International Journal of Scientific & Engineering Research Volume 10, Issue 5, May-2019
ISSN 2229-5518

STATIC AND DYNAMIC PERFORMANCE OF HOLLOW FLANGE TAPERED WEB STEEL BEAM

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Abstract— Hollow flanged web tapered steel beam (HFTWSB) is a new hollow flange I-section made using steel rectangular hollow sections (RHS) as flanges and a tapered cold rolled steel plate as web. Due to the increased torsional rigidity, hollow flange sections can provide good flexural capacities and thus are effective flexural members in long span applications. The production of proposed HFTWSBs will be done by welding currently available RHS to a web plate, which allows engineers to use as beam by varying beam conditions to suit their design requirements. Tapered steel members are mostly chosen instead of prismatic because of its better cross-section utilization along the member, which makes them an economical alternative. By using cold rolled steel also can increase the load carrying capacity. This project deals with the analytical study on HFTWSBs using ANSYS workbench 16.1 version.

Index Terms Hollow flange tapered web steel beam, taper ratio, cold rolled steel, rectangular hollow tubes, load carrying capacity, deflection, cyclic performance, seismic performance.

1 Introduction

I-beams, as the name states are manufactured in the shape of a capital "I". The core of the I-beam, better known as the web, will ensure resistance against shear forces. The flanges provide resistance to bending moments. Nowadays in structural design field, use of innovative steel members in large span applications are increasing. Use of nonprismatic members is increasing due to its reduced weight, economic, aesthetic and other considerations.

The demand for lighter steel structures is increasing in construction industry. The main advantages of steel structures over reinforced concrete structures are its inherent strength, prefabrication and quicker transportability to the site and faster erection. With increased use of steel, the varieties of steel sections are introduced. Among these sections, the Hollow structural sections (HSS) are most consistent one. A hollow structural section is a type of metal profile with a hollow cross section. HSS members can be circular, square, or rectangular sections; however other shapes such as elliptical are also available. Rectangular and square HSS are commonly called as steel tube or box section. The hollow flanges increase the torsional rigidity and have an increased flexural capacity.

Cold rolled steel having high strength to weight ratio than hot rolled steel. So in this project web of the beam specimens are made up of cold rolled steel. “L” shaped tapering is provided to web.

This study explaining the two point loading analysis and comparison with a conventional tapered I-section and static and dynamic seismic performance of HFTWSB also explained.

2 ANALYTICAL STUDIES

2.1 Material Selection

The materials used for the specimens are hot rolled and cold rolled steel. Cold rolled steel is used as web and compared with hot rolled steel web. Both are available materials in industry.

The flanges are modeled by considering as MS steel tubes commonly available in our markets. Yield strength of materials used are listed below (Table 1).

Table 1: Materials used and their yield strength

Steel	Yield strength
Hot rolled	250 MPa
Cold rolled	420 MPa

2.2 Loading Condition

Two types of loading analysis are carried out in two steps such as two point load analysis and cyclic load analysis. The two point load analysis is done for all models and selected the best model for cyclic loading analysis.

2.3 Modeling

75 X 25 size hollow tube is used as flange and cold rolled steel sheet of 3mm and hot rolled steel sheets of 10mm and 3mm are used for making web and they are welded together. Beams are of 1m length.

2.4 Test setup

The first test setup contains beam simply supported at both ends and vertically loaded at two points on the flange.

The next test setup contains beam column joint. The loading point is 1m away from joint (at the smaller end of beam). And cyclic analysis is carried out for this setup.

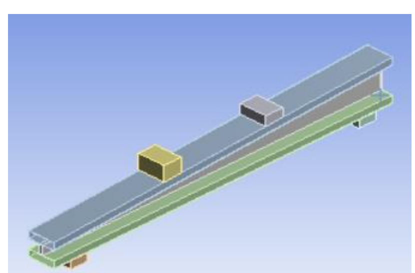

Fig 1 : Two point loading condition.

International Journal of Scientific & Engineering Research Volume 10, Issue 5, May-2019
ISSN 2229-5518

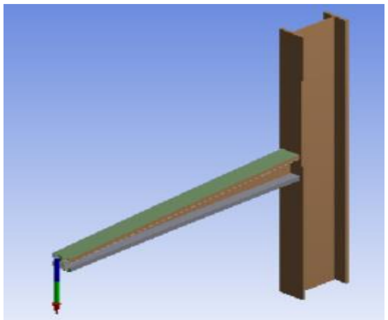
Fig 2: Cyclic loading in beam column joint.

3 RESULTS AND DISCUSSION

Analysis of specimens was conducted in 5 stages.

3.1 FIXING THE SHAPE OF THE SPECIMEN

Specimens with different geometry are modeled, analysed and compared the result obtained with conventional I-section for fixing the shape of the specimen. Material used for these specimens is of hot rolled steel. All specimens having 1m length and same taper ratio (Hmin and Hmax kept constant).

Table 2: Models used in stage-1

Name	Flange (mm)	Web thickness (mm)	Length (mm)	Hmin (mm)	Hmax (mm)
CI	75 x 7.6	4.4	1000	80	140
HF_10	75 x 25 x 1.29	10	1000	80	140
HF_10 _CF	75 x 25 x 1.29	10	1000	80	140
HF_10 _EW	75 x 25 x 1.29	10	1000	80	140

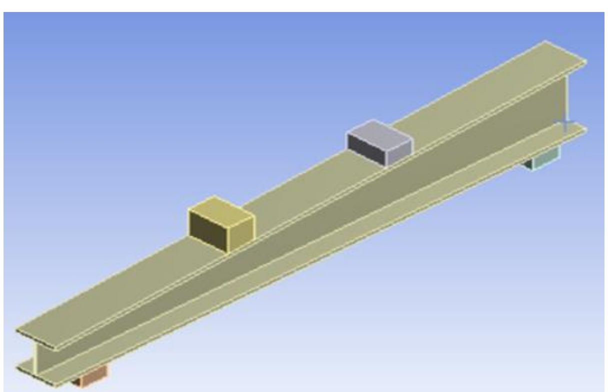
Fig 3: conventional tapered I-section (CI)

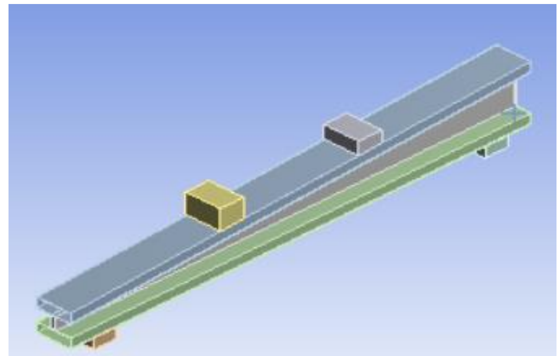
Fig 4: hollow flange tapered web steel beam with 10mm web thickness (HF_10)

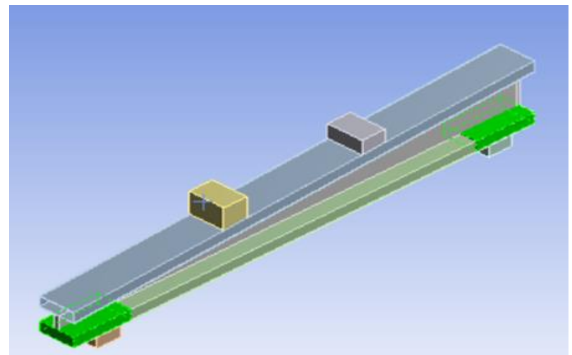
Fig 5: HF_10 filled with concrete only at the supports (HF_10_CF)

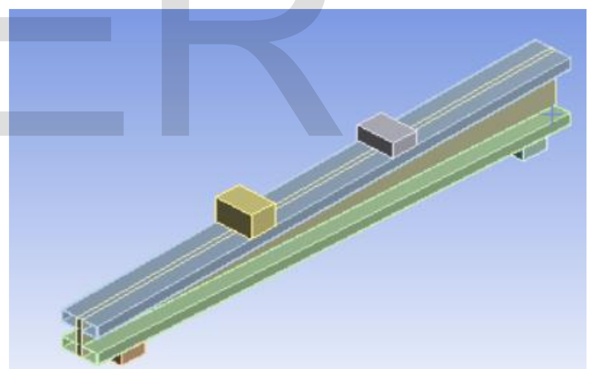
Fig 6: HF_10 with extended web into the flanges (HF_10_EW)

Table 3: Results obtained after analysis.

Name	Weight (kg)	Total Deflection (mm)	Ultimate load (kN)
CI	12.24	13.51	133.25
HF_10	8.67	41.87	38.816
HF_10_CF	9.16	31.066	43.078
HF_10_EW	12.2	24.47	132.96

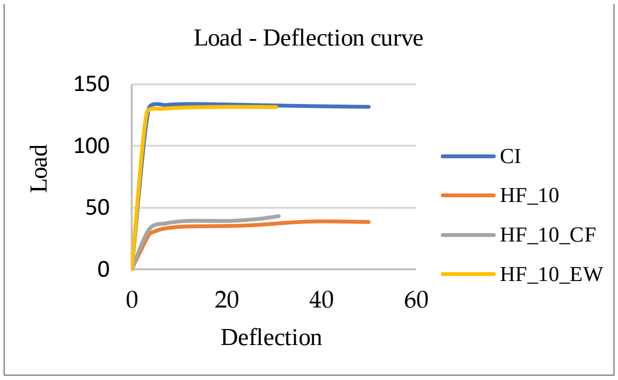

Fig 11: Load – Deflection graph

Only extended tapered web hollow flanged steel beam (also known as windowed flange) gives load carrying capacity same as that of conventional beam with same weight under two point loading

3.2 COMPARISON OF COLD ROLLED AND HOT ROLLED STEEL WEB

In this stage a beam with extended web (Fig 12) is used by changing its web with cold rolled steel sheet (3mm is the maximum thickness of available cold rolled steel) and compared with the hot rolled web having same thickness.

Table 4: Models used in stage-2

Name	Flange (mm)	Web thickness (mm)	Length (mm)	Hmin (mm)	Hmax (mm)
HF_3_CR	75 x 25 x 1.29	3	1000	80	140
HF_3_HR	75 x 25 x 1.29	3	1000	80	140

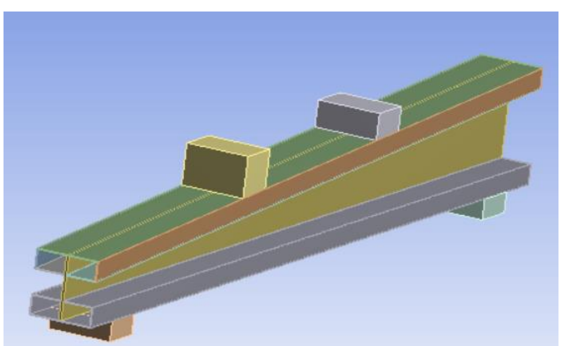

Fig 12: Geometry of the specimen used in second stage.

Table 5: Results obtained after analysis.

Name	Weight (kg)	Total Deflection (mm)	Ultimate load (kN)
HF_3_CR	6.48	8.11	87.33
HF_3_HR	6.48	7.5	68.6

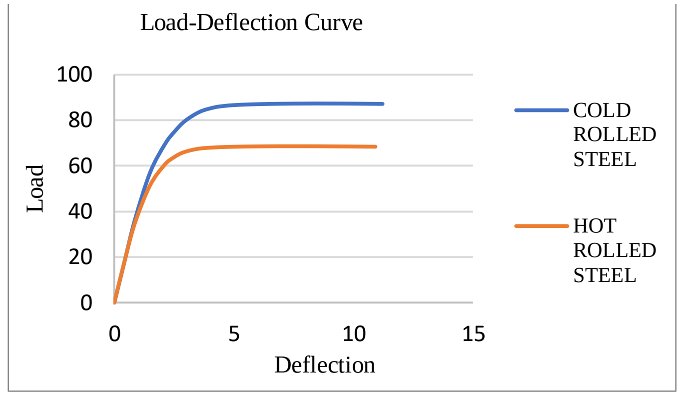

Fig 13: Load – Deflection graph

Specimen with cold rolled web gives more load carrying capacity than specimen with hot rolled web.

3.3 CYCLIC LOADING ANALYSIS OF BEAM COLUMN JOINT AND COMPARISON BY CHANGING TAPER RATIO OF BEAM AND KEEPING WEIGHT CONSTANT

To study the dynamic seismic performance of the HFTWSBs cyclic loading analysis is conducted by changing taper ratios and keeping weight constant. Beam with cold rolled web is used because of its better performance under two point loading.

Column specimen is made up of ISMB 200.

Table 6: Models used in stage-3

Name	Flange (mm)	Web thickness (mm)	Length (mm)	H min (mm)	H max (mm)
HF_3_CR _TR 1	75 x 25 x 1.29	3	1000	100	100
HF_3_CR _TR 1.75	75 x 25 x 1.29	3	1000	80	140
HF_3_CR _TR 2	75 x 25 x 1.29	3	1000	73	146
HF_3_CR _TR 2.5	75 x 25 x 1.29	3	1000	62	155
HF_3_CR _TR 3	75 x 25 x 1.29	3	1000	56	168

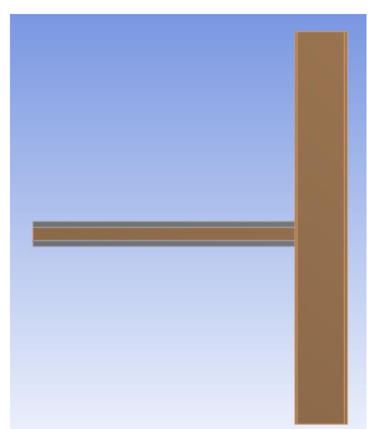

Fig 14: HF_3_CR_TR 1

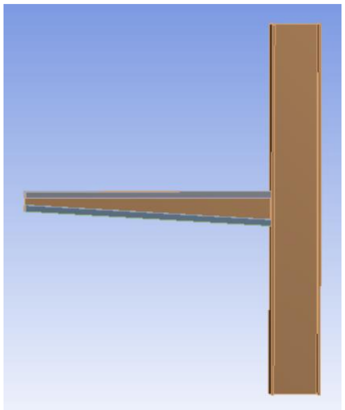

Fig 15: HF_3_CR_TR 1.75

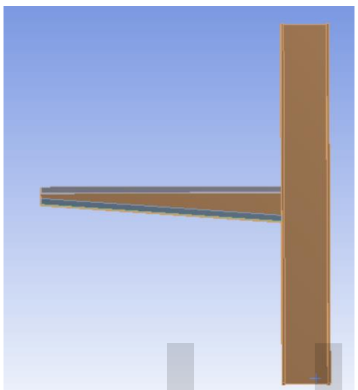

Fig 16: HF_3_CR_TR 2

Fig 17: HF_3_CR_TR 2.5

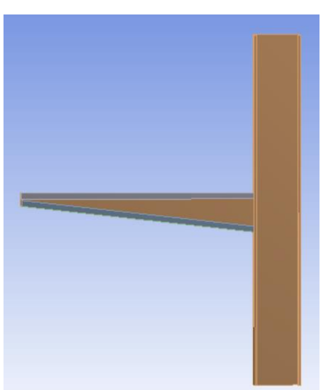

Fig 18: HF_3_CR_TR 3

Table 7: Results obtained after analysis.

Name	N Load				P Load			
	T (s)	N	Def. (mm)	UL (N)	T (s)	N	Def. (mm)	UL (N)
HF_3_CR_TR 1	33	8.25	50.04	5075.9	39	9.75	60.07	5449.9
HF_3_CR_TR 1.75	29	7.25	40.02	13383	31	7.75	40.02	13311
HF_3_CR_TR 2	29	7.25	40.02	14146	31	7.75	40.02	14093
HF_3_CR_TR 2.5	29	7.25	40.02	15500	31	7.75	40.02	15528
HF_3_CR_TR 3	33	8.25	50.04	17232	31	7.75	40.02	17348

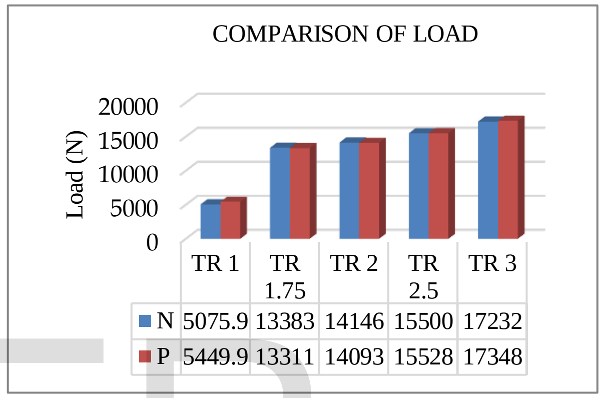

Fig 19: Graph showing comparison of negative and positive loads of each specimen

In cyclic loading analysis specimen with taper ratio 3 shows better load carrying capacity because of the increased area of connection at beam column joint. But specimen without tapering undergoes more cycles of loading before failure.

3.4 CYCLIC LOADING ANALYSIS OF BEAM COLUMN JOINT AND COMPARISON BY CHANGING INCLINATIONS AND KEEPING TAPER RATIO CONSTANT

In this stage specimen HF_3_CR_TR 3 is used, because of its more load carrying capacity under cyclic loading. And the inclinations with horizontal have been changed to know which inclination gives better load carrying capacity under cyclic loading.

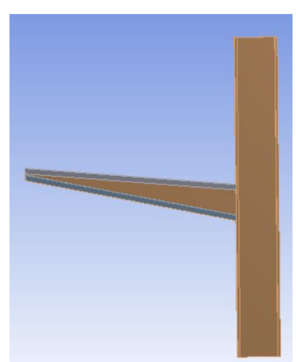

Fig 20: beam column joint with 5degree inclination.

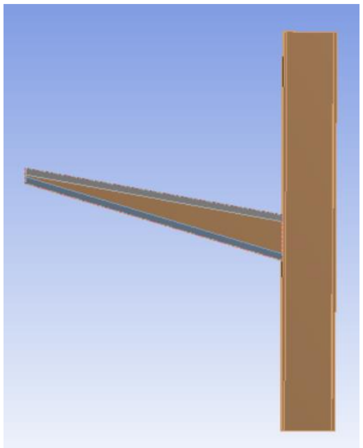

Fig 21: beam column joint with 10degree inclination.

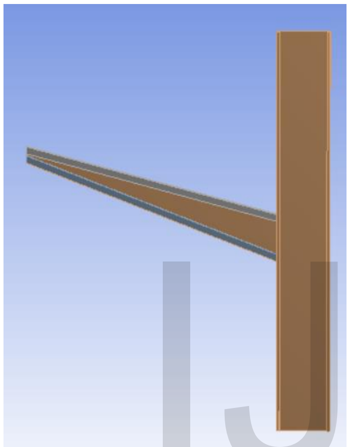

Fig 22: beam column joint with 15degree inclination.

Table 7: Results obtained after analysis.

I	N Load				P Load				Average load (N)
	T (s)	N	Def. (mm)	UL (N)	T (s)	N	Def. (mm)	UL (N)	
0º	33	8.25	50.04	17232	31	7.75	40.02	17348	17290
5º	29	7.25	40.02	17102	27	6.75	30	16809	16955.5
10º	25	6.25	30	16040	27	6.75	30	17159	16599.5
15º	25	6.25	30	16642	27	6.75	30	17432	17037

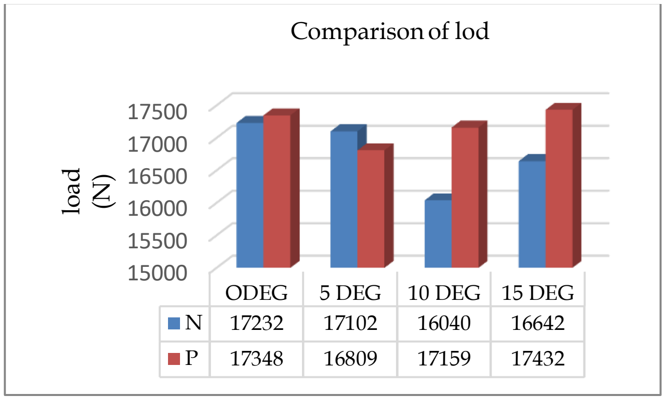

Fig 14: Graph showing comparison of negative and positive loads of each specimen

Beam column joint with 0 degree inclination gives more load carrying capacity.

4 Conclusions

From this study we can conclude that hollow flanged tapered cold rolled extended web steel beam with taper ratio 3 having 0 degree inclination shows better performance in seismic analysis. So we can use this beam in multi storey buildings as frames below the floors.

Selected the geometry of the section for further study, such as extended tapered web hollow flanged steel beam (also known as windowed flange) gives load carrying capacity same as that of conventional beam with same weight under two point loading. Specimen with cold rolled web gives more load carrying capacity than specimen with hot rolled web. In cyclic loading analysis specimen with taper ratio 3 shows better load carrying capacity because of the increased area of connection at beam column joint. But specimen without tapering undergoes more cycles of loading before failure. Beam column joint with 0 degree inclination gives more load carrying capacity.

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