ABSTRACT

Tension members are used in a variety of structures such as trusses, transmission towers etc. The most widely used structural shapes are the angle sections and the channel sections. Angles may be used as single angles or double angles and the connection may be bolted or welded. Most of the design provisions for hot-rolled tension members are available and only few studies were reported in the literature regarding the behaviour of cold-formed steel bolted angle tension members.

The main objective of the study is to investigate the behaviour of cold-formed steel single and double angles subjected to tension. Experimental, Theoretical and Numerical investigations were carried out. The entire study is divided into four distinct phases.

In the first phase, experimental investigations were carried out to study the behaviour of cold-formed steel single and double angles. One hundred and twenty experiments were conducted on single and double angles of different cross sections. The cold-formed steel angle specimens used in this investigation were fabricated from cold formed steel sheets by bending and press breaking operations. Both plain and lipped angles of various sizes were chosen to study their effect. Seventy two numbers of single plain and lipped angles made from thicknesses 2,3 and 4 mm connected to gusset plates at their ends by ordinary black bolts were tested. Forty eight numbers of double angles of 3 and 4 mm thicknesses connected to the opposite side of gusset
plate and to the same side of the gusset plate at their ends by black bolts were also tested. All the specimens were tested to failure. Load vs deflection behaviour, ductility co-efficient, and the failure modes were studied. Three types of connection failure such as tearing failure, net section fracture failure and block shear failure were observed. It is observed that in the case of single lipped angles the increase in ultimate load is 1.2 times greater than that of single equal plain angles. The increase in ultimate load for double angles connected back to back side of the gusset plate is 1.25 times greater than that of double equal angles connected to the same side of the gusset plate. The ultimate loads and failure modes obtained through experiments were compared with the numerical values obtained through ANSYS.

In the second phase, various International codes of practice were reviewed and experimental results were compared with the codal predictions. These International codes include, the British Code of Practice for Design of Cold-formed Sections: BS: 5950 (Part 5) – 1998, the American Cold-formed Steel Design Manual: AISI Manual -2001, Australian/NewZealand Standard for Cold-formed Steel Structures: AS/NZS : 4600-2005. The load carrying capacities obtained from the experimental investigation were also compared with the loads predicted by the different codes of practices. In case of single angles the values predicted by AISI and AS/NZS are nearly 11% lower than the experimental ultimate loads irrespective of whether the angle is equal or unequal and provided with or without lip. BS code underestimates the values for single angles by 29% with respect to experimental ultimate loads. In case of double angles the ultimate loads predicted by the AISI and AS/NZS are nearly 20% lower than the experimental ultimate loads. BS code
underestimates the values for double angle members by 21% with respect to experimental ultimate loads.

In the third phase, numerical investigations were carried out using finite element software ANSYS. In order to simulate the experimental behaviour using the analytical model, material non-linearities and geometric non-linearities were incorporated. A non-linear static analysis was carried out to determine the ultimate load carrying capacity of the single and double angle sections. Load vs deflection behaviour was also studied for all the specimens. The numerical results were compared with the experimental results. The numerical model developed using ANSYS to predict the behaviour of single and double angles was found to simulate the experimental behaviour very closely.

In the fourth phase, an equation for predicting the strength of angle section was developed using the commercially available statistical software Sigmaplot 10. In order to establish the form of equation, regression analysis including linear and nonlinear regression analysis have been performed. The equation was developed with the geometrical factors such as connection eccentricity ($\bar{x}$), connection length (L), width of connected leg of the angle ($a_c$), net width of connected leg of the angle ($a_{cn}$), width of unconnected leg ($a_d$), nominal bolt diameter (d) and angle thickness (t) that have effect on net section efficiency. Based on the experimental, theoretical and numerical investigations the behaviour of bolted cold-formed steel single and double angles subjected to tension was well understood. The proposed design equation can be readily used by any designer and is useful in formulation of the revised Indian codal provisions for cold-formed steel members.