ABSTRACT

With the increasing use of composite construction worldwide, there is a growing interest in utilizing Concrete-Filled Tubes (CFTs) as primary column members. The interest arises from the fact that the properties of steel and concrete in the CFTs are fully utilized, so that the strength, stiffness and ductility of the structures constructed from the CFTs can be enhanced simultaneously. Although the use of this type of construction has increased over several decades in the past, the connection details used for connecting the steel beam with CFT column are not well established, and their inelastic cyclic behaviour has not been understood well.

In the Northridge Earthquake of 1994, the failure of the beam-column connections was found to be the common failure mode in steel structures. This has led to the recent research on improving the design of the beam-column connections, to avoid connection failure before the strength of the beam, column and the panel zone is fully developed. However, research on the connections of tubular columns is limited. Therefore, a better understanding of the inelastic behaviour of connections is needed, to make concrete-filled tubular (CFT) columns, a viable alternative in composite construction.

The main objective of this research is to identify a suitable joint detail for connecting steel beams to CFT columns in seismic regions. To fulfil this objective, a research program that included an extensive literature review,
design of connections, experimental testing, and finite element analysis by using RUAUMOKO Software, was undertaken. In this study, the connections for the steel beam to the CFT column were designed, according to the AISC (2011). The testing program consisted of testing four half-scale interior connections for steel beams and concrete filled tubular (CFT) columns, under cyclic displacement controlled load. Square and circular steel tubular columns were considered with two different types of connections: (i) End-plate type connections with flat and curved extended end-plates bolted to the CFT column with steel rods passing through the column and (ii) Through beam type connections, where the beam passes through the joint, and is connected with additional bolted bracket, without any welding between the beam and the column.

Another objective of this research is to develop a simple analytical model by using RUAUMOKO Software, to represent the response of the end-plate type connection and through beam type connection.

The experimental results of the two types of connections, demonstrated that the flat and curved extended end-plate type connections to the square and circular CFT columns respectively, using rods passing through the composite column, reached the drift angle of more than 5% and the beams had an inelastic rotational angle of more than 0.054 radians at their end, which is in excess of 0.04 radians as recommended by AISC (2002) for high seismic areas. The curved end-plates connected to the circular CFT columns were as effective, as they have been for connections with flat end-plates to square CFT columns.
The rods passing through the composite column provided a direct load path through the column, causing compression only on the outside of the column. This resulted in a stiff load path, and no damage was observed in the column tube.

For bolted through beam type connections, site welding can be avoided for connections to both circular and square CFT columns, and the location of the yielding can be moved away from the column face; also this type of connection showed a stable behaviour with drift ratio greater than 6% and the beams had an inelastic rotational angle of 0.077 and 0.059 radians for the connection with square and circular CFT columns respectively, at their end. It is recommended that the bolted through beam connections can be used in high seismic regions.

The behaviour of the panel region was examined, by comparing the calculated and the measured shear capacities of the panel zone and it was found that the equations used for calculating the panel zone capacity are conservative and can be used for design.

The comparison between the experimental results and the