cap plates. These guide plates will be for the installation of the upper hollow structural steel columns (1). The width of the guide plates is designed to properly insert the open end (15) of the upper column. The height of the guide plates (10) is lower than a diaphragm plate (11), which is attached to the inner wall of the upper column. At the top of the cap plate (6), there is also a group of threaded shear studs or bolts with leveling nuts (7) located around all sides of the group of guide plates (10), one set on each side. A set of threaded shear studs or bolts and leveling nuts (7) will be used to connect the triangular brackets (12), which are parts of the female connection for the following purposes:

1. Stabilizing upper columns during the construction period
2. Adjusting elevation and plumbness of upper columns
3. Assembling both the upper and lower columns
4. Improving the load carrying capacity of the cap plate

Figures 5 and 6 illustrate the components of female connection consisting of triangular brackets (12) welded to the sides of a hollow structural steel column (1), one on each side. It is used in conjunction with a set of threaded shear studs, leveling nuts (7) and tightening nuts (19) of the male connection to serve the purposes previously mentioned. The open end (15) of the upper hollow structural steel column, underneath the female connection, will be mounted over

the group of guide plates (10) welded on the cap plate during the installation process. Inside the opening (15), a diaphragm plate (11) is attached to inner walls of the upper steel columns. The diaphragm plate is to strengthen and stiffen hollow structural steel column wall due to the compression force transferred from triangular brackets (12). There is a circular hole (16) at the center of the diaphragm plate (11), which is to facilitate the concrete fill during the concrete slab pouring. At the base of the female connection (5), openings with required reinforcement (13) are prepared in the directions of steel reinforcement of the post-tensioned concrete slab. The openings are to facilitate the installation of steel slab reinforcement (17) (18) by inserting steel reinforcement through the openings in both direction (x and y), as shown in Figure 7 and Figure 8. These steel reinforcements will be spliced to the steel reinforcements of the post-tensioned concrete slab in order to strengthen the connection and to prevent concrete cracks at the interface of concrete slab and steel column enhancing the continuity of the post-tension concrete slab.

The triangular bracket (12) is made of two triangular reinforcing steel plates and one rectangular steel plate, assembled together by welding. The triangular brackets are welded onto the outer walls of the steel column (5) at the female connection. At the center of each support plate, a drilled hole (14) was prepared and used for inserting a set of threaded shear stud and leveling nut (7) at the male connection side (9). The main functions of triangular bracket (12) can be divided according to each phase of the construction as follows.

1. During the construction period, the triangular bracket (12) will perform in conjunction with a set of threaded shear studs or bolts and leveling nuts (7) to connect the lower column with the upper column and to facilitate field adjustment, i.e. elevation and plumbness of the upper column. Then the securement of the upper column to the lower column can be performed by tightening nuts (19) onto the threaded shear studs or bolts (8).
2. After the stage of concrete pouring, the triangular brackets (12) will perform in conjunction with the threaded shear studs or bolts (8), and nuts (19) to help carry some loads transferred to cap plate (6) from the concrete slab (3). The thickness of the post-tensioned concrete slab (3) will be at least the distance from the bottom surface of the cap plate (6) of the male connection to the top of the triangular brackets (Figure 9).

The installation of a connection system between hollow structural steel column and post-tensioned concrete slab can be written in sequence as follows.

1. Assemble the upper and lower hollow structural steel columns together by placing the upper column on top of the cap plate of the lower column. The open end (15) of the female connection (5) of the upper column will be placed over a group of guide plates (10) and welded on the male connection (4) of the lower column with the installation of shim plates as required. The threaded shear studs or bolts (8) will be inserted through the holes at the horizontal rectangular plate of the triangular bracket (14) on top of the leveling nuts (9) (Figure 7 and 8).
2. Adjust the elevation and plumbness of the upper column as desired by wrenching the leveling nuts (9).
3. Tighten the upper column to the lower column by tightening the fixing nuts (19) into the threaded shear studs or bolts (8) protruding from the drilled hole (14) of the triangular bracket (12).
4. Install the additional steel reinforcement (17) and (18) by inserting through the opening (13) prepared on each side of the female connection (5) in both directions. Afterwards the additional steel reinforcement and slab reinforcement will be spliced together to ensure the continuity of the post-tensioned concrete slabs at the connecting point. This will secure the overall integrity, and prevent the initiation of concrete crack at the interface of concrete slab and steel column face.

Claim

What is claimed is:

1. A connection system configured for connection between hollow structural steel columns and post-tensioned concrete slabs, the connection system, when installed, comprising:
 - a male connection at a top of a lower hollow structural steel column
 - and a female connection at a base of an upper hollow structural steel column,
 - the male connection comprising
 - a steel cap plate at the top of the lower hollow structural steel column,
 - a group of guide plates at a top center of the steel cap plate, and
 - a group of threaded shear studs or bolts and leveling nuts located around all sides of the group of guide plates, one set on each side,
 - the female connection comprising
 - triangular brackets connected to each side of the upper hollow structural steel column, each of the triangular brackets provided with a drilled hole,
 - a diaphragm plate located inside an open end and attached to inner walls of the upper hollow structural steel column, and
 - openings provided above the triangular brackets, one on each side of the upper hollow structural steel column,

wherein the open end of the female connection of the upper hollow structural steel column is placed over the group of guide plates of the male connection of the lower hollow structural steel column, each threaded shear stud or bolt is inserted through the drilled hole on a top of the leveling nut, a tightening nut is tightened onto the threaded shear stud or bolt protruding from the drilled hole, and additional steel reinforcements are inserted through the openings and spliced to steel reinforcements of the post-tensioned concrete slabs.
2. The connection system according to Claim 1, wherein the openings are provided in directions of the steel reinforcements of the post-tensioned concrete slabs.

3. The connection system according to Claim 2, wherein the additional steel reinforcements are inserted through the openings in x and y directions.
4. The connection system according to Claim 1, wherein the steel cap plate is wider than a width of the hollow structural steel column.
5. The connection system according to Claim 1, further comprises a circular hole at a center of the diaphragm plate, configured to facilitate a concrete fill during the concrete slab pouring.
6. The connection system according to Claim 1, wherein the triangular bracket is made of two triangular reinforcing steel plates and one rectangular steel plate, assembled together by welding.