Local Flange Buckling in Plate Girders with Trapezoidal Corrugation of Web

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***Abstract*-One of the issues raised since the steel structure was introduced in the construction industry is how to reduce the weight and cost of the component parts such as girder and beams. Efficient and economical design of girders and beams normally requires thin webs. However, extremely slender web will cause the web to buckle. To overcome this, the corrugated web can be used, which require no stiffening, 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 four beams are investigated by varying the depth of the web from 250mm to 400mm with 50mm increment. All the parameters of beam like flange width, span, and corrugation profile are kept constant. Theoretical investigation is carried out using Direct Strength Method (DSM) of North American code (NAS) 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, numerical analysis and experimental results are compared.**

***Index Terms*—(NAS), (DSM) ,trapezoidal corrugation, British standard**

I. INTRODUCTION

Plate girders are often manufactured with corrugated webs usually of a trapezoidal or other type. The corrugated profile in webs provides a kind of uniformly distributed stiffening in the transverse direction of a girder. In comparison with plate girders with stiffened fiat webs, a girder with a trapezoidal corrugated web enables the use of thinner webs, thus for less cost a higher load-carrying capacity is achieved. Besides the convenience during manufacture, this should be the most important reason why the application of such girders can be widely increased (and is still increasing). It is well established, that fundamental to the assessment of the load carrying capacity is a reliable prediction of the load-deformation response when local buckling, initial geometric imperfections of steel sections, residual stresses produced by manufacturing processes, and material nonlinearities are taken into account. In cold formed steel structures. Economical design of girders and beams normally requires thin webs. Stiffeners or the latest innovative technique by strengthening the web by making it corrugated. The conventional welding of stiffeners to allow the use of thin webs has two disadvantages i.e. high fabrication cost and a possible reduced life due to fatigue cracking that may initiate at the stiffener weld. The use of corrugated plates to replace the stiffened flat plates for the web of a girder can eliminate both disadvantage through the advances in welding technology, fabrication of sections with corrugated web has been made easy. A number of testing programs have been conducted by previous researcher to find the best way to utilizes corrugated webs. Studies on the behaviors of beams with corrugated webs subjected to shear have been conducted since early 1960's but the full capacity of corrugated plates is still underestimated and only since 1980 has its behaviors been studied in detail The corrugated plate is nowadays used for structural component in aircraft, ships, offshore structures, bridges and buildings. In Trapezoidal plate corrugated webs require no stiffening except at supports, so it permits the use of thinner plates with significant weight saving. Because of its high slenderness ratio, stability due to shear force should be concerned primarily.

Design as per North American Specification Of Cold Formed Steel (Nas) Method

Based on IS: AISI.S100-2007

Nominal section strength

Effective yield moment $M_n=S_e*F_c$
S_e=Elastic modulus
F_c= yield stress

Lateral Torsion Buckling Strength

$M_n=S_c*F_c$

Sc-Elastic section modulus of effective section calculated relative to extreme compression fiber at F_c

Distortional Buckling Strength

$M_n=[1-0.22(M_{crd}/M_y)^{0.5}](M_{crd}/M_y)^{0.5} \,.\, M_y$,
$M_{crd}=S_f*F_d$
F_d-Elastic distortional buckling stress
$F_d=\beta.k_d.[\pi^2E/12(1-\mu^2)][t/b_0]^2$
$K_d=0.5< 0.6[b_0D \sin\theta/(h_0t)]^{0.7}< 8$
b_0 –Out- to-out flange width
D-Out-to-out lip dimension
θ-Lip angle
h_0 - Out-to-out web depth
$F_e= C_b \pi^2 E d I_{yc} / S_f (K_y.L_y)^2$
C_b is conservatively taken as unity for all cases
d- Depth of section
I_{yc}- Moment of inertia of compression portion of section about centroidal axis of entire section parallel to web, using full unreduced section.
Fe= $C_b \pi^2 E d I_{yc} / S_f (K_y.L_y)^2$
1)Fe>2.78Fy
2)2.78Fy>Fe>0.56Fy
3)Fe<0.56Fy
For second case
$F_c =10/9 F_y (1-(10F_y/36F_e)$
$M_n =S_c*F_c$
Iyc=$I_{yy}/2$
S_f-Elastic section modulus of full unreduced section relative to extreme compression fiber
K_y-Effective length factor for bending about y axis y axis

t-Base steel thickness

K_d=0.6[100x15xSin90/(300x1.2)]

=1.629 (0.5< 2.3 < 8)

$F_d = \beta.k_d.[\pi^2 E/12(1-\mu^2)][t/b_0]^2$

$M_{crd} = S_e * f_y$

$M_y = S_{fy} \times F_y$

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

II. NUMERICAL ANALYSIS

The finite element method is a numerical analysis technique for obtaining approximate solutions to wide variety of Engineering problems. Most of the engineering problems today make it necessary to obtain approximate numerical solutions to problems rather than exact closed form solutions. 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. The original body of structure is then considered as an assemblage of these elements connected at a finite number of joints called Nodes or Nodal points. This method of analysis has an advantage of that it can take care of any boundary Ly-Unbraced length of member for bending about and loading conditions.

By Means of Ansys12 SOFTWARE

An engineering problem can be solved in three phases.

- Preprocessing
- Solution
- Post processing

TABLE I
TENSION TEST RESULT ON STEEL SHEET

Specimen Details	Young's Modulus (N/mm2)	Yield Stress (N/mm2)
Coupon 1	1.99 x 105	210
Coupon 2	1.97 x 105	212
Coupon 3	2.15 x 105	209
Average	2 x 105	210

Fig. 1. COUPEN test of specimen

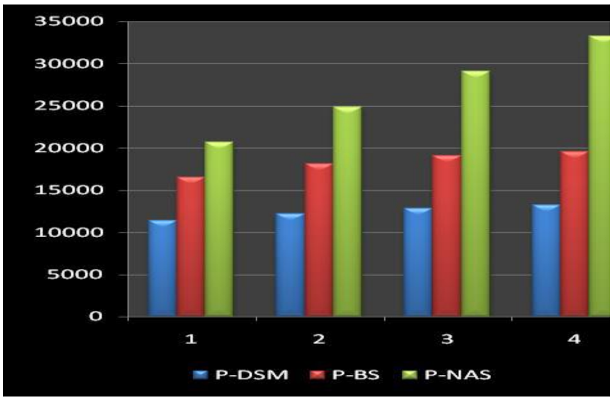

Fig. 2. Comparison Chart Of Codal Provision

Stress Vs Strain Graph for Tensile Test Coupon (Test Sheet-1)

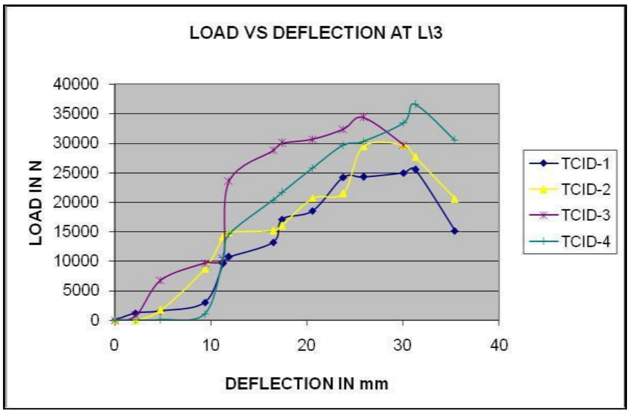

Fig.3.Load Vs Deflection at L/3

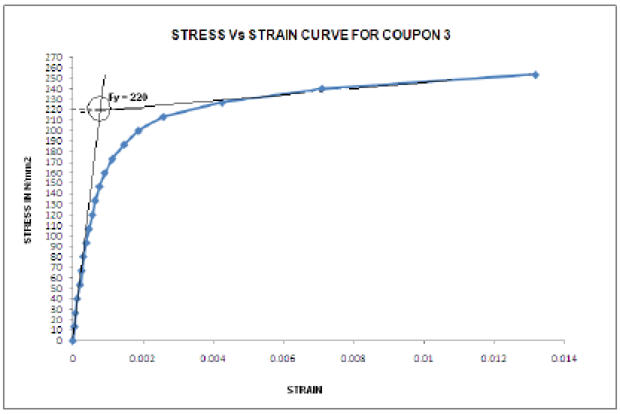

Fig. 4. Comparison of Theoretical and Experimental

Load vs. L/3 deflection, Load vs. Mid span deflection , Load vs. Deflection- right end support at Top , Load vs. Strain at web , Load vs. strain at compression flange , Load vs. strain at tension flange

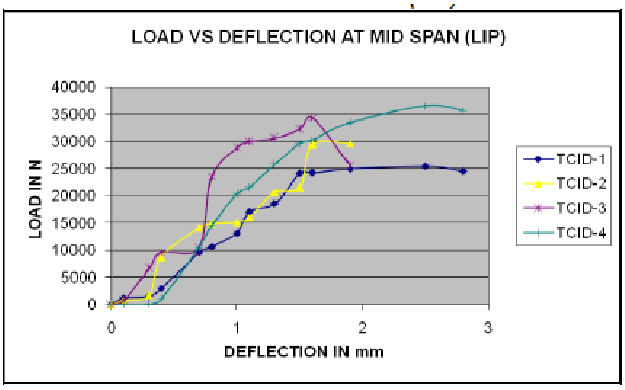

Fig.5. Load Vs Deflection at Mid Span (LIP)

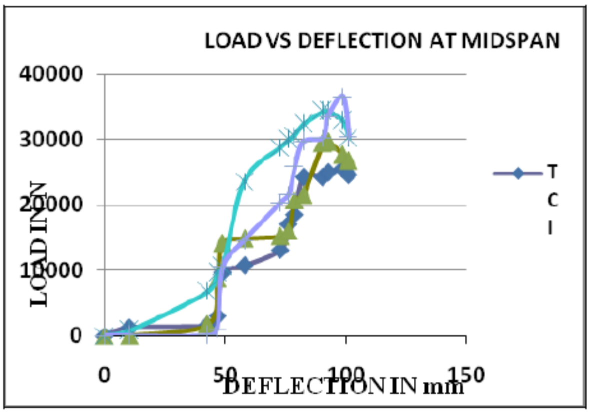

Fig.6. Load Vs Deflection at Mid Span

III. RESULT DISCUSSION

Due to corrugation in the web, the web has been stiffenedand the failure in the web is eliminated. Due to increases in depth, the moment of inertia of the specimen increases. As the moment of inertia increases the load carrying capacity also increases. Deflection at mid-span of the specimens is increases due to the depth of specimens are increases. The specimens are laterally buckling at initial loads of around 15KN of all four specimens and finally to lateral torsional buckling occurs.Due to the stiffeners provided at the loading point and support, the bearing failures is arrested. The load carrying capacity specimen's increases due to the w/t ratio is increases.

From the graph it is noticed that, the maximum vertical displacement at mid-span decreases to 48% for specimen, TCID-2, TCID-4, when compared to specimen TCID-1. From the graph, it is noticed that the maximum vertical displacement at L/3 distance, gradual decrease in displacement to about 35% from TCID-1 to TCID-4.

The maximum lateral displacement at the middle of compression flange of specimen decreases to about 6.38%. The maximum strain at web, decreases to about 52%, at tension flange decreases to about 53%,at compression flange decreases to about 20%. The average load carrying capacity of specimen increases to about 1.097%. Strain in compression flange increases, as there exist chances of failure of specimen at maximum load.

IV. CONCLUSION

Within the parametric study, Increase in depth of web from 250mm to 400mm increases the load carrying capacity of the specimen. Adoption of corrugated in the web eliminated the failure in the web, due to the corrugation of web has been stiffened. The ratio of the strength predicated using theoretical to experimental for all beams put together was found to have mean 0.8697 and standard deviation of 0.0567.

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