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Performance Analysis of Column to Column Bolted Connections

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Abstract—The bolted connection is a new application for mounting rectangular hollow section (RHS) columns in prefabricated multi-high-rise steel structures, which may bear the combination of bending moment and shear under permanent, live, wind loads or earthquake . To investigate the performance analysis of a bolted connection of column to column this study conducted a comparison between detachable precast composite column and hollow steel column to column connection. Conducted loading tests and finite element analysis (FEA) of column-to-column bolted connections with different base plate thicknesses, different base plate dimensions, bolt as well as one column with beam connection. The influences of the base plate thickness, different bolt dimensions on the stiffness and strength of the connections, bolt tension and contact force were studied, and the failure mode and mechanism of the connection were obtained.Failng of column occurs without any fail in the bolted connection.

Index Terms— Ansys 16.1, Lateral loading, Hollow steel column, Detachable precast column, Finite element analysis, Force reaction, Total deformation

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1 INTRODUCTION

Prefabricated steel structures have become an important type of building in many countries. It can be constructed according to a standardized design, industrial production and on-site assembly, which significantly reduce labor intensity and shorten the construction period. The square pipe columns were all connected on-site using bolts instead of welding these structures together, which significantly shortened the construction period.

In this paper detachable precast column is compared with the hollow steel column of same parameter as per Fig 1. The precast members are connected by end-plates. The joint of the proposed connection consists of two endplates (lower and upper column plates), nuts, and high-strength bolts. The hollow steel column has more load carrying capacity and self weight when compared to detachable precast column. In this paper modification has done for hollow steel column to column joint by connecting beam to the column, by changing thickness of base plate, by cutting the hollow base plate and by changing the diameter of bolt.

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2 OBJECTIVES

- To compare detachable precast column and steel column according to load carrying capacity and self weight.
- To conduct performance analysis of bolted connection of steel column with rigid beam joint at different parametric condition
- To conduct performance analysis of bolted connection of steel column without rigid beam joint when lateral load is applied.
- To choose the better performance

3 LITERATURE REVIEW

X.C. Liu , H.X. Wang , Z.W Yang , S.H. P u Zhang (2016) conducted static tests and finite element analysis (FEA) of 12 column-to-column bolted-flange connections with different flange thicknesses, bolt edge distances, flange edge widths and bolt hole diameters, as well as one column without a connection. A significant prying action occurred on the flange contact surface increase the bolt tension in the tensile region and caused the bolt shanks to experience tension and bending moment. The formulas for the yield bearing capacity were proposed and were verified by the test and FEA.

X.C. Liua, X.N. Hea , H.X. Wanga , A.L. Zhanga In this paper the bolted-flange connection is used to connect rectangular HSS columns in prefabricated multi-story and high-rise steel structures. It subject to axial compression, bending moments and shearing under the combination of dead, live, wind loads or earthquake action. It applied to 12 column to column bolted flange connections with different flange thickness, bolt edge distance], flange edge widths and bolt hole diameters as well as one column without connection.

Wanga, Ling Lib,Dabiao Chena,Ting Xua This paper investigated behavior of two blind bolted extended endplate connections using Hollow-Bolts to square hollow section (SHS) column. The characteristics of the Hollow-Bolt were firstly examined (nine direct tension tests and six double shear tests).Strain intensities at connection region and load transfer mechanisms of flexural resistance and catenaries mechanism were analysed.Results indicated that the premature failure of thin column wall disabled the full utilization of Hollow-Bolts strength. Hollow-Bolts presented lower initial normalized stiffness due to their limited pre-tensions, and lower level of centenary mechanism development due to the reduced strength of Hollow Bolt under large deformation .

Matthew D. Elliott a , Lip H. Teh ,Aziz Ahmed Investigates the behavior and strength of structural steel bolted connections whose failure modes involve shear yielding and/or fracture. Such failure modes include the shear-out (or tear out) and the block shear failure modes. The paper points out that the location of fracture initiation can be easily misidentified by a superficial inspection of the deformed and fractured state of the bolt hole. The paper also explains that the ultimate shear-out capacity of a steel bolted connection can be reached without fracture. The explanation is demonstrated through a finite element analysis that does not simulate fracture.

Amir Ahmad Hedayata, Ehsan Ahmadi Afzadia,Amin

This study was aimed to propose appropriate failure criteria for bolt fracture prediction in shear when threads are excluded from the shear plane. Three methods here referred to as MTD1, MTD2 and MTD3 were proposed.MTD1 and MTD2 were based on the monitoring of the level of stress and strain at the critical elements of the bolt shank.MTD3 was based on the extended finite element method and consisted of two main steps including defining crack initiation and crack evolution.MTD1 and MTD3 were reasonably acceptable for prediction of the bolt fracture in shear with negligible amount of error.MTD1 is a suitable method only the capacity of the system at the onset of the first bolt fracture is required.

Matthew D. Elliott a , Lip H. Teh ,Aziz Ahmed Investigates the behavior and strength of structural steel bolted connections whose failure modes involve shear yielding and fracture. Such failure modes include the shear-out (or tear out) and the block shear failure modes. The paper points out that the location of fracture initiation can be easily misidentified by a superficial inspection of the deformed and fractured state of the bolt hole. The paper also explains that the ultimate shear-out capacity of a steel bolted connection can be reached without fracture. The explanation is demonstrated through a finite element analysis that does not simulate fracture.

Thang Nguyen Dao, A.M.ASCE1 and John W. van de Lindt, M.ASCE Objective of this paper is to investigate the seismic performance of a new light frame cold-formed steel-frame system. The system includes floor trusses, open panels, V-braced panels, columns, and connections. Results of this experimental program provided insight into the behavior of the subassemblies under cyclic loading. Result indicate that the system has good ductility as a result of the screwed plate connections between the light-gauge members and between the light-gauge members and square columns

2 FINITE ELEMENT ANALYSIS

DETACHABLE PRECAST CONCRETE COLUMN

A non-linear static analysis was done in ANSYS workbench 16.1 for detachable precast column. The specimen shown in Fig.2 was loaded to failure to investigate the structural performance of the proposed column-to-column joint. Specimen was fabricated with two thick plates, each having a thickness of 45 mm. The use of thick plates in Specimen was to accommodate end nuts that connected column reinforcing bars to the lower and upper plates as shown in Fig 3.Specimen successfully transferred moments between the upper and lower columns, creating a rigid joint for moment connection.

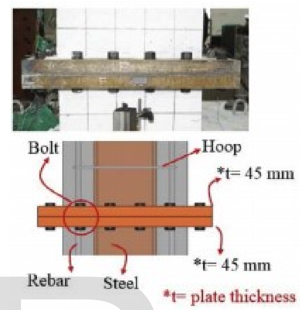
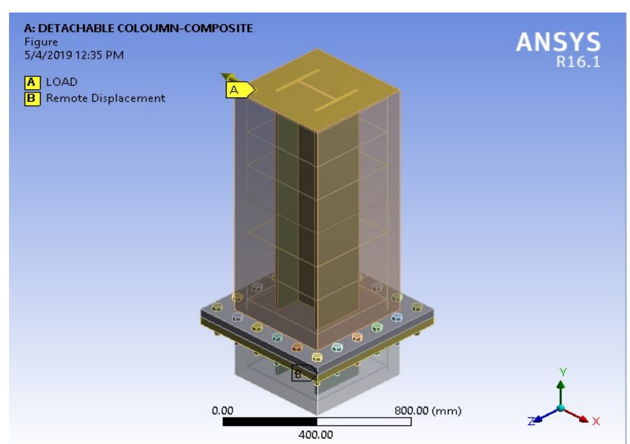


FIG 3: Column to column connection

Material properties and specimen details are given in table 1.

Plates of 700 × 700 × 45 (mm) for both Lower and upper plates were used. Nuts of M22 (Height: 22 mm) Bolts used. Embedded H-steel for of H-250 × 250 × 9 × 14 and Column re-bars of HD25 (diameter: 25 mm) were used. Column section 500 × 500 (mm) is taken. The model of detachable pre cast column is shown in the below picture.



Detachable precast column model

Summary and material properties of the column plates [19].

	C1
Concrete** (test values)	f'_c = 21 MPa E_c = 21,540 MPa Size: 500 × 500
Re-bar* (test values)	f_y = 550 MPa E_s = 206,000 MPa 4-D25
Steel* (test values)	f_y = 350 MPa E_s = 205,000 MPa H-250 × 250 × 9 × 14
Plate* (test values)	f_y = 350 MPa E_s = 205,000 MPa Size: 700 × 700 Thk: 45 mm
Metal filler plate* (test values)	N/A
Bolt and nuts* (nominal values)	f_y = 900 MPa f_u = 1000 MPa E_s = 206,000 MPa M22-F10T

HOLLOW STEEL COLUMN

A non-linear static analysis was done in ANSYS workbench 16.1 for hollow steel column. A specimen of hollow steel section of same parameter as that of detachable precast concrete is taken. The specimen is given in the Fig 3.

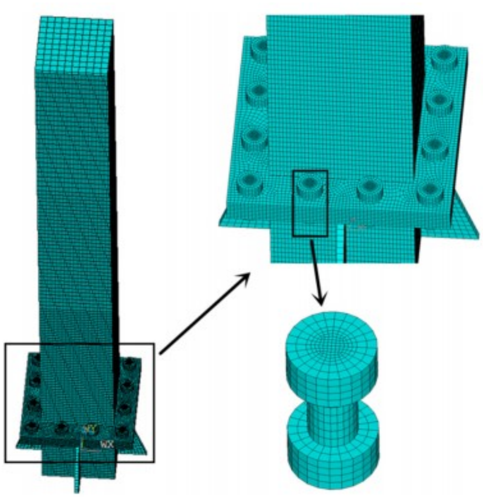


Fig 3: finite element model

Same lateral load has been applied on both the specimen and compared the load carrying capacity and self weight.

RESULT

From the result obtained from the ANSYS fig 4 steel columns has more load carrying capacity and less self weight as compared to detachable precast concrete column. So hollow steel column is more economical.

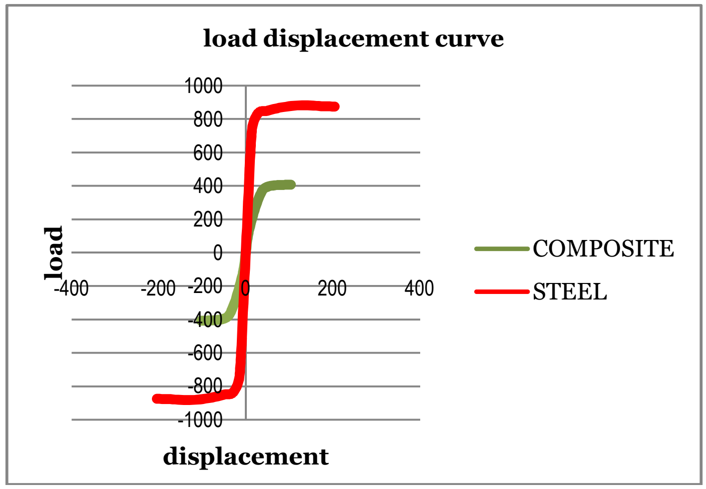


Fig.4:load displacement curve

MODELLING

In this paper two types of modeling has done. Type 1 is by connecting a beam to the column. Type 2 is without connection beam to the column.

1 COLUMN WITH BEAM CONNECTION

Here a beam length of 2m connected to the column at a distance of 1.3 m from the top. Beam size is taken as 450×300mm.Two cases are taken such as changing the thickness of base plate and by cutting the base plate at different dimensions.

CASE 1

Here base plate is taken as 30mm, 35mm, 40mm, 45mm.The graph has plotted for the 4 different cases in fig 5.The load and displacement of each base plate thickness is given in Table 1.when thickness is more the load taken by the column will be more.

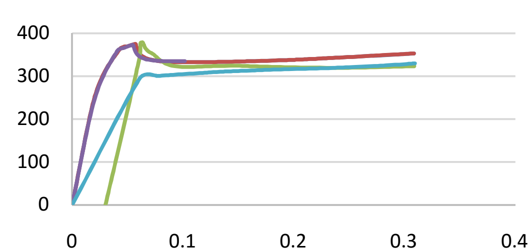


fig.5: Load displacement curve

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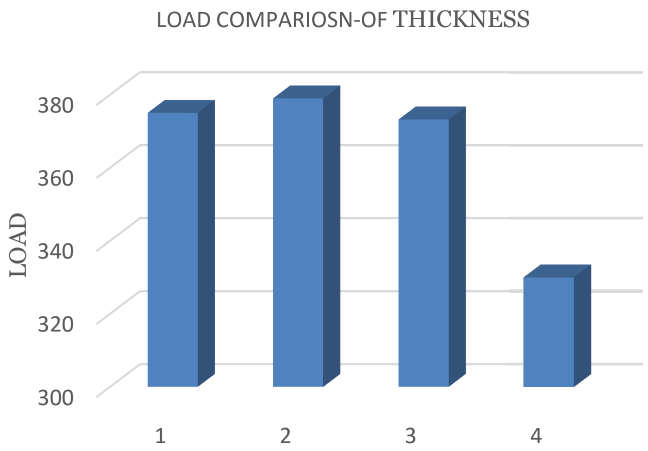


THICKNESS	DISPLACEMENT MM	LOAD KN
30	56.858	375.06
35	63.169	379.03
40	54.597	373.25
45	309.44	329.98

Table 1

From the above study it shows that when load applied to the beam then there is no effect on the column joint. So column joint connection is more stronger so load can transfer through the connection without any failure of bolt

CASE 2

Here base plate cut into three dimensions such as 25mm from bolt hole, 50mm from bolt hole and 75mm from bolt hole.(Fig 6).The load for different hollow dimension is given in Table 2.

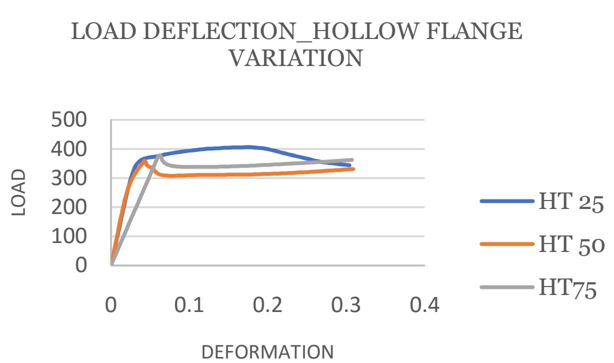
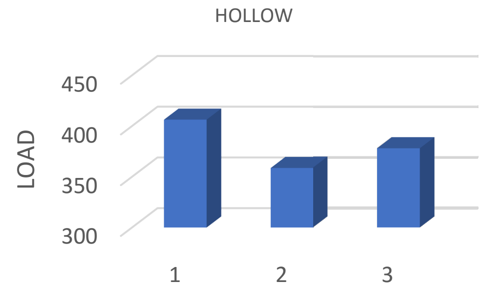


FIG 6: Load Displacement Curve



SI NO.	HOLLOW MM	DEFLECTION MM	LOAD KN
1	25	163.81	406.36
2	50	42.327	358.7
3	75	62.863	377.79

Here by cutting the base plate self weight of column is reduced and will be more economical comparing to the previous one. After applying load there is no effect on the column joint.

2 COLUMN WITHOUT BEAM CONNECTION

Here column joint is analyzed without any beam connection. Load is applied laterally on the beam. Performance is analyzed at two cases. case 1 is at different thickness and case 2 is at different hollow base plate.

CASE 1

Here base plate is taken as 30mm, 35mm, 40mm, 45mm.The graph has plotted for the 4 different cases in fig 7.column joint is studied without any beam connection. Lateral load is applied by taking 3m column. Due to lateral load there is no effect on the bolted joint. The displacement and load were given in Table 2.

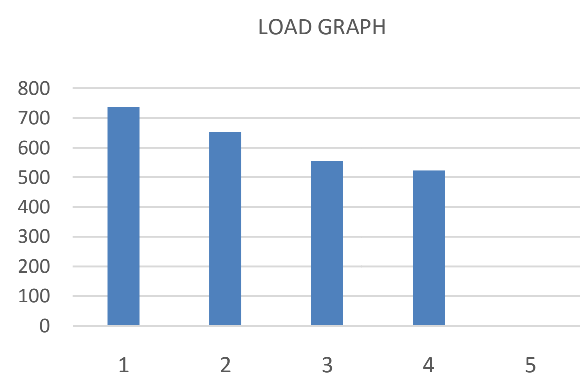


Fig 7: load displacement graph

THICKNESS	DISPLACEMENT (MM)	LOAD (K N)
30	0.0382	735.91
35	30.326	653.21
40	27.685	554.56
45	35.24	522.96

Table 2

CASE 2

Here base plate cut into three dimensions such as 25mm from bolt hole, 50mm from bolt hole and 75mm from bolt hole.(Fig 8).The details of displacement and load are given in Tabl3.Here when lateral load applied to the column the column bents without any displacement of bolt connection. so bolted connection is safe.

Load displacement **curve**

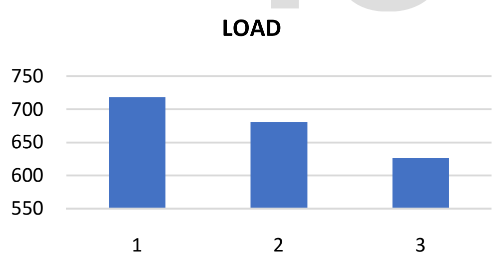


Table 3

SI.NO.	HOLLOW MM	DISPLACEMENT MM	LOAD KN
1	25	39.	718.23
2	50	30.326	680.59
3	75	30.328	626.28

CONCLUSION

1) Finite element models of the columns with base plate were built and joints are analyzed. Here detachable precast column is compared with hollow steel connections. Compared by applying the same lateral load for both. From the Ansys software load carrying capacity is more the detachable precast column. and detachable has more weight than steel. so hollow steel column s more economical and can be easily constructed de to less self weight.

2) In first case Performance of column bolted connection with rigid column beam connection analyzed by changing the base plate thickness and hollow base plate. When load applied o the beam, the beam fails without any failing of column to column joint. it shows that column to column joint can transfer load at any condition without failing.

4).In second case column joint analyzed by removing the beam.Laterl load is applied at the top of column. The study states that column joint does not fail at any loading condition

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