Experimental Study of Square Hollow Beam & Column for Connection

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Abstract— Most of the steel structures in India are made of conventional steel sections (such as angle, channel and beam sections). However, new hollow steel sections (such as square and rectangular hollow sections) are gaining popularity in recent steel constructions due to a number of advantages such as its higher strength to weight ratio, better fire resistance properties, higher radius of gyration, lesser surface area, etc. This type of hollow sections can save cost up to 30 to 50% over the conventional steel sections (Tata Steel brochure, 2012). But unlike the conventional steel sections these hollow sections do not have standard connection details available in design code or in published literature. To overcome this problem the objective of the present study was identified to develop a suitable and economic connection detail between two square hollow sections which should be capable of transmitting forces smoothly and easy to be fabricated. To achieve the above objective, a square hollow beam to square hollow column connection was selected and modeled in commercial finite element software ABAQUS. This model was analyzed for nonlinear static (pushover) analysis considering a number of connection details. Following four alternative scheme of connection details were selected for this study: (i) using end-plate, (ii) using angle section, (iii) using channel sections, and (iv) using collar plates. The base model (rectangular hollow beam welded to one face of the rectangular hollow column) is also studied for reference. The performance of the selected connection details are compared and the best performing connection details is recommended for rectangular hollow beam-to- rectangular hollow column joints. The result shows that the load carrying capacity of the joint and the maximum deformation capacity is highly sensitive to the type of connection used. Also, the location of formation of plastic hinges in the structure (which can be at joint or at beam) depends highly on the type of connection used.

Key words: Hollow Sections, Non Linear (Pushover) Analysis, Capacity Curve, Plastic Hinge, Deformation, Connection

I. Introduction

A. Background

Connecting technology plays an important role in the performance of hollow section structures. A distinction has to be made between CHS and RHS connected members, because the behavior of joints, e.g. local behavior of members is different. A particular case is represented by beam-to-column joints in building frames with Concrete Filled Hollow Section (CFHS) columns. Both welded and/or bolted connections can be used in such a case. For beam-to-column joints of hollow section frames (e.g. RHS columns and beams or hollow section columns and I or H section beams), blind bolting technology is available. This section summaries the main aspects concerning the behavior and design of hollow section connections loaded predominantly statically. This means they can also be used for seismic resistant buildings, since seismic motions are not considered as generating fatigue phenomena. European standard [prEN 1993-1-8: 2003], application rules to determine the static resistances of uni-planar and multi-planar joints in lattice structures composed of circular, square or rectangular hollow sections, and of uni-planar joints in lattice structures composed of combinations of hollow sections with open sections. Most of the steel structures in India are made of conventional steel sections (such as angle,

B. Objective and Scope

Based on the literature review presented above the main objective of the present study is identified as to develop improved beam-to-column connection detail for square hollow beam to square hollow column ensuring smooth flow of forces.

1) Followings are the Scopes and Limitation of the Present Study:

Only RHS or SHS sections are to be considered in this study for both column and beams some time hollow columns are filled with concrete or other materials for improving compressive force capacity. This type of concrete filled hollow sections (CFHS) are however kept outside the

2) Scope of the Present Study

Only welded connections are to be considered

II. Methodology

- To achieve the above objectives the following methodology has been worked out:
- Select the geometry of a square hollow beam to square hollow column connection.
- Model the selected connection in commercial finite element software ABAQUS.
- Plan for possible alternative connection details for the selected beam-to-column connection.
- Analyze the selected beam-to-column connection for nonlinear static analysis considering CHAPTER 4.

III. Results & Discussions

As discussed in the previous chapter, the main objective of this research work is to develop a suitable connection between two box sections considering welding connective. To achieve this objective, the first thing to be considered is the parameters required to accomplish this work. From the extensive literature review which has been done for this research work, some inherent difficulties have been found out while designing a suitable connection between two hollow sections. The main difficulty is that the works which have done previously are basically between one hollow section and one conventional section. So direct extensions from that connection details is not feasible due to geometric differences. For this some new parameters should also be considered. So in this chapter firstly a Fe analysis is done for the model consisting two Square Hollow sections with the help of ABAQUS software up to failure. Then analyzing the results the main parameters like flow of forces, location of the formation of plastic hinge are sorted out and then some proposed connection details have been modeled fulfilling the criteria. Then a thorough comparative analysis has been done among the proposed connection details to select the best connection detail for the problem in all aspects.

So this chapter consists of modeling and analysis of the proposed connection details fulfilling the criteria of designing a suitable connection detail and selection of the best possible connection detail among the proposed ones.

A. *Capacity Curves*

This section presents the comparison of the capacity curves obtained from pushover analysis of the joint for different schemes of connection details. Fig. 4.11 compares the performance of selected connection details through the resulting capacity curves of the joint. The important characteristics of these curves are presented in Table 4.1. This figure (and the table) shows that the load carrying capacity of the joint and the maximum deformation capacity is highly sensitive to the type of connection used. The table shows that ultimate shear force capacity of the joint may vary 267 kN in basic model (welded) to 506 kN in

Scheme 3 (an increase of almost 90%) Similarly, the deformation at collapse is varying from 306 mm in basic model to 627 mm in Scheme 3 (an increase of about 105%) Comparison of Capacity Curves for Different Scheme of Connections

Connection Scheme	Maximum Strength (kN)	Yield Deformation (mm)	Ultimate Deformation (mm)	Ductility Factor	Formation of Plastic Hinge at
Basic	267	76	306	3.98	Beam-to-Column Joint
Scheme-1	315	104	413	3.97	Beam-to-ColumN Joint
Scheme-2	404	100	592	5.92	Beam-to- Column Joint
Scheme-3	506	152	627	4.20	Beam
Scheme-4	398	98	587	5.99	Beam-to-Column Joint

Table 4.1: Pushover Analysis Results of the Joint for Different Scheme of Connections

The results presented in Table 4.1 clearly shows that the performance of the joint with connection details of Scheme 3 performs best among others with respect to the ultimate load and deformation at collapse. Table 4.1 also presents the location of the formation of plastic hinge during the inelastic deformation. This data confirms the effectiveness of Scheme 3 as the plastic hinge form in this scheme in the beam-end away from beam-to-column joint whereas in all other cases the formation of plastic hinges occur in the beam-to-column joint

IV. Summary & Conclusions

A. *Summary*

New hollow steel sections (such as square and rectangular hollow sections) are gaining popularity in recent steel constructions in India due to a number of advantages (such as: high strength to weight ratio, higher efficiencies in resisting forces, better fire resistance properties, Higher radius of gyration, lesser surface area). Unlike the conventional steel sections these hollow sections do not have standard connection details available in design code or in published literature. To overcome this problem the objective of the present study was identified to develop a suitable and economic connection detail between two hollow sections which should be capable of transmitting forces smoothly and easy to be fabricated.

To achieve the above objective, a square hollow beam to square hollow column connection was selected and modeled in commercial finite element software ABAQUS. This model was analyzed for nonlinear static (pushover) analysis considering a number of connection details. Following four alternative scheme of connection details were selected for this study: (i) using end-plate, (ii) using angle section, (iii) using channel sections, and (iv)using collar plates. The base model (rectangular hollow beam welded to one face of the rectangular hollow column)

The performance of the selected connection details are compared and the best performing connection details is recommended for rectangular hollow beam-to- rectangular hollow column joints.

V. Conclusions

The important conclusions drawn from the present study are listed as follows:

- Load carrying capacity of the joint and the maximum deformation capacity is highly sensitive to the type of connection used.
- Ultimate shear force capacity of the joint found to vary from 267 kN in basic model (welded) to 506 kN in Scheme 3 (using channel) with an increase of almost 90%. Similarly, the deformation at collapse is varying from 306 mm in basic model to 627 mm in Scheme 3 (an increase of about 105%).
- The formation of the plastic hinge is usually found to occur at the beam-to-column joint for all the different schemes of connection details except Scheme 3. Scheme 3 results the plastic hinge in the beam end away from joint.
- Performance of the joint with connection details of Scheme 3 (columns jacketed with two channel sections

and connected with beam by welding) performs best among others with respect to the ultimate load, deformation at collapse and formation of plastic hinges.

VI. FUTURE SCOPE

This study can be further extended as follows:

- Present study is based on exterior beam-to-column joints. Similar study can be executed for interior beam-to column joints
- This study considers equal beam and column sections in the selected joints. It will be interesting to study the responses of the joint with varying dimensions of beam and column sections.
- Results in this study are based on nonlinear static (pushover analysis). This can be extended to include nonlinear dynamic analyses.

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