Analytical Study on Effect of Dimensions of Tapered Cover Plates and vertical stiffeners on Replaceable I-Beam to CHS Column Joint

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***Abstract*—The moment resisting frames with welded beam to column connections are vulnerable to fragile failure and normally explain giant residual deformation followed by earthquakes. Because of this, a new steel structural system with good energy dissipation is required to deal with such sudden falls. Modern researches on I beam to Circular Hollow Section(CHS) column joints with exterior diaphragms and replaceable links also established their efficiency in seismic application. This research investigates the influence of dimensions of tapered cover plates(TCPs) and vertical stiffeners(VSs) on connection behavior using ANSYS software.**

***Keywords*— Tapered cover plates, vertical stiffeners, CHS column.**

I. INTRODUCTION

Moment resisting frames with welded steel beam column joints are vulnerable to fragile crack and normally show large residual deformation after earthquakes. Therefore, a new steel structural system with good energy dissipation is required to deal with such sudden falls. Modern researches on I beam to Circular Hollow Section (CHS) column joints with exterior diaphragms and replaceable links also established their efficiency in seismic application. To promote the performance, researchers have used smart materials in the connection configurations.

Structures with circular sections acquire many structural and architectural advantages due to their closed geometry. They require less protection against corrosion than comparable structures made with open sections. An extra advantage is that, the internal empty space can be used to provide aeration facilities or to pack with concrete. Circular columns packed with concrete increases compressive strength and shows improved seismic resistance. Circular hollow sections are very effective when considering design resistances along with torsional resistance and bending stiffness. On the whole, even though circular columns are more costly than open sections, it offers enhanced strength-to-weight proportion that provides more cost-effective moment resistant frames with suitable design.

For those joints among CHS column and I beam, the joints with exterior diaphragm or internal diaphragm is frequently applied. The results shows that the joint with external diaphragm is more reasonable, since the diffusion of force is clear, stress circulation of joint region is uniform and it is easy to be constructed. It has relatively large stiffness, good plasticity, and high bearing capacity. A number of researches were performed in past 20 years on exterior diaphragm joints to circular columns.

Two major problems of the joints among CHS column and I beam with exterior diaphragm are, (i) deformation in the web section, (ii) strain attentiveness and out of plane deterioration in the diaphragm plates(DPs) leads to rupture of plates, welds and columns. Moving the end of beam away from the face of the CHS column face and designing the dimensions of external diaphragm for the complete strength of beam flanges are suggested for designing connections that will offer required homogeneous stress distribution around and into the column, which will improve the two deficiencies mentioned above.

The purpose of this study is to investigate the cyclic response of an exterior diaphragm joint among a steel I beam and a CHS column. The joint consist of 2 DPs, welded to the perimeter of CHS column and bolted to the flanges of I beam with two tapered cover plates(TCPs). A web stub (WS) is welded to the face of the column and bolted to the web of I beam. TCPs were incorporated in the joint to act as disposable or replaceable sacrificial components that disperse major part of energy while rest of the joint parts remains elastic to minimize the post-seismic repair.

Chunyan Quan et al. (2017) conducted a research on replaceable connection among CHS column and I beam under cyclic loads. The pretension force on the bolts of TCPs has large effects on connection behavior. In general, reduced preloading force cause reduction in load bearing capacity, but also reduce stress demands on DPs and beam flanges. Higher energy dissipation and rotation capacity is by the action of slippage of bolts

Majd Khador et al. (2016) studied the cyclic response of exterior diaphragm connections to CHS column using replaceable links. Parametric investigation on influence of the TCP steel grade shows that grade S355 amplified the joint moment capacity compared to grade S235. On the other hand, this was accompanied by an enhancement of force demand in the beam and DP and a diminution in the maximum rotation of the plastic hinge region. Use of the weaker steel grade S235 is more favorable option than S355 grade.

II. ANALYTICAL INVESTIGATION

A. *Finite element modelling*

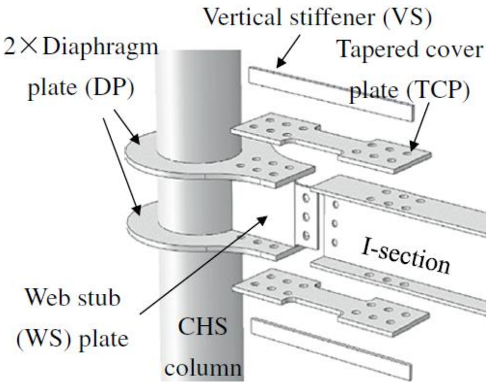


Fig 1. Joint before assembly

The connection shown in Fig 1 consists of 2 DPs, which have width of 90 mm, which is shop welded to the external circumference of a 2m CHS 244.5X10 column under satisfactory quality control, and connected to the flanges of a 2 m UKB 203X133X30 beam with 2 TCPs using 24 M_{22} bolts of Class10.9. A web stub plate is welded to the outer surface of the CHS column and attached to the I-beam web using 3 M_{16} bolts of Class10.9 to transmit the shear forces. The grade of steel joint parts was S355 in all models. The only exemption was TCP, which is with a steel grade of S235. Seven models are taken for study by varying the dimensions of TCPs and VSs.
Symmetric model is used in order to save analyzing time.

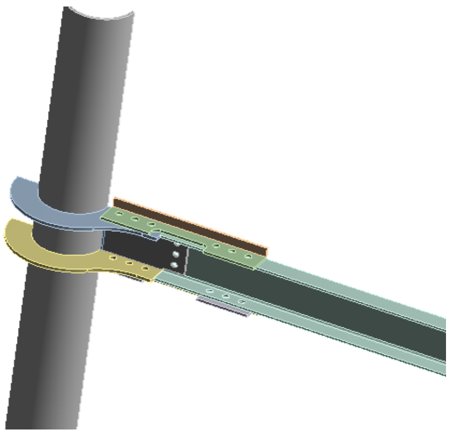


Fig 2. Symmetric model

B. *Loading procedure*

Cyclic displacement up to 80mm is provided in 30 cycles

Cycle number	Vertical displacement d_a (mm)
1 to 6	± 7.5
7 to12	± 10
13 to 18	± 15
19 to 22	± 20
23 to 24	± 30
25 to 26	± 40
27 to 28	± 60
29 to 30	± 80

The loading procedure was based on the ANSI/AISC 341-10 (2010) specifications for qualifying cyclic loading of beam to column moment joints. The entire loading procedure was separated into a number of steps. Gravitational force of joint components and Pretensioning force of the bolts were applied in 4 steps, 1/4 in each step, inorder to keep away from numerical abortion due to rapid change in forces. Vertical displacement at the end of beam was applied in the final step.

C. *Bolts preloading force*

Bolt preloading force (Fp,Cd) acting on them was designed according to the specifications of Eurocode 3, BS EN 1993:1:8 ,2005 for slip-resistant connections:

$$F= 0.7 \times f_{ub} \times A_s$$

Where, f_{ub} is ultimate strength of the bolts; A_s is the tensile stress area of a bolt.

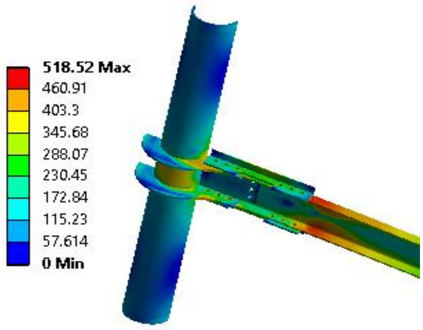
III. RESULTS AND DISCUSSIONS

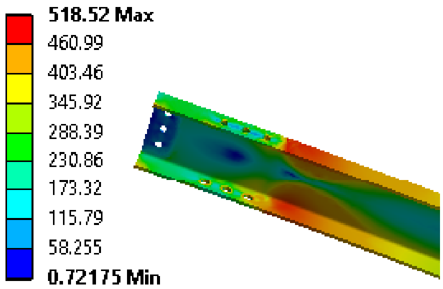
The cyclic analysis of models were analyzed in ANSYS Workbench. Results obtained from analysis were tabulated and shown in the table below. Stress values of the joint parts of 7 models are shown in Table1.

Table 1.Stress on joint components

SPECIMEN	STRESS(N/mm^2)				
	I-Beam	TCP	DP	CHS Column	Web stub
TCP12-VS40X12	518	356	426	278	414
TCP12-VS30X12	483	385	364	276	370
TCP12-VS30X8	468	384	347	273	382
TCP12-VS30X6	435	410	349	275	372
TCP12-No VS	411	387	376	303	333
TCP15-No VS	425	345	409	304	337
TCP20-No VS	475	371	479	325	364

The specimen name TCP12-VS40X12 denotes the thickness of TCP and dimensions of VS.





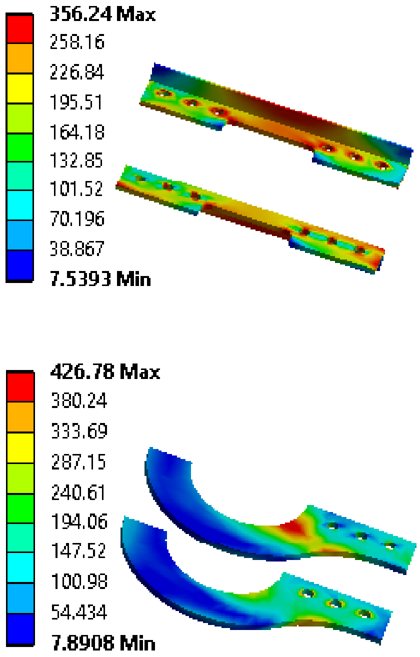
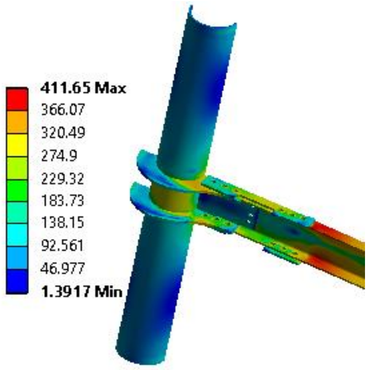
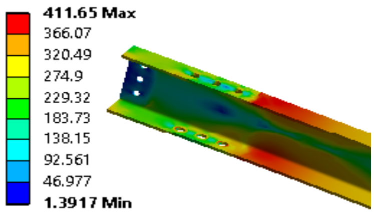
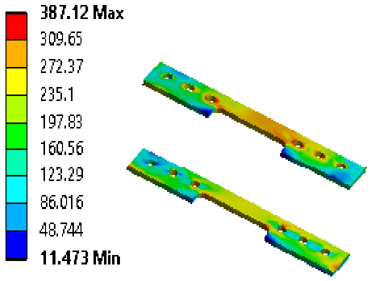


Fig 3. Mises stress contours of TCP12-VS40X12







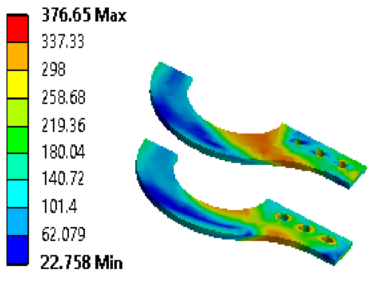
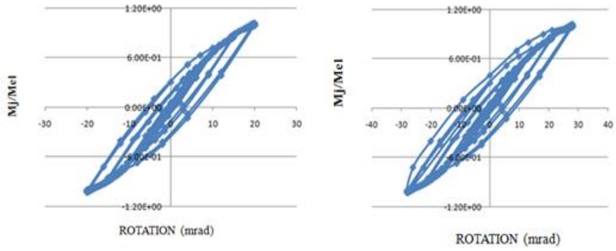
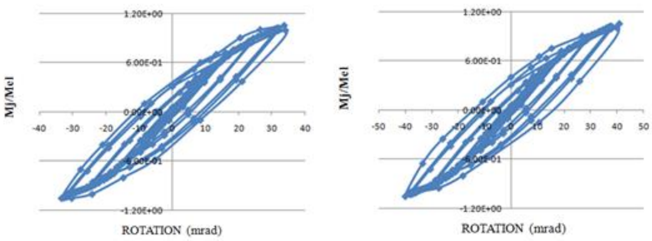


Fig 4. Mises stress contours of TCP12-No VS

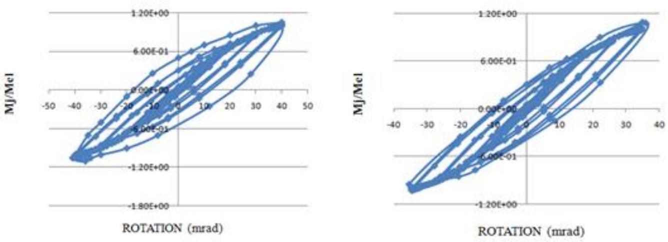
The hysteric response of the joint with varying dimensions of TCPs and VSs are shown in Fig 5. Hysteresis curve is drawn between normalized moment and rotation. Moment reaction of the connection is normalized with plastic moment capacity of I beam.



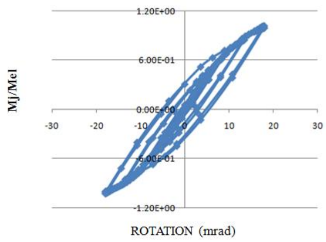
TCP12-VS40X12 & TCP12-VS30X12



TCP12-VS30X8 & TCP12-VS30X6



TCP12-No VS & TCP15-No VS



TCP20-No VS

Fig 5. Normalized moment- rotation curves

IV. CONCLUSION

In this study all the parameters are made constant except the dimensions of tapered cover plates and vertical stiffeners. Steel grades of both TCP and VS are S235, while steel grade of all the other joint components are S355.

From the obtained information it is obvious that the diminution of cross sectional area of vertical stiffener decreases the stress demands on the joint components and from the normalized moment rotation curves we can found that the diminution in stiffness of joint improves the hysteric behavior of joint. Increase in thickness of TCP without VS, increases the stress demands and decreases the rotation capacity.

In the model without vertical stiffener (TCP12-No VS) all the joint components except the sacrificial element TCP are within the elastic limit. Rotational capacity of this model is greater than the models with vertical stiffeners. This increases the energy dissipation capacity of the joint.

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