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Analysis and Optimization of Composite Cold Formed Steel Connections

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Abstract—*The concept of concrete infilled cold-formed steel framing construction has been widespread after understanding structural characteristics with a massive research in recent years. The present study serves as an important element for cold formed concrete infilled steel sections to achieve the structural sustainability. Series of numerical studies have been carried out to analyse the behavior of bolted connections in the concrete infilled cold formed steel rectangular beam-column sections. Numerical studies are carried out using the finite element software 'ANSYS'. Different connection patterns are modeled and analysed in order to understand the role of various cold formed steel elements on the load carrying capacity of beam column joints. It is observed from the present study that rigidity of concrete infilled cold-formed steel bolted connections is enhanced and also the stress-strain relationship is improved as compared to hollow cold-formed steel bolted connections. It is also observed from the study that the connections patterns used in current study proved to be economical with minimum complexity at joints.*

1. INTRODUCTION

The cold formed steel sections filled with concrete are the sections which are used in the construction of steel structure. Nowadays, various type of sections, such as the square hollow section (SHS), circular hollow section (CHS), rectangular hollow section (RHS) etc., are being used as a structural element. However, industries develop new different sections with the desires for both aesthetics and efficiency. With reference to the production process, steel sections can be categorized into two forms, one is hot-rolled sections and the other is a cold formed steel section. These types of steel units can be distinguished by the method of manufacturing process. Hot-rolled units are formed under the heat state during the production process while the cold-formed steel units are manufactured at room temperature. Cold-formed sections (CFS) are fabricable as pre-engineered buildings, economic in transportation and ease in handling. Light weight sections are used in earthquake resistant design in order to resist inertial forces of building. Concrete infilled cold formed steel sections have turn out to be one of the popular construction adoptions in low-rise building, medium-rise building and residential construction. In the past, concrete infilled cold-formed tubular steel sections were used as secondary structural units due to the lack of design standards / codes for engineers to design as primary members. Due to the growth in construction industry and research activities design principles were developed to support the safety and instability issue. Nowadays concrete infilled cold-formed steel sections are adopted as a primary structural members.

The thickness of cold formed tubular steel sections varies from 0.9 mm to 3.2 mm. The strength obtained from these cold-formed tubular steel sections is higher than that of hot-rolled steel sections per unit weight. When concrete is filled in the cold-formed steel sections, stability characteristics of both slender and short columns are modified which improves the strength of the structural member against buckling. In addition to this, the infilled concrete will also play an important role in improving the post-peak behavior of the slender and short columns.

Based on the elastic plate buckling theory in Panels subjected to gravity loading, development criteria for maximum connection spacing was studied (Yener,1984). Design of Cold-formed tubular Steel Beams with the help of Rectangular Hollow Flanges was studied and investigated (Somnath, 2004).

Studies reporting experimental research on concrete infilled high strength cold-formed stainless steel hollow columns. Behavior of columns was observed using various concrete cylinder whose strength varied between 40 - 80 Mpa. Series of tests were performed to find out the effects of the shape of plate thickness, steel tube, and infilled concrete strength. These stainless steel high strength tubular columns were of rectangular and square hollow sections. The concrete infilled stainless steel high strength tube specimens were tested under uniform axial compression. The strain relationships, column strength, and various failure modes of these columns were studied (Young B and Ellobody E [4], 2006).

Studies were carried out to develop a new steel beam which was cold-formed, with a thin slender web and two rigid tubular rectangular flanges. Which are formed using the intermittent screw fastening process to enhance flexural capacity and maintained less fabrication cost. Also describes detailed work on the structural behavior of the new rectangular hollow flange beams which were subjected to the flexural action (Wanniarachchi S [5], 2006).

For slender columns a check is performed on the C350 square cold formed steel sections to work out with applicable column style curve for cold-formed tubular sections and for the beams check on plastic bending test is done and performed to work out with the plastic bending capability (Hancock G and Zhao X [7], 2006).

Four specimens of through-diaphragm connections crammed with concrete hollow rectangular steel columns were tested under cyclic load condition which is provided laterally. The stiffness, strength, energy dissipation capability and malleability were evaluated completely at different loads. The physical curves, moment-rotation, square measure are stable and exhibits no obvious strength for deterioration or for stiffness degradation (Cheng Y and Schafer W [8], 2007).

Several literatures were reviewed on cold-formed steel connections namely welded connections, storage rack connections, screwed connections and bolted connections. Proper positioning of these connections in application of cold formed steel sections was also studied (Huei, 2010).

Seismic behavior of concrete filled rectangular steel columns employed lateral load conditions with variables such as geometry of diaphragms, horizontal stiffeners, and configuration (Qin, 2013).

Studies were carried on ninety three unpublished experiments on bolted connections of cold-formed steel sections for rupture in the net section. This article also includes a study on the strength reduction coefficient for restricting the shear lag effect (Emerson 2013).

In present study, the distortion patterns on the Load carrying ability of Beam-Column connections are studied. Secondly, the flexural performance of Rectangular Hollow cold formed tubular steel sections and Concrete infilled cold -formed tubular steel sections is studied. Finally, the Stress-Strain performance of Bolted connection patterns in Cold-formed steel tubular rectangular sections is discussed.

2. NUMERICAL MODELLING OF BEAM COLUMN JOINTS

Modelling is done after going through various research papers, Books and Standard codes. For this proposed study the section dimensions are employed according to British Standard BS 5950: Part 01: 2000[9] (table-1).Pitch distance and Bolts are according to IS 801 and IS 1363(part 1) respectively. Each model has different geometry and twenty different replicas have been modelled as shown in Fig. 1 - Fig. 20. Components (parts) are prepared for every model separately according to the specified dimensions. Then these components are assembled precisely with the help of bolts and to form the required model shape. In the initial stage the hollow parts are assembled with the help of desired joint components and then the concrete core is infilled in these hollow assemblies and after this 09 mm holes are made through out for bolt insertion by keeping appropriate pitch distance in between two bolts according to IS 801(part 1) and fastened with the help of 08 mm diameter bolts by following IS 1363 (part1) to give the desired infilled cold formed steel connections.

Table (1) Cold formed Steel Dimensions

Section	Dimensions
Beam (RHS)	100 X 50 X 900 X 2.5 mm
Column (RHS)	100 X 50X 900 X 2.5 mm
Gusset Plate thickness	05 mm
Infilled solid core	95 X 45 X 900 mm
Bolt diameter	08mm
Cleat Angle thickness	05mm

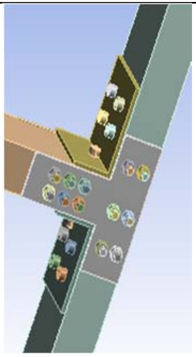
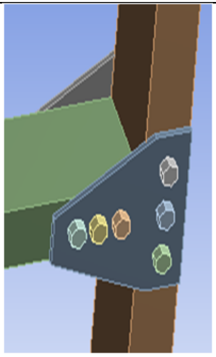


Fig. 1. Model-1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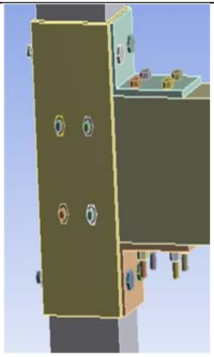
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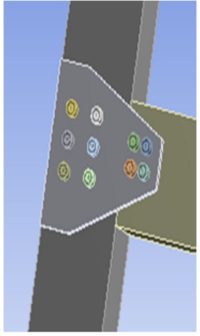
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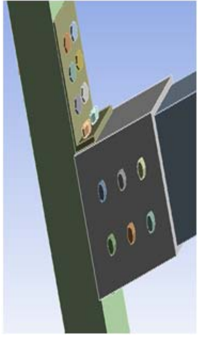
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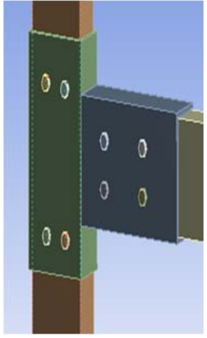
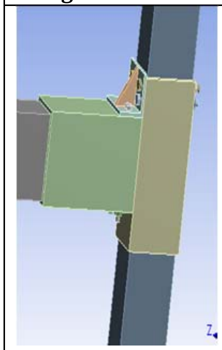


Fig. 6. Model-6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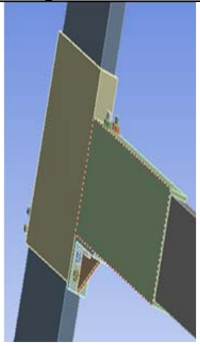
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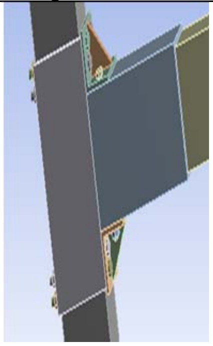
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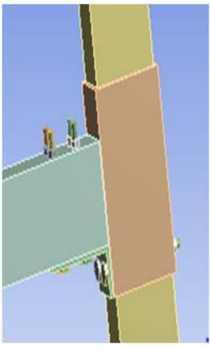

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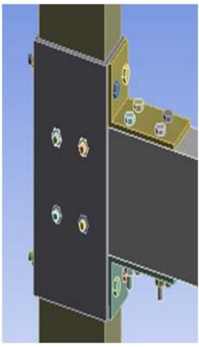


Fig. 11. Model -11

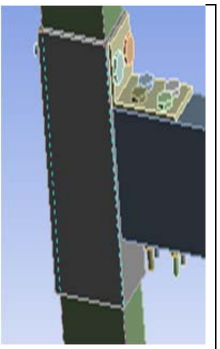


Fig. 12. Model-12

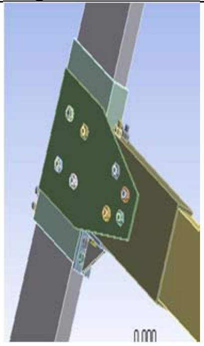


Fig. 13. Model-13

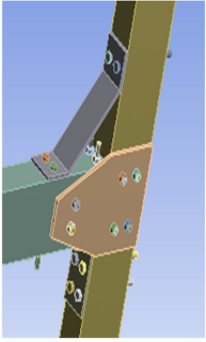
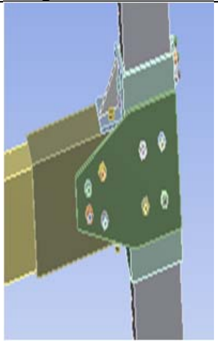


Fig. 14. Model-14



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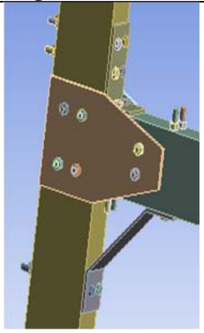


Fig. 16. Model-16

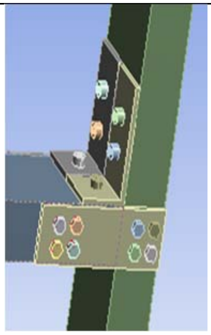
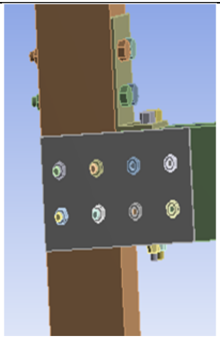


Fig. 17. Model-17

Fig. 18. Model-18



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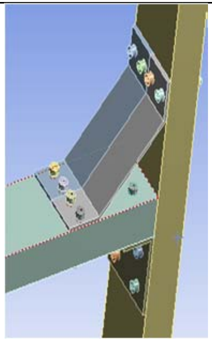

Fig. 20. Model-20

3. DISCUSSIONS

For the analysis purpose all twenty models have been analyzed. Each model is investigated by keeping support condition as fixed to the both ends of column (Fig. 22) and assigning properties for infilled concrete section as shown in table-3 and hollow steel section as shown in table-4. Followed by this Meshing is done (Fig. 21). A series of point loads is applied normally downward on far extreme end of beam of column-beam assembly as shown in Fig. 22 and the magnitude of this load is changed periodically (i.e. 2 kN, 4 kN, 6 kN, 8 kN, 10 kN and so on). The deflection, stress and strain is noted at each loading condition on the Beam. These deformation values are then plotted on load vs. deformation curve and compared with different curves for different models connection patterns. After interpretation of these results solution is made.

Table 2: Infilled concrete properties.

Property	Value
Density	2400 kg/m3
Young’s modulus	3 x 104 MPa
Poisson’s ratio	0.18
Grade of concrete	M25
Compressive Strength	25000 Pa

Table 3: Cold formed steel properties

Property	Value
Density	7850 kg/m3
Young’s modulus	2 x105 MPa
Poisson’s ratio	0.3
Tangent modulus	2 x 103 MPa
Yield strength	350 MPa

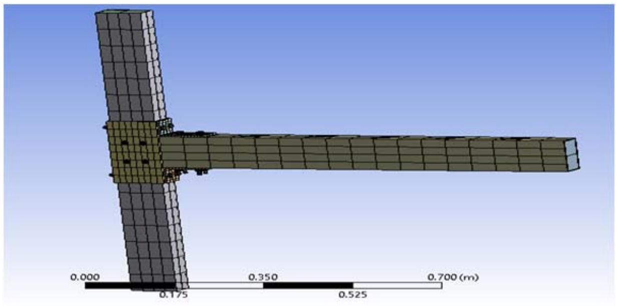

Fig. 21: Mesh configurations of the beam column joint.

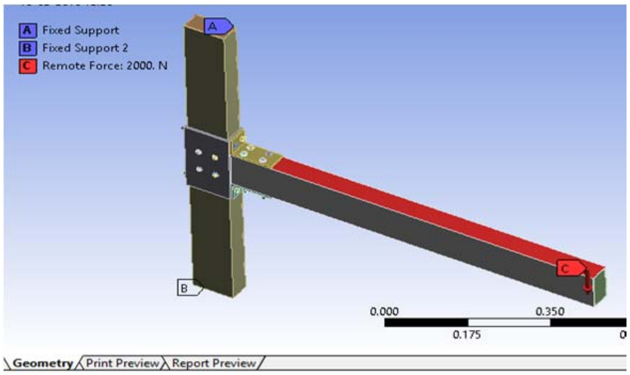

Fig. 22: Support and loading conditions used.

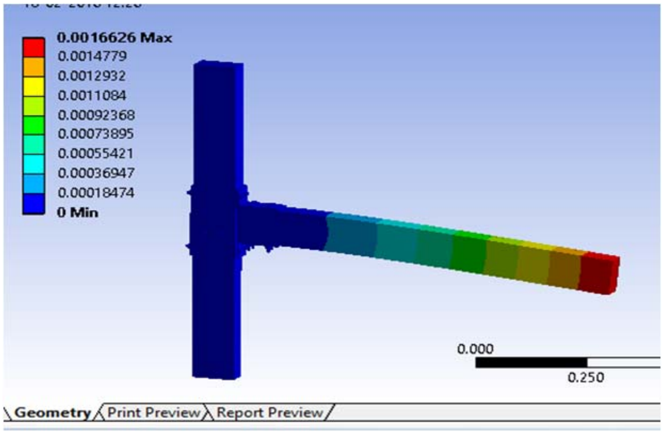

Fig. 23: Total deflection.

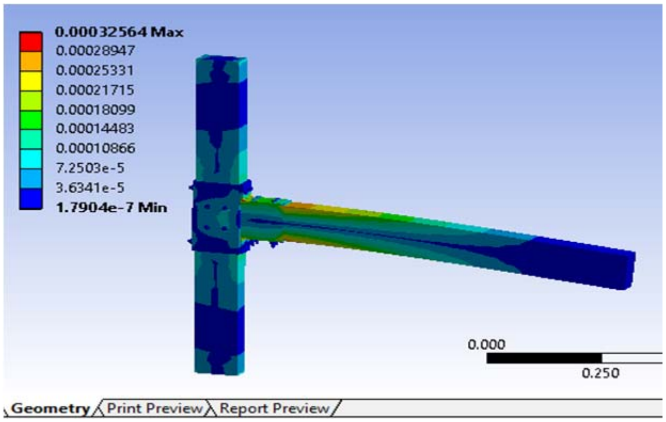

Fig. 24: Strain distribution in connection patterns.

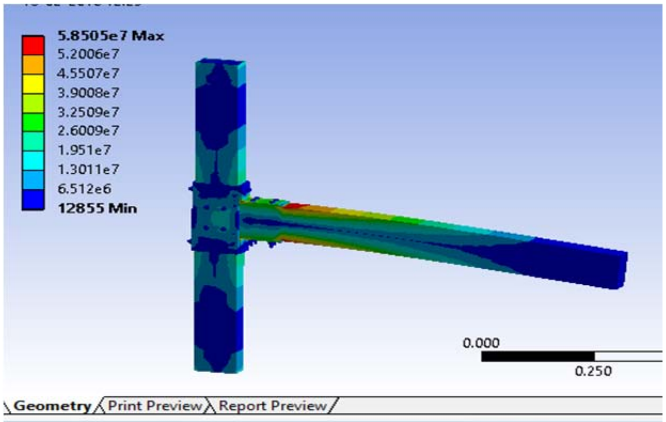

Fig. 25: Stress distribution in connection patterns

After analysis the Load and deformation values obtained are tabulated and plotted as load Vs deformation relationship as shown in Fig. 26, Fig. 27, Fig. 28, Fig. 29 ,Fig. 30 and Fig. 31. From this relationship achieved deformation is compared with different connection patterns and conclusion is made on this basis.

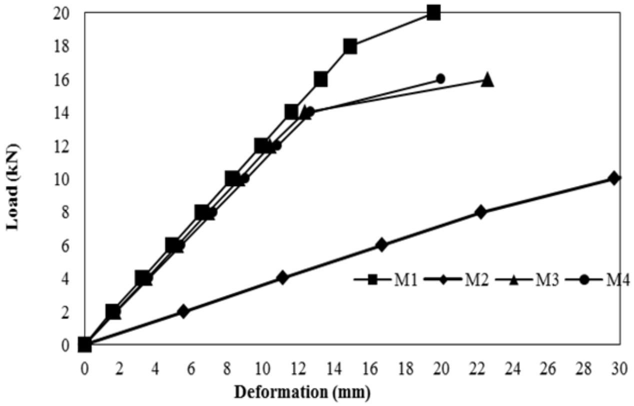

Fig. 26: Load vs. deformation curves for the connection patterns (i) M1 (ii) M2 (iii) M3 (iv) M4.

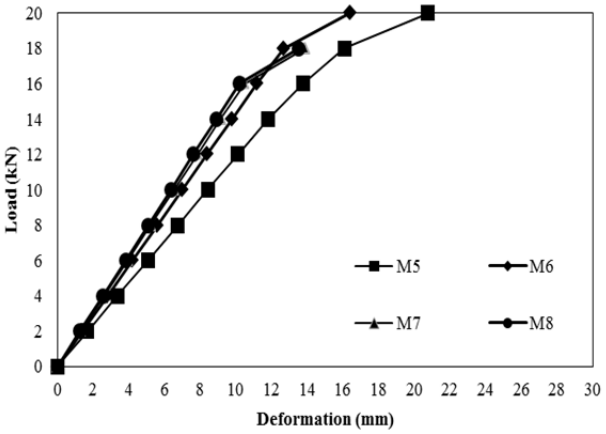

Fig. 27: Load vs. deformation curves for the connection patterns (i) M5 (ii) M6 (iii) M7 (iv) M8.

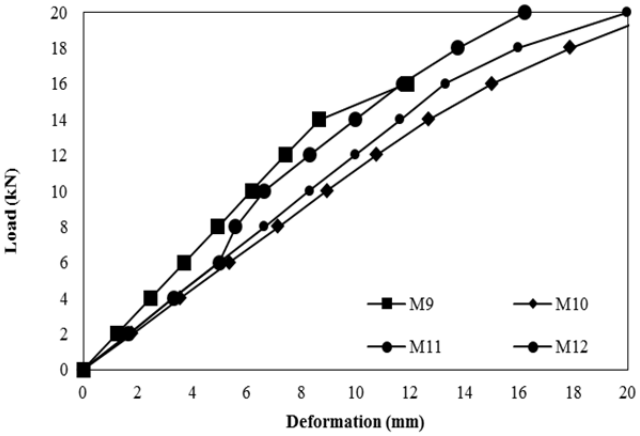

Fig. 28: Load vs. deformation curves for the connection patterns (i) M9 (ii) M10 (iii) M11 (iv) M12.

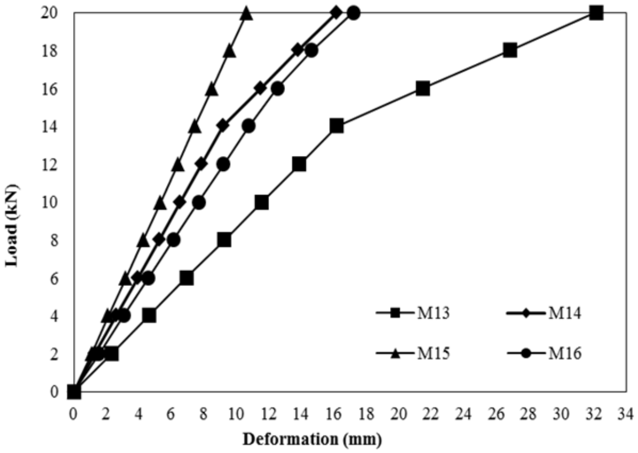

Fig. 29: Load vs. deformation curves for the connection patterns (i) M13 (ii) M14 (iii) M15 (iv) M16.

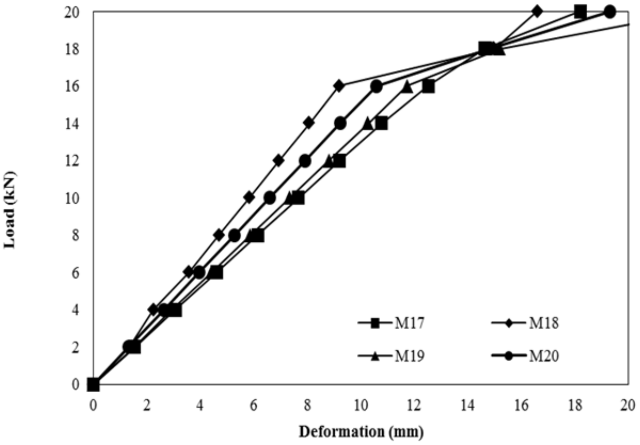

Fig. 30: Load vs. deformation curves for the connection patterns (i) M17 (ii) M18 (iii) M19 (iv) M20.

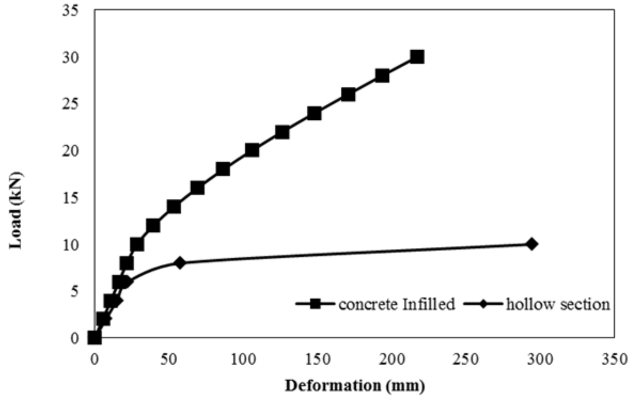

Fig. 31: Load vs. deformation curves for the concrete in filled and hollow section connection patterns.

4. CONCLUSION

It is observed from the present study that rigidity of concrete infilled cold-formed steel bolted connections is enhanced and also the stress-strain relationship is improved as compared to hollow cold-formed steel bolted connections. It is also observed from the study that the connections patterns used in current study proved to be economical with minimum complexity at joints.Flexural strength of the M15 connection is higher than other connection patterns also deformation is in control up to a load value of 20 kN. Effect of different connection patterns on the stress-strain performance of concrete filled tubular cold-formed steel sections are studied.Observations showed that stiffener plate supported connections has minimum deformation on comparing to other connection patterns.

In addition to this concrete infilled rectangular connections increases flexural strength up to (20-40) %.

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