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A PATHWAY TO DIGITAL TRANSFORMATION IN THE STEEL INDUSTRY: A PERFORMANCE STUDY ON BOLTED COLD-FORMED STEEL ANGLE TENSION MEMBERS USING ANSYS TOOL

Mr.D.V.Vidhyasagar
Assistant Professor,
Department of Civil Engineering,
Thanthai Periyar Government Institute of Technology, TamilNadu,Vellore-632002

ABSTRACT

Tension members are the structural elements that are intermittently confront as prime structural members adopted for trusses and horizontal bracing system in usual construction processes and its connections are of far reaching concern in any steel design. In the present scenario there has been tremendous increase in steel tension members which is cold formed and endorsed in array of structures. The fundamental goal of this research is to investigate the performance of single and double angle cold formed steel specimens. A total of 48 experiments were carried out on single and double angles of various cross sections with single and double line connections. The cold formed steel angle specimens used in this study were created by bending and press breaking cold formed steel sheets with a thickness of 2mm. With 10mm diameter black bolts, eight single plain angle specimens, eight single lipped angle specimens, and thirty two double angle specimens were inserted on either side of the gusset plate. Different types of connection failure, Load-deflection patterns were studied. Comparison of Standards of Australian, New Zealand and British with experimental results were incorporated. The Finite Element (ANSYS) models provide a supplementary tool to verify the design methods of cold formed steel members with various configurations which provides a way towards digital transformation in the steel Industry.

Keywords: Cold-formed angles; Tension members; shear lag; Load-Deflection

1. INTRODUCTION

Steel structures have always been considered as a prime choice of design engineers construction material over other structures. Enormous development and advancement has taken place in due course time in steel construction. Steel elements which are cold formed were the universally accepted material that are used as roof materials, deck slabs, panels, body for trailer, agricultural materials, aircraft bodies, etc. Angles are considered to be the key elements and extensively used sections when compared to the distinctive models of existing rolled sections in the market. In practical usage angles are linked with gusset plates using one leg and it causes the stress distribution which is not uniform due to idiosyncrasy of the applied load. The cutback of load bearing capacity is caused due to the extreme effect shear lag. Chesson and Munse(1963) determined the shear lag effects using single and double angles which is produced from hot rolled sections. Their research comprehended the numerous configurations with various cross sectional area, various connections, materials and manufacturing mechanisms. The ideology of lag due to shear and its consequences on the angles depends upon on test results which contain two hundred and eighteen specimens of which one hundred and thirty seven were angle specimens of distinct configurations. Epstein and Chamarajnagar (1996) studied the material nonlinear influences using the criteria developed by Von-Mises and stress-strain pattern of the material was assumed to be perfectly plastic after creating quadratic brick model with 20 nodes. Wu and Kulak (1997) carried out research over angle tension members. Totally twenty four

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specimens were utilized to determine the loads at ultimate condition and finally compared with past researches.

In addition to the experiment, research using finite element was done to examine the distribution of stress at the critical portion of cross section when the maximum load was applied. Epstein and McGinnis (2000) predicted the material non-linearity by plastic yield criterion using Finite element Analysis. The finite element output is in agreement with the experimental output. Chi – Ling Pan (2004) tested steel channel sections that are cold formed with variation in magnitude to examine the influence of lag due to shear effect. Results based upon the test results was evaluated and compared with findings based on different details. Mohan Gupta and L.M.Gupta (2004) figured out angles using bolts by Finite Element method considering the problems such as material shape, stress and strain pattern, the connection between the angle and the plate, the failure pattern and the influence of creating the holes etc. Gupta and Gupta (2005) investigated angles using limit state methodology considering block shear failure and yield at cross sectional area. The safety factor derived represented the adequacy of design strengths. Valdier Francisco de paula et al (2008) conducted experiments on 66 specimens using cold-formed steel angles tied with bolts under tension. The regression analysis under linear condition was done and equation for net value of section efficiency was derived. Prabha et al (2011) conducted the research on aspect of shear lag effect in angles connected by single leg. Numerical expression for cold-formed steel members was derived which is in agreement with of IS:800-2007. Geethu C V et al (2014) concentrated on the effects of eccentric action on connections over bolted angle member capacities. It was analyzed that eccentricity at the connections induced bending effects which in turn decreases the failure capacity of a section.

A model was developed using finite element theory to predict the effect of eccentricity on the specimens. Haigen and Weichao (2015) calculated the ratio between stress on the composite T-girder and derived a equation of forces at transverse section as well as the cantilever flange and finally arrived at the shear lag coefficient. Ashour et al (2018) discussed about the relationship between Shear Lag and the Loading in Composite Beams and concluded that shear lag is completely depends upon the loading conditions. The effects of shear lag over box girders and the effect of shear lag has to be considered for in the analysis and design of beams, in particular with the beams with high flange width (Sherrawi and Edaan, 2018). Mohammad Abedin et al (2019) founded that with respect to connection using single-angle, the influence of parameters such as length of connection, eccentric action, and plate thickness plays the major role, where as in double-angle connections the thickness has less effect on shear lag effect. All previous researches are for the hot rolled steel angle sections whereas the research gap is there with respect to cold-formed steel structures. An attempt has been made to pore over the performance of cold-formed steel angle members.

2. EXPERIMENTAL WORK

On single and double angles of varied cross sections with single and double line connections, 48 experiments were undertaken. Eight single specimens with plain angle, eight single lipped angle specimens and with double angles joined to the either side of the gusset plate were loaded and tested in an UTM using 10mm diameter black bolts. The cold formed steel angle specimens that have been utilized for this investigation were manufactured from cold formed steel sheets with thickness 2mm by bending processes. Ideal tension tests were carried out coupons and the stress with respect to strain pattern was drawn as represented in Fig 1. The samples were examined as two peculiar section composition as single and double angles. The single angles were tested as plain angles and lipped angles. The double angles were tested as two configurations namely as double angles which is connected to side opposite to that of plate and double angles are fixed to side parallel to that of the gusset plate.

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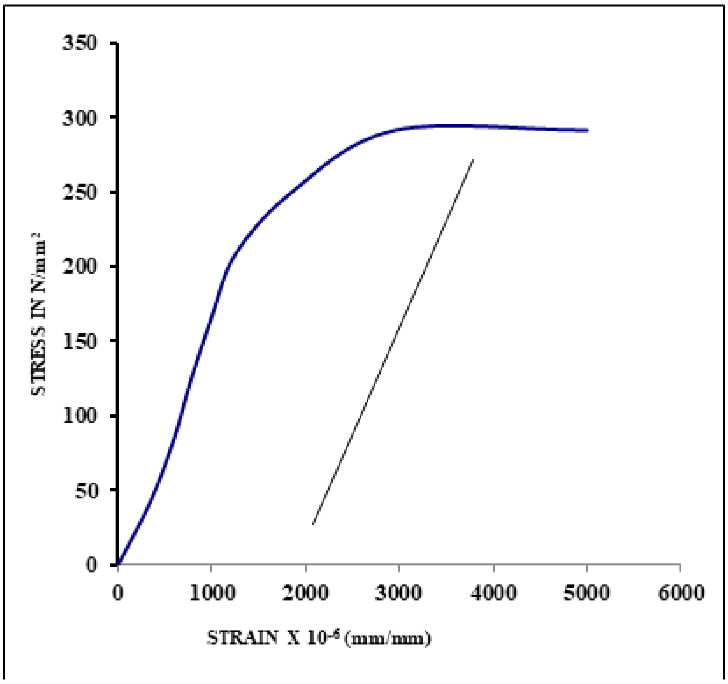
At ends the single and double angle specimens were joined with two mild steel gusset plates with thicknessof8 mm. The bolts of diameter were used to connect all the members 10mm with gusset plate. The specimens were manufactured for length of 500 mm. The gusset plate length was fixed as per the pitch requirement and the edge distance recommended by Indian Standards. The gusset plates were used for double angle specimens but not for the single angle specimens. The gusset plate is joined to all the members on the larger side using the bolts. All the specimens were tested in an UTM which has the capacity of 400kN. Dial gauge was used for measuring the change in length. Fig 2 and 3 depicts the Experimental setup of single as well as double angle specimens.



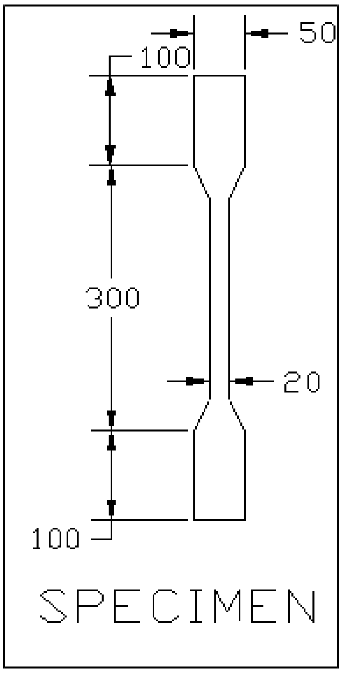


Figure 1 Standard tension test

Figure. 2 Single plain angle connected to gusset plate

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Figure 3 Double lipped angle sample joined over same side of gusset plate

3. NUMERICAL INVESTIGATION

The angle specimens were modelled using ANSYS software. SHELL 63 element type was used to model the angles. With the modelled angle specimens, the deformation due to shear failure of the bolts was neglected. Through the bearing, the load was believed to be transferred from gusset plate to the angle.

4. RESULTS AND DISCUSSION

The performance of cold-formed steel angles when subjected to tension due to eccentric action were examined.

i) Experimental work:

a) Ultimate load-carrying capacity

The ultimate loads determined from experiment for the entire cold-formed steel single and double angles were determined. From the data's it is inferred that with respect to single angles the load carrying capacity of lipped angle increases by 18.02% when considered to that of plain angles. With respect to double angles the ultimate load carrying capacity increases by 5% for angles connected to side contrary to that of gusset plate when considering on the same side of the gusset plate.

b) Load Verses Deflection behaviour

Fig 4 represents load-deflection behaviour for single angles. From the graphs, it is determined that the ultimate load carrying capacity increases with the increase in cross-sectional area. It is also inferred that stiffness increases with the increase in the rigidity of the connection.

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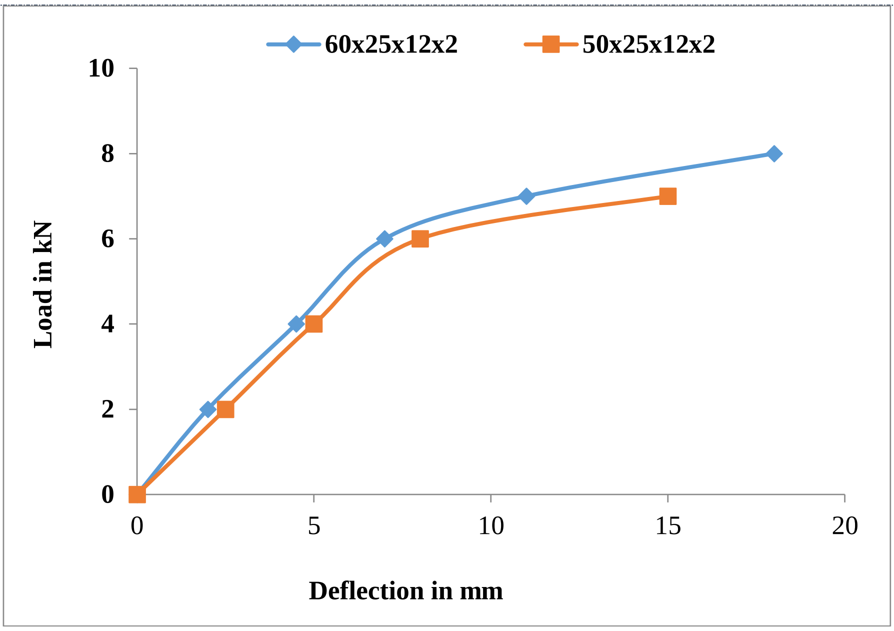

Figure 4 Load versus Deflection performance of single lipped angle specimen(singleline connection)

c) Types of Failure

The various types of failure were observed for all single as well as double angled samples. Tearing failure, block shear failure, net section fracture failure was noticed as in Fig 5 and Fig 6. The failure patterns are unique for single with that of double angle sections. The mode of failure is based upon the cross sectional area of specimen and grimness of connection. The visible gap arises from the corner of the angle to the

Figure 5 Block shear failure mode for single lipped angle specimen

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Figure 6. Net section failure mode for double plain angle specimen connected to opposite side of gusset plate

ii) Comparison of experimental Versus Numerical values

A comparison is made from the determined ultimate loads obtained from the experiment with the load carrying capacity from equations recommended by the following codes AS/NZS:4600-2005, BS:5950 (Part 5)-1998 is made. The tensile capacity equations given by international codes considered the effect of lag due to shear and included the reduction factor for capacity with the net area of the section. In case of single line connection and double line connection the loads determined using ANSYS are greater than the values obtained from experiment and that determined by BS. Inclusion of lip improves the load bearing capacity of the angles by 18%.

iii) Numerical investigation

To execute the non-linear analysis, the models were prepared for angle specimens in agreement with the experimental set up with the inclusion of geometric fallibility. Considering the nonlinear problem it is dependent on path, a step by step load increment is done to get the solution. Yield value is determined using criteria recommended by Von-Mises. After each load increment the program adjusts before applying the next load increment to indicate the nonlinear changes in structural stiffness. ANSYS applied Newton-Raphson method of equilibrium iterations. The general post processor in ANSYS helps to vizualize results after increment of each load increments. Fig 7 and 8 indicates the distribution of stress.

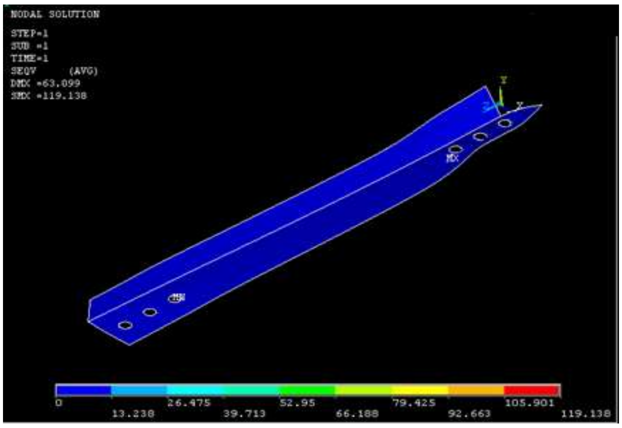

Figure 7 Stress distributions for single plain angle 50x25x2

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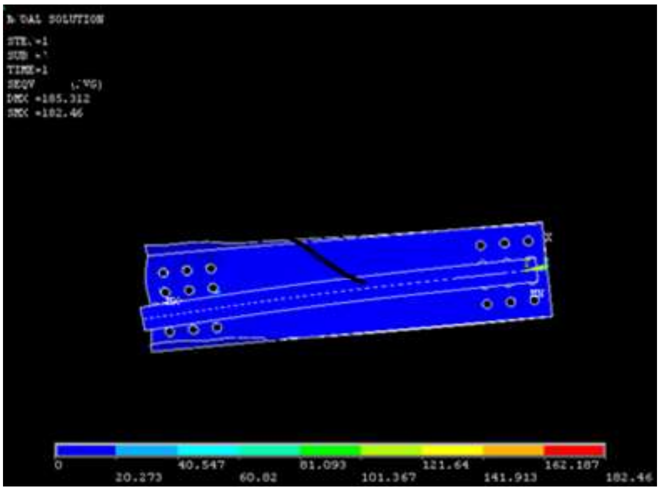

Figure 8 Stress distribution for double lipped angle connected to same side of the gusset plate (60x60x15x2)

5. CONCLUSIONS

The following findings were from the research.

1) As the size will increases the load bearing capacity will be increased. Increasing the number of bolts enhances the connection rigidity and load bearing capacity.
2) The provision of lip improves the load bearing capacity of single angles by 18%. The load bearing capacity increased by 5% for double angles connected to the side opposite to that of gusset than the angles connected to same side of gusset plate.
3) Cold-formed steel angles with larger legs experienced local buckling under eccentric tensile loading conditions.
4) In view of single line connection and double line connection the values predicted by AS/NZS are very high than that of loads from experiment and loads calculated by British Standard.
5) From the finite element analysis the stress contours were obtained which indicate maximum stresses experienced by the innermost bolt holes.
6) The application of ANSYS tools in performance study on bolted cold formed steel angle tension members helps in better understanding of plastic failure in the post–yield region.

Conflict of interest

The author has no conflict of interest.

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