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# EXPERIMENTAL INVESTIGAION ON BEHAVIOUR OF COLD FORMED BUILT-UP I-SECTION WITH TRAPEZOIDAL CORRUGATED WEB BY VARYING THE FLANGE WIDTH

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***Abstract-*** ***The purpose of usage of cold formed steel is increasing rapidly around the world due to many advances in construction and manufacturing technologies and relevant standards. However the structural characteristics of thin walled structure is characterized by a range of buckling modes such as local buckling, global buckling, distortional buckling or flexural torsional buckling. These buckling problems generally lead to severe reduction and complicated calculations of their member strength.***

***Hence it is necessary to eliminate or delay these buckling problems and simplify the strength calculation of cold formed structures. To overcome this, the corrugated web can be used, which require no stiffners, so it permits the use of thinner plates with significant weight saving.***

***In this thesis, the behavior of built-up lipped-I section with trapezoidal corrugation in web under two point loading are investigated. Totally seven beams are investigated Analytically, Theoretically and Experimentally by varying the width of flange from 80mm to 140mm with 20mm increment and by varying tension or bottom flange width from 60mm to 100mm keeping top flange width constant as 100mm. All the parameters of beam like depth of web, span, and corrugation profile are kept constant.***

***Theoretical investigation is carried out using North American code (2008), and British standard 5950 -1998.A Non-linear numerical analysis is also carried out using ANSYS 12.0 software. The results predicted using codes and analytical and experimental works are compared.***

***Keywords: Trapezoidal Corrugation, North American Specification,(NAS), Ansys12.0, Cold-Formed Steel (CFS).***

## I. INTRODUCTION

Cold Formed Steel Structural members are cold formed in rolls or press brakes from flat steel. Under mass production they are framed most economically by cold rolling, while smaller quantities of specials shapes are most economically produced on press brakes. Members are connected by spot, fillet, plug, or spot welds, by screw, bolds, cold rivets, or any other special devices. The use of cold formed steel structures has become increasingly popular in different fields of building technology.

There has been a steady growth in the use of cold formed steel frame in the residential construction, automobile industry, ship building, rail transport, the aircraft industry engineering, agricultural and industrials equipments, chemical, mining, nuclear and space industries. The structural properties and type of loading of built-up I – Sections with corrugations cause, typical static behaviour of these structures.

Cold formed steel members are widely employed in steel accessible cost of high-strength low-alloy steels, weathering steels, and zinc-coated steels have led to members with height/thickness ratios, rendering them even more susceptible to local buckling and to another buckling mode called distortional, Z sections, hat, rack, etc. Hence, current versions of technical codes for cold-formed steel design have warned about the importance of this phenomenon, outlining procedures to evaluate member strength based on distortional buckling.

It is most widely used all over the world, because of more advantages than the hot rolled steel section and replace hot rolled steel for its more economical design as well as easy to construct the structures.

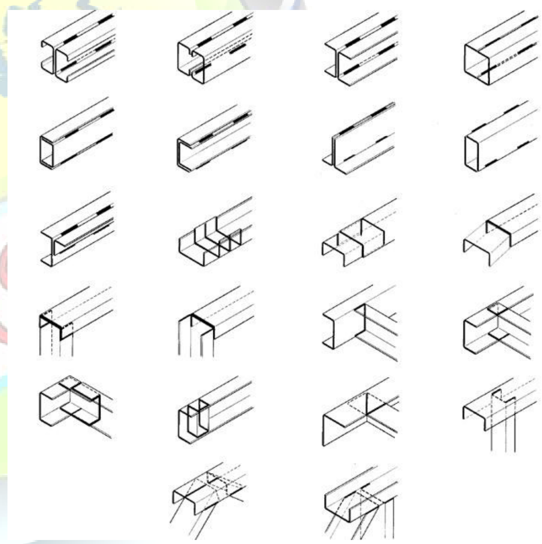

**Fig .1Cold Formed Steel Sections**

## II. THEORETICAL WORK

### General

The following three buckling patterns can occur in the corrugated webs:

- Local buckling mode
- Global buckling mode
- Distortional buckling mode

The details of specimen used in the theoretical investigation are as follows.

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**Table .1 Details of Specimen**

| Specimen | Span L (mm) | WebThk $t_w$(mm) | Flange Thk $t_f$ (mm) | Flange width $b_f$ (mm) | | Lip (mm) | Depth of Web h (mm) |
|---|---|---|---|---|---|---|---|
| | | | | Top | Bottom | | |
| **BY VARYING THE WIDTH OF FLANGE** | | | | | | | |
| TCIF – 1 | 3000 | 1.2 | 2 | 100 | 100 | 15 | 350 |
| TCIF – 2 | 3000 | 1.2 | 2 | 80 | 80 | 15 | 350 |
| TCIF – 3 | 3000 | 1.2 | 2 | 120 | 120 | 15 | 350 |
| **BY VARYING TENSION OR BOTTOM FLANGE WIDTH** | | | | | | | |
| TCITF – 4 | 3000 | 1.2 | 2 | 100 | 90 | 15 | 350 |
| TCITF – 5 | 3000 | 1.2 | 2 | 100 | 80 | 15 | 350 |
| TCITF – 6 | 3000 | 1.2 | 2 | 100 | 70 | 15 | 350 |
| TCITF – 7 | 3000 | 1.2 | 2 | 100 | 60 | 15 | 350 |

**Design Calculation of Corrugated I Section as per NAS-2008 for Specimen-1 (TCIF-1(80mm-80mm))**

**Flexural Strength for TCIF-1:**

Nominal flexural strength;

$M_n$ $=S_e * F_c$

Where, $M_n$ = Bending moment in kNm

$S_e$ = section modulus = **79.641 x 10$^3$ mm$^3$.**

$F_Y$ = Yield strength in MPa = 210 MPa.

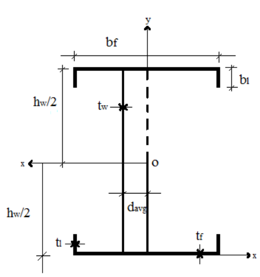
Section modulus ($S_e$):

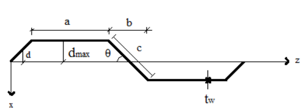
$M_n$ = $S_e * F_Y$

$M_n$ = 210 X 79.641*10$^3$

= 16.72 kNm

**Wcr = 33,449 N.**




**Lateral torsional buckling strength:**

$F_e = C_b\ \pi^2 E\ d\ I_{yc} / S_f (K_y.L_y)^2$

$= 1 \times \pi^2 \times 2\text{x}10^5\text{x}350\text{x}6.207\text{x}10^6/76.843\text{x}10^3 (1\text{x}3000)^2$

= 6200 N/mm$^2$

= 231.13 N/mm$^2$

**$M_n$** **= $S_c$*$F_c$**

= 67.284x10$^3$x 231.13

= 18.2551 x 10$^6$ Nmm

**W = 31103.18 N**

**Distorsioal buckling strength:-**

**$K_d$** **=0.6[80x15xSin90/(350x1.2)]**

=1.458 (0.5< 1.458< 8)

**$F_d$** **$=\beta$.kd.[$\pi^2$E/12(1-$\mu^2$)][t/b$_0$]$^2$**

=1x1.458x$\pi^2$x2x10$^5$/[(12(1-0.3$^2$)][1.2/80]$^2$]

= 110.126 N/mm$^2$

**$M_{crd}$** **= $S_e$*$f_y$**

= 76.843x 10$^3$ x 110.126

= 8.462 x10$^6$ Nmm

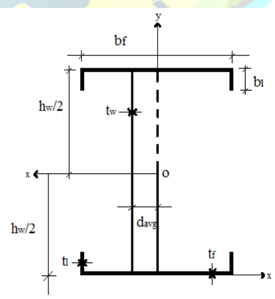
**$M_y$** **= 16.72 x** 10$^6$ Nmm

**$M_n$** **= [1-0.22($M_{crd}$/$M_y$)$^{0.5}$] ($M_{crd}$/$M_y$)$^{0.5}$*$M_y$**

= [1-0.22(8.462x10$^6$/16.72x10$^6$)$^{0.5}$](8.462x10$^6$/16.72x10$^6$)$^{0.5}$x16.72x10$^6$

= 10.03x10$^6$ Nmm

**W** **= 20066 N**



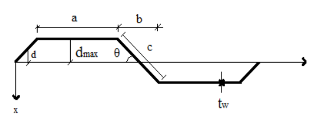




**Table .2 Theoretical work Results from NAS**

| Specimens | North American specification |
|---|---|
| | **Load Carrying Capacity** |
| TCIF-1 | 33500 N |
| TCIF-2 | 41267 N |
| TCIF-3 | 45800 N |
| TCIF– 4 | 51532 N |
| TCITF – 5 | 25500 N |
| TCITF – 6 | 26956 N |
| TCITF – 7 | 41267 N |

**DESIGN AS PER BEREAU OF INDIAN STANDARD IS 801-1975.**

**Nominal Moment Capacity:-**

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**Lateral Torsional Buckling:-**

$L^2 \times S_e / D^* I_{yc} > 0.36\Pi^2 E/F_y < 1.8\, \Pi^2 E/F_y$

$F_b = 2/3^* F_y - (F_y^2 / (5.4^* \Pi^2 E))^* L^2 \times S_e / D^* I_{yc}$

$M_n = F_b {}^* I_{yc} / Y_c$ Nmm.

**Load carrying capacity**:

The nominal flexural strength, $M_n$, is the minimum of $M_{ne}$, $M_{nl}$.

The load carrying capacities of the specimens are calculated as follows:

**Table .2 Theoretical work Results from IS**

| Specimens | Indian Standard Load Carrying Capacity |
|---|---|
| TCIF-1 | 34500 |
| TCIF-2 | 40320 |
| TCIF-3 | 46143 |
| TCIF– 4 | 51956 |
| TCITF – 5 | 25470 |
| TCITF – 6 | 27080 |
| TCITF – 7 | 40320 |

## III. ANALYTICAL WORK

### INTRODUCTION

The finite element method is a numerical analysis technique for obtaining approximate solutions to wide variety of Engineering problems. The basic concept behind the finite element analysis is that structure is divided into a finite number of elements having finite dimensions and reducing the structure having infinite degrees of freedom to finite degrees of freedom. Then original structure is assemblage of these elements connected at a finite number of joints called or Nodal points (Nodes). For the finite element analysis advanced software ANSYS 12 were used.

### BOUNDARY CONDITION

One end of the specimen was constrained in *X, Y and Z* directions and the other end of the specimen was constrained Y and Z direction. The nodes at the vertical side of the compression flange above, end stiffeners were constrained in the Z direction. The load was applied along transverse lines of the upper surface of the top flange above the stiffeners.

**SPECIMEN: TCIF-1 (80mm - 80mm)**

**ANSYS ANALYSIS FOR SPECIMEN TCIF -1**

Specimen TCIF – 1 is of 80mm – 80mm top and bottom flange width, thickness is of 2mm.Web height is of 350mm and thickness 1.2mm.Length of the specimen TCIF – 1 is 3000mm.Lip size is of 15mm.

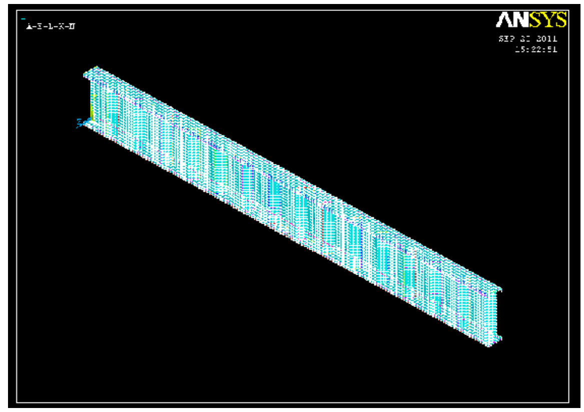



**FIG.2A ANALYSIS OF SPECIMEN BY ANSYS**

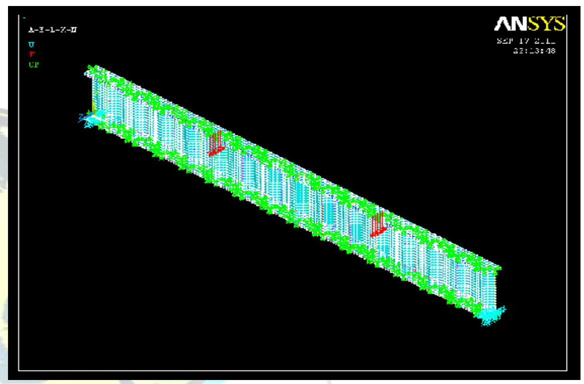
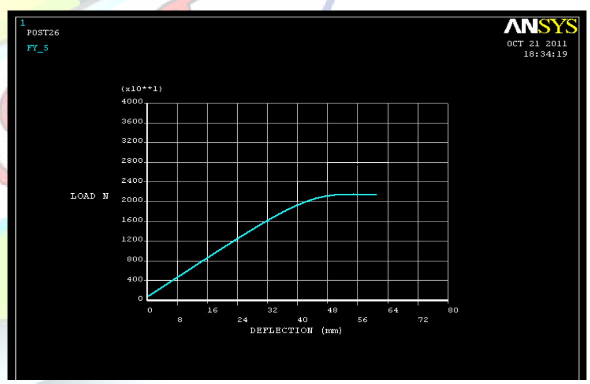



**FIG.2B ANALYSIS RESULT OF SPECIMEN BY ANSYS**



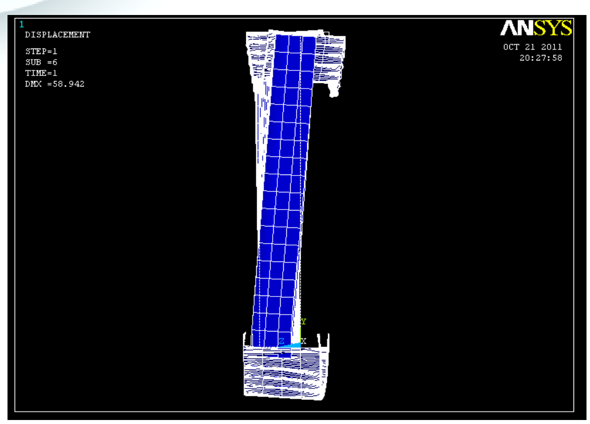



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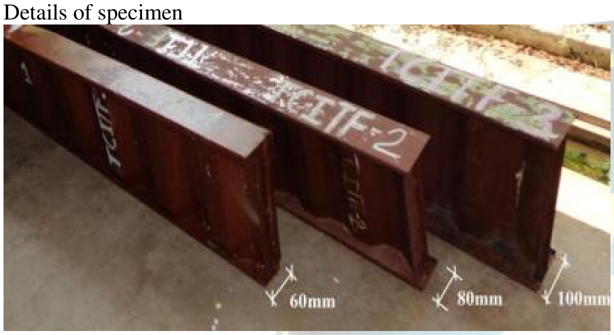
**Table .3 Analytical work Results from ANSYS**

| Specimens | ANSYS |
|---|---|
| | Load Carrying Capacity |
| TCIF-1 | 42500 N |
| TCIF-2 | 45000 N |
| TCIF-3 | 47500 N |
| TCIF – 4 | 49000 N |
| TCITF – 5 | 25600 N |
| TCITF – 6 | 27100 N |
| TCITF – 7 | 45000 N |

## III. EXPERIMENTAL TEST SETUP

**Fabrication of Specimen:-**

Details of specimen





**TEST SETUP**

- Specimen was tested in a loading frame of capacity **50 T or 500 kN**.
- Specimens were laterally clamped at support to avoid lateral Specimen was tested in a loading frame of capacity displacement.
- Specimen is placed over a hinged support to provide hinged-end condition.
- Two point loading at L/3 distance is applied by placing a steel box section over the specimen.
- A roller support was provided at L/3 distance between specimen and the steel box section.
- A hydraulic jack with a capacity of 100 kN was placed over the steel box section for applying the load.
- 3 LVDT's are placed in such a arrangement that, one at L/2, one at L/3 and the third one to measure the lateral displacement of the specimen.

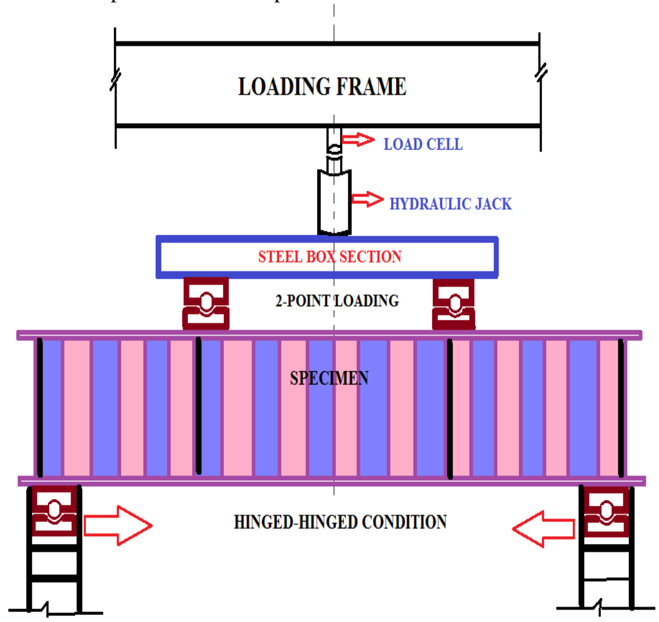



FIG.3 TYPICAL EXPERIMENTAL ARRANGEMENT

**1=> Load cell**
**2=>Hydraulic jack**
**3=>Steel box section**
**4=>Roller support (Simply supported condition)**
**5=>Roller support (Hinged-Hinged condition)**
**6=>LVDT at L/3 dist.**
**7=>LVDT at Mid-span.**
**8=>Strain gauge at Mid-span top.**
**9=>Strain gauge at Mid-span bottom.**

- While testing of all specimens, displacement, strain and load are recorded in **Data Acquisition System.**
- Load is applied gradually up to failure, using the recorded readings, the following graphs are plotted.

## ANALYSIS OF EXPERIMENTAL RESULTS

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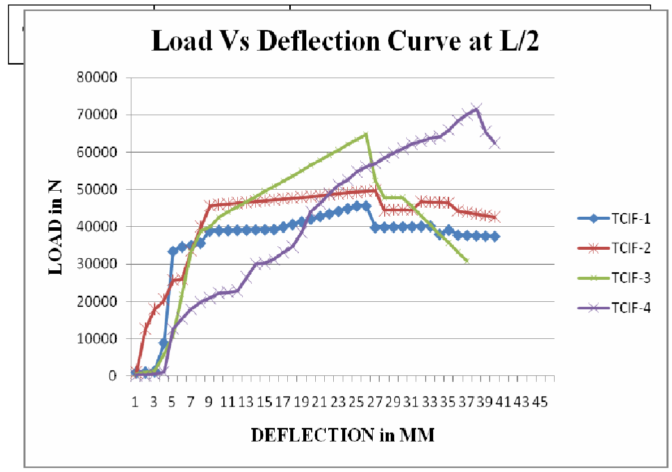
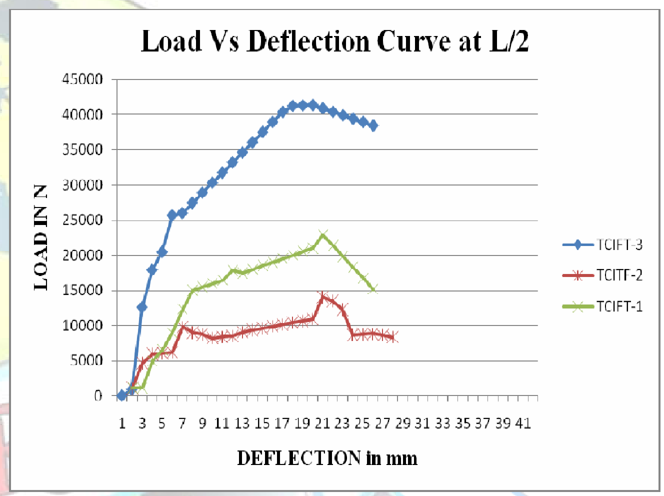






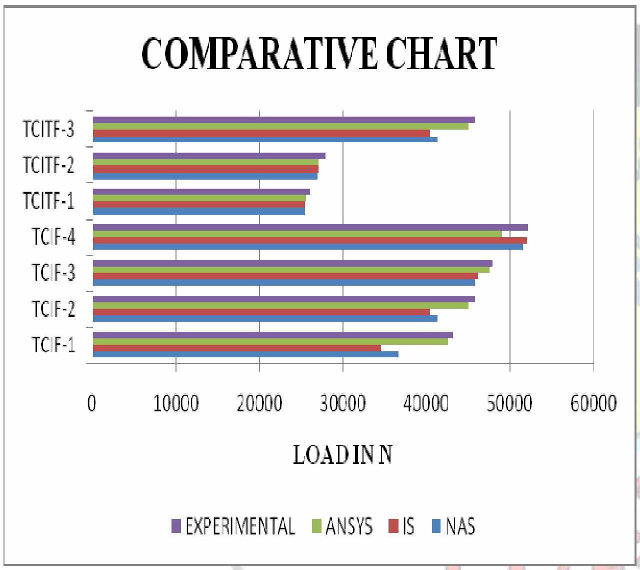


| SPECIMEN | FAILURE LOAD(N) | TYPE OF FAILURE |
|---|---|---|
| TCIF-1 | 43000N | Lateral torsional buckling |
| TCIF-2 | 45700N | Lateral buckling in compression flange |
| TCIF-3 | 48000N | Lateral buckling in compression flange |
| TCIF-4 | 26000N | Lateral buckling in compression flange |
| TCITF-5 | 27180N | Lateral torsional buckling |

## IV. Results and Discussion

- From the table formulated, it can be concluded that the results of analytical and experimental work are well in good agreements, but comparatively the theoretical results were little lesser.
- As slenderness ratio increases, the ratio between ultimate stress to yielding stress were found to be same between experimental and analytical analysis.
- From the table the average value of $P_T/P_E$, $P_A/P_E$, such as 0.9248, 0.9767, and 0.9510, 0.98125, were found to be same in both parametric study.
- From the standard deviation calculation,
  i) $P_T/P_E = 0.046451$
  ii) $P_A/P_E = 0.02327$
- It can be observed that the ratios between analytical and experimental results are reliable solutions.
- From the comparative chart plotted above the ultimate load carrying capacity in all cases were found to be more or less same.

| SPECIMEN | $P_T$ N | $P_E$ N | $P_A$ N |
|---|---|---|---|
| TCIF-1 | 33500 N | 42500 N | 43000N |
| TCIF-2 | 41267 N | 45000 N | 45700N |
| TCIF-3 | 45800 N | 47500 N | 48000N |
| TCIF-4 | 51532 N | 49000 N | 26000N |
| TCITF-5 | 25500 N | 25600 N | 27180N |
| TCITF-6 | 26956 N | 27100 N | 45000N |
| TCITF-7 | 41267 N | 45000 N | 48000N |




## V. CONCLUSION

Some of the salient features of the experimental test results are presented as given below.

- From the table formulated, it can be concluded that the results of analytical and experimental work are well in good agreements, but comparatively the theoretical results were little lesser.
- Failure mode of specimen were, Initiation of local buckling of top compression flange, and Finally, Beam failed by lateral torsional buckling and lateral buckling as revealed by experimental results.
- Due to the corrugation provision, there is no failure in shear zone or web portion.

It can be observed that the ratios between analytical and experimental results are reliable solutions.

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