International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

Study of Equal Angle Tension Members by IS 800-1984 & IS 800-2007

Chetan Jaiprakash Chitte

[1]Assistant Professor, R. C. Patel Institute of Technology, Shirpur-425405, Maharashtra, India

Abstract: ***There are various types of Design method such as working State method and Limit State Method. The design methodologies for the steel structures namely, working stress design method and limit state design methods are briefly explained. The latest version of the Code of Practice for general construction in steel IS 800:2007 is based on Limit State Method of design. The design concept is totally changed in comparison to earlier IS 800:1984 which is based on elastic method. In the present work, the detailed analysis of structural components as tension members is done for single equal angle sections using Limit State Method and Working Stress Method and the comparative study of the same is represented in the form of graphs and tables, which highlights the actual economy achieved by Limit State Method over Working Stress Method for single equal angle sections. The observations made based on this study are very much useful to the practicing structural engineers.***

Keywords: IS 800:1984, IS 800: 2007, Limit state method, Working stress method, Equal angle section

1. Introduction

Structural steel has several advantages over other competing materials such as concrete and wood, such as high strength to weight ratio, high ductility, uniformity, and its ability to be fully recyclable. Ductility and toughness are very important when steel is subjected to earthquake loads or impact loads. It offers much better compressive and tensile strength than concrete. It is difficult to assess at the design stage how safe a proposed design will actually be consistent with economy. The codes published by the Bureau of Indian Standards for design of steel structures are IS800:1984 and IS800:2007. Earlier for designing steel structures Working Stress Method (IS800:1984) is used. Now designing is done using Limit State Method (IS800:2007). In view of this an effort has been made to high light the actual economy may be achieved by adopting Limit state method in the design of tension members based on IS800:2007.

2. Comparative study of IS: 800-2007 and IS: 800-1984

Codes of practice provide the minimum requirements that a design has to satisfy. In India, Bureau of Indian Standards (B.I.S.) is the statutory body that publishes the codes of practice to be followed in the Indian Professional practice. Though the codes of practices issued by B.I.S. are revised after 20 to 25 years, the second revision of IS 800 was published in 1984. The third revision of the code was released after about 24 years, in December 2007, by the B.I.S. The material contained in the code reflects the state-of-the-art of knowledge and is based on the provisions in other international codes as well as other research publications. This version of the code is based on the Limit state method of design philosophy whereas the earlier version was based on Working stress method.

2.1. Major Modifications

In the latest revision of IS: 800, the following major modifications have taken place:

1) The standard is based on limit state method, reflecting the latest developments and the state of the art.
2) In view of the development and production of new varieties of medium and high tensile structural steels in the country, the scope of the standard has been modified permitting the use of any variety of structural steel provided the relevant provisions of the standard are satisfied.
3) The standard has made reference to the Indian Standards now available for rivets, bolts and other fasteners.

2.2 Concept of Working Stress Method

In the elastic method of design, the worst combination of loads is ascertained and the members are proportioned on the basis of working stresses. These stresses should never exceed the permissible ones as laid down by the code. The method basically assumes that the structural material behaves in linear elastic manner, and that adequate safety can be ensured by suitably restricting stresses in the material due to the expected working loads (service loads) on the structure. Stresses caused by the 'characteristic' loads are checked against the permissible stress which is a fraction of yield stress. Thus the permissible stress may be defined in terms of factor of safety, which takes care of the overload or other un-known factors. Thus, Permissible stress = Yield stress / factor of safety Thus, in working stress method Working stress ≤ permissible stress.

2.3 Concept of Limit State Method

The object of limit state design can be paraphrased as achievement of an acceptable probability that a part or whole of structure will not become unfit for its intended use during its life time owing to collapse, excessive deflection etc, under the actions of all loads and load effects. The acceptable limits of safety and serviceability requirements before failure occurs are called as limit state. For achieving the design objectives, the design shall be based on characteristic values for material strengths and applied loads (actions), which take into account the probability of variations in the material strengths and in the loads to be supported. The characteristic values shall be based on statistical data, if available. Where such data is not available, these shall be based on experience. The design values are derived from the characteristic values through the use of partial safety factors, both for material strengths and for loads. In the absence of special considerations, these factors shall have the values given in this section according to the material, the type of load and the limit state being considered. The reliability of design is ensured by satisfying the requirement

Design action ≤ Design strength

3. Comparison of Analysis of Tension member by IS: 800-2007 and IS: 800-1984

Table A

IS 800:1984	IS 800 :2007
The permissible stress in axial tension σat in Mpa on the net effective area of The section shall not exceed σat = 0.6 fy (where fy = minimum yield stress of steel) [Clause 4.1,page no.37]	Factored design tension T in the member shall be :- T < Td (clause 6.1,page no.32) Where, Td = Design tensile strength of the member least of Tdg , Tdn, Tdb Tdg = design strength due to yielding of gross section Tdn = design strength due rupture of critical section Tdb = design strength due to block shear

Table B

IS 800:1984	IS 800 :2007
Net effective area =Anet = A1+ A2 K For angles and Tees (clause 4.2, page no.37) With bolted and welded connection Provide a reduction coefficient to take Account of the unavoidable Eccentricities, stress concentrations etc. In case of single angle connected Through one leg K = 3A1 /(3A1 + A2) A1 = area of connected leg A2 = area of outstanding leg In case of double angle connected same side of the gusset plate K = 5A1/(5A1 + A2)	For angles (clause 6.3.3,page no.32) With bolted and welded connection Tdn = 0.9 x fu x Anc/γm1 + β x Ago x fy/γmo = αAn x fu/γm1 α = 0.6 for one or two rivets = 0.7 for three rivets = 0.8 for four or more rivets β = 1.38-0.076 x w/t x fy/fu x bs/L An = net area of the total cross section Anc = net area of the connecting leg Ago = gross area of outstanding leg t = thickness of leg L = length of end connection

4. Calculations

Analysis of Tension member is done by IS: 800-2007 and IS: 800-1984. Various equal angle sections are considered from steel table. Following notations are used in calculations:

(a) Working stress method:
A1 = area of connected leg
A2 = area of outstanding leg
Anet = net cross-sectional area
k = coefficient of reduction
σat = maximum permissible tensile stress

(b) Limit state method
Ag = Gross cross-sectional area
Fu = Characteristic ultimate tensile stress
Fub = Characteristic ultimate tensile stress of the bolt
Fy = Characteristic yield stress
γmo = Partial safety factor against yield stress and buckling
γm1 = Partial safety factor against ultimate stress
Tdg = Yielding strength of gross section under axial tension
Tdn = Rupture strength of net section under axial tension
Tdb = Design strength of bolt under axial tension; Block shear strength at end connection

4.1 Steps for Analysis of Tension members by Working stress method

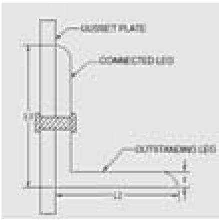
Step 1: Section from steel table.
Step 2: Diameter of bolt or rivet

$\emptyset = 6.01\sqrt{t}$

t = thickness of section
Step 3: Gross diameter

$= \text{nominal dia.} + 1.5\text{ mm}, \emptyset \leq 25\text{mm}$

$= \text{nominal dia.} + 2\text{mm}, \emptyset > 25mm$



Step 4: Area of connected leg, A_1

$$A_1 = \left(\text{connected leg length} - \frac{\text{thickness of section}}{2} - \text{Gross dia.}\right) \times \text{thickness of section}$$

Step 5: Area of outstanding leg, A_2

$$A_2 = \left(\text{outstanding leg length} - \frac{\text{thickness of section}}{2}\right) \times \text{thickness of section}$$

Step 6: Net area of section

$$\text{Anet} = A_1 + A_2 \times K$$

(Clause 4.2.1.1. pg – 37)

$$K = \frac{3A1}{3A1+A2}$$ - For single angle section (Clause 4.2.1.1. pg - 37)

$$K = \frac{5A1}{5A1+A2}$$ - For double angle section (Clause 4.2.1.2. pg - 37)

Step 7: Strength of member

$= \sigma at \times \text{Anet}$

$= 0.6\text{ fy} \times \text{Anet}$

4.2 Steps for Analysis of Tension members by Limit state method

Step 1: Given data

$(\text{section}, A_g, \text{gusset thickness}, fu, fub, fy, \gamma_{mb}, \gamma_{mo})$

Step 2: Assume diameter of bolt (d)
Diameter of hole (dh)
Pitch distance $(p = 2.5\ d)$
End distance $(1.5\ dh \text{ or } 1.7\ dh)$
Step 3: Tension capacity of section

$$T_{dg} = \frac{A_g . fy}{\gamma_{mo}}$$

A_g= Gross area of section
Step 4: Find bolt value
1) Shear capacity of bolt (Clause 10.3.3. pg – 75)

$$Vdsb = \frac{\frac{fu}{\sqrt{3}} \times (n_n \times A_{nb})}{\gamma_{mb}}$$

$$\left(A_{nb} = 0.78 \times \frac{\pi}{4} \times d^2\right) (n_n = 1)$$

2) Bearing capacity of bolt (Clause 10.3.4. pg – 75)

$$Vdpb = \frac{2.5\ kb.t.d.fu}{\gamma_{m1}}$$

kb is smaller of

$$\frac{e}{3dh} \text{ or } \frac{p}{3dh} - 0.25 \text{ or } \frac{fub}{fu} \text{ or } 1$$

Bolt value is least of above

$$\text{no. of bolts} = \frac{\text{tension capacity}}{\text{bolt value}}$$

Step 5: Capacity of the section

1) Design strength due to yielding of gross section (Clause 6.2. pg - 32)

$$T_{dg} = \frac{A_g . fy}{\gamma_{mo}}$$

2) Design strength due to rupture of critical section (Clause 6.3.3. pg - 33)

$$T_{dn} = \frac{0.9 \times Anc \times fu}{\gamma_{m1}} + \frac{\beta \times Ago \times fy}{\gamma_{mo}}$$

Where,
Anc = area of connected leg

$\left(= \text{connected leg length} - \text{dia of hole} - \frac{\text{thick.of section}}{2}\right) \times \text{thick. of section}$

Ago = Area of outstanding leg

$\left(= \text{outstanding leg length} - \frac{\text{thick.of section}}{2}\right) \times \text{thick. of section}$

$$\beta = 1.4 - 0.076 \left(\frac{w}{t}\right)\left(\frac{fy}{fu}\right)\left(\frac{bs}{lc}\right)$$

Check for β:

$0.7 \leq \beta \geq \frac{fu \times \gamma_{mo}}{fy \times \gamma_{m1}}$

Where,
w = unconnected leg length
t = thickness of section
$bs = w + wi - t$
$wi = \text{connected leg length} \times 0.6$
$lc = \text{pitch} \times (\text{no.of bolts} - 1)$

3) Design strength due to block shear (Clause 6.4. pg – 33)

$$T_{db1} = \frac{Avg \times fy}{\sqrt{3} \times \gamma_{mo}} + \frac{0.9 \times Atn \times fu}{\gamma_{m1}}$$

$$T_{db2} = \frac{0.9 \times Avn \times fu}{\sqrt{3} \times \gamma_{m1}} + \frac{Atg \times fy}{\gamma_{m0}}$$

Where,
$Avg = Lv \times t$
$Lv = e + p \times (\text{no.of bolts} - 1)$
$Avn = Lc \times t$
$Lc = Lv - [(\text{no.of bolts} - 1) + 0.5] \times dh$
$Atg = Lt \times t$
$Lt = \text{connected leg} - wi$
$Atn = (Lt - 0.5dh) \times t$

Comparison of load carrying capacity of various equal angle sections is shown in tabular and graphical form as below.

5. Result

Table C

Equal Angle Section	Thk. of Section	Capacity of Section (kN)	
		Working Stress Method (WSM)	Limit State Method (LSM)
ISA 200 x 200x 12mm	12	573	1059
ISA 200 x 200x 15mm	15	711	1314
ISA 200 x 200x 18mm	18	846	1564
ISA 200 x 200x 25mm	25	1151	2131
ISA 150 x 150x 10mm	10	349	660
ISA 150 x 150x 12mm	12	416	786
ISA 150 x 150x 15mm	15	514	972
ISA 150 x 150x 18mm	18	609	1154
ISA 130 x 130x 8mm	8	239	460
ISA 130 x 130x 10mm	10	296	570
ISA 130 x 130x 12mm	12	352	678
ISA 130 x 130x 15mm	15	435	837
ISA 110 x 110 x 8mm	8	197	387
ISA 110 x 110 x 10mm	10	244	479
ISA 110 x 110 x 12mm	12	289	569
ISA 110 x 110x 15mm	15	336	700

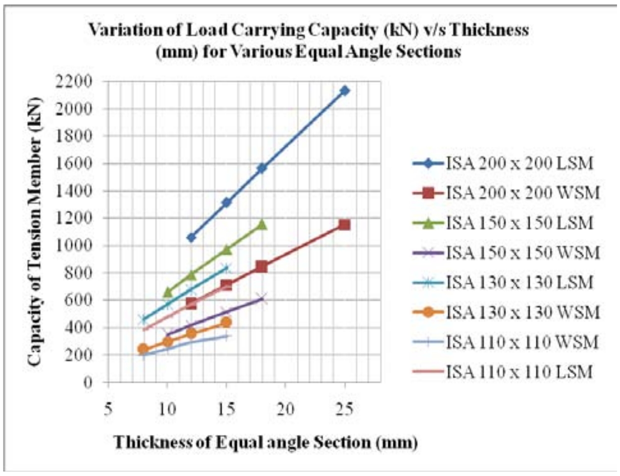


Figure 1: Capacity of tension member

Table D

Equal Angle Section	Thk. Of Section	Capacity of Section (kN)	
		Working Stress Method (WSM)	Limit State Method (LSM)
ISA 100 x 100 x 6mm	6	134	256
ISA 100 x 100 x 8mm	8	176	350
ISA 100 x 100 x 10mm	10	217	433
ISA 100 x 100 x 12mm	12	258	513
ISA 90 x 90 x 6mm	6	117	238
ISA 90 x 90 x 8mm	8	155	313
ISA 90 x 90 x 10mm	10	191	387
ISA 90 x 90 x 12mm	12	226	459
ISA 80 x 80 x 6mm	6	102	211
ISA 80 x 80 x 8mm	8	134	278
ISA 80 x 80 x 10mm	10	165	342
ISA 80 x 80 x 12mm	12	194	405
ISA 75 x 75 x 5mm	5	79	165
ISA 75 x 75 x 6mm	6	94	167
ISA 75 x 75 x 8mm	8	123	254
ISA 75 x 75 x 10mm	10	151	319

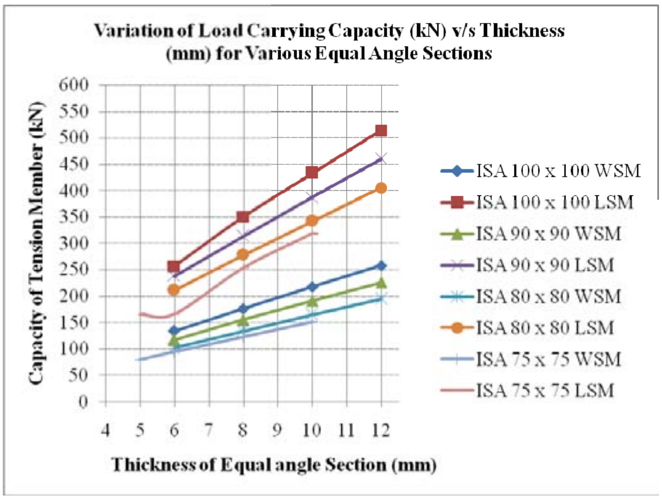


Figure 2: Capacity of tension member

6. Conclusion

With comparison of the design methodology as per Table C, Table D, Fig.1 & Fig.2 for basic structural element following conclusions are drawn and summarized

1) Capacity of section is increased in IS: 800:2007 as compare to IS 800:1984.
2) The design of tension member using Angles by Limit state method (IS 800-2007) is economical over the working stress method (IS 800-1984) which values for 12% to 54%.
3) In LSD, in addition to net section failure and block shear failure, yielding of the gross section must also be considered so as to prevent excessive deformation of the member

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Author Profile

Chetan Jaiprakash Chitte, received M. Tech. degree in Structural Dynamics & Earthquake Engineering from VNIT Nagpur, in 2006 and Bachelor of Civil Engineering from SPCE, Mumbai. He has 4.6 Years experience in the area of structural designing and 5.11 Years of experience in the area of teaching. Currently he is working as an Assistant Professor in Civil Engineering Department, at R. C. Patel Institute of Technology, Shirpur