Comparative Study of Steel Structures Design Using IS 800:1984 & IS 800:2007

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Abstract— 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. The design methodologies for the steel structures namely, working stress design method and limit state design methods are briefly explained. The importance of limit state design meth od is highlighted. In the present work, the detailed study of structural components as tension members and compression members by designing using Limit State Method and Working Stress Method has been carried out and submitted the comparative study of the same in the form of graphs.

Index Terms— IS 800:1984, IS 800:2007, Limit state method (Plastic method), Working stress method (Elastic method).

1 Concept of Elastic 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 unknown factors. Thus,

Permissible stress = Yield stress / factor of safety

Thus, in working stress method

Working stress ≤ permissible stress

2 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

2.1 Partial Safety Factors:

The variation due to the difference between the overall resistances of a structure to a set of loads, predicted by the design calculations and the resistance of the actual structure is taken care of by a set of partial safety factors or γ factors. The specific effect of variability in material and geometric properties is taken care of by the partial safety factors for strength, γm. The variability of the loads on the structure, or more specifically, the load effects on the various structural components, is reflected through the partial safety factors for loads (load factors) γ_{fk}.

Table 1 Partial Safety Factor for Materials, γ_m

Sr. no.	Definition	Partial safety factor	
1	Resistance governed by yielding, γ_{mo}	1.10	
2	Resistance of member to buckling, γ_{mo}	1.10	
3	Resistance governed by ultimate stress, γ_{m1}	1.25	
4	Resistance of connection:	Shop fabrications	Field fabrications
	Bolts – Friction type, , γ_{mf}	1.25	1.25
	Bolts – Bearing type, , γ_{mb}	1.25	1.25
	Rivets , γ_{mr}	1.25	1.25
	Welds , γ_{mw}	1.25	1.50

Table 2 Partial Safety Factors for Loads, γ_f for Limit States

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Combination	Limit state of strength					Limit state of serviceability			
	DL	LL		WL/EL	AL	DL	LL		WL/EL
		Leading	Accompanying				Leading	Accompanying	
DL+LL+CL	1.5	1.5	1.05	-	-	1.0	1.0	1.0	-
DL+LL+CL +WL/EL	1.2 1.2	1.2 1.2	1.05 0.53	0.6 1.2	-	1.0	0.8	0.8	0.8
DL+WL/EL	1.5 (0.9)*	-	-	1.5	-	1.0	-	-	1.0
DL+ER	1.2 (0.9)	1.2	-	-	-	-	-	-	-
DL+LL+AL	1.0	0.35	0.35	-	1.0	-	-	-	-

* This value is to be considered when stability against overturning or stress reversal is critical

Abbreviations: DL= Dead Load, LL= Imposed Load (Live Loads), WL= Wind Load, CL= Crane Load (Vertical/horizontal), AL=Accidental Load, ER= Erection Load, EL= Earthquake Load.

3 Codal Provisions for Design of Tension Member by Working Stress Method (IS 800:1984)

3.1 Axial Stress

The permissible stress in axial tension, σat, in MPa on the net effective area of the sections shall not exceed:

$$\sigma at = 0.6\, fy$$

3.2 Design Details

i) In the case of single angle connected through one leg the net effective sectional area shall be taken as:

$$A_l + A_2 k$$

where,

$$k = 3A_1 / (3A_1 + A_2)$$

ii) In the case of a pair of angles back-to-back (or a single tee), connected by one leg of each angle (or by the flange of the tee) to the same side of a gusset, the net effective area shall be taken as,

$$A_l + A_2 k$$

where,

$$k = 5A_1 / (5A_1 + A_2)$$

4 Codal Provisions for Design of Tension Member by Limit State Method (IS 800:2007)

The factored design tension T, in the members shall satisfy the following requirement:

$$T < T_d$$

Where,

T_d = Design strength of the member.

The design strength of a member under axial tension, T_d, is the lowest of the design strength due to yielding of gross section, T_{dg}; rupture strength of critical section, T_{dn} ; and block shear T_{db} ,given in 4.1,4. 2, & 4.3 below respectively.

4.1 Design Strength Due to Yielding of Gross Section

The design strength of members under axial tension, T_{dg}, as governed by yielding of gross section, is given by,

$$T_{dg} = A_g f_y / \gamma_{mo}$$

Where,

γ_{mo} = partial safety factor for failure in tension by yielding

4.2 Design Strength Due to Rupture of Critical Section

a) Plates

The design strength in tension of a plate, T_{dn}, as governed by rupture of net cross-sectional area, An, at the holes is given by,

$$T_{dn} = 0.9 A_n f_u / \gamma_{m1}$$

Where,

γ_{m1} = partial safety factor for failure at ultimate stress

b) Single Angles

The design strength, T_{dn}, as governed by rupture at net section is given by:

$$T_{dn} = 0.9 A_{nc} f_u / \gamma_{m1} + \beta A_{go} f_y / \gamma_{mo}$$

Where,

$$\beta = 1.4 - 0.076 (w / t) (fy / fu) (bs / Lc)$$

Where,

w = outstand leg width,

b_s = shear lag width and

L_c = length of the end connection, that is the distance between the outermost bolts in the end joint measured along the load direction or length of the weld along the load direction.

4.3 Design Strength Due to Block Shear

The block shear strength, Tdb of connection shall be taken as smaller of

$$T_{db} = [A_{vg} f_y / (\sqrt{3}\, \gamma_{mo}) + 0.9 A_{tn} f_u / \gamma_{m1}] \text{ or}$$

$$T_{db} = (0.9 A_{vn} f_u / (\sqrt{3}\, \gamma_{m1}) + (A_{tg} fy / \gamma_{mo})$$

5 Codal Provisions for Design of Compression Member by Working Stress Method (IS 800:1984)

5.1 Axial stress

The direct stress in compression on the gross sectional area of axially loaded compression members shall not exceed 0.6fy nor the permissible stress σac, calculated using the following formula,

$$\sigma_{ac} = \text{[illegible]}$$

Where,

σ_{ac} = permissible stress in axial compression, in MPa;

f_{cc} = elastic critical stress in compression, = [illegible]

E = modulus of elasticity of steel (2×10^5 MPa);

λ (= l/r) = slenderness ratio of the member, ratio of the effective length to appropriate radius of gyration;

n = a factor assumed as 1.4.

6 Codal Provisions for Design of Compression Member by Limit State Method (IS 800:2007)

1. The design compressive strength Pd, of a member is given by ;

$$P < P_d$$

Where,

$$P_d = A_e f_{cd}$$

2. The design compression stress, fcd of an axially loaded compression member shall be calculated using following formula,

$$f_{cd} = \frac{f_y/\gamma_{mo}}{\varphi + (\varphi^2 - \lambda^2)^{0.5}}$$

Where,

φ = 0.5[1 + α (λ – 0.2) +λ2]

λ = non dimensional effective slenderness ratio = [illegible]

f_{cc} = euler buckling stress = [illegible]

Where,

KL / r = effective slenderness ratio or ratio of effective length, KL to appropriate radius of gyration, r

α = imperfection factor

χ = stress reduction factor for different bucking class , slenderness ratio and yield stress

σ_{mo} = partial factor of safety for material strength.

7 Comparative Study

Table 3 List of Studied Parameters

1.	Type of Member	Tension member
	Sections analysed	ISA35x35x6 to ISA200x200x25
2.	Type of Member	Compression member
	Sections analysed	ISJB150 to ISHB450
	Length of column	3m, 4m,5m
3.	End condition	Both ends of column pinned

7.1 Comparison of Tension member by both codes

Here, the load carrying capacity (L.C.C) of tension member is carried out by both IS 800-1984 & IS 800-2007 and comparison is shown accordingly in the form of graphs for all the equal angle sections.(Fig.1 & fig.2).

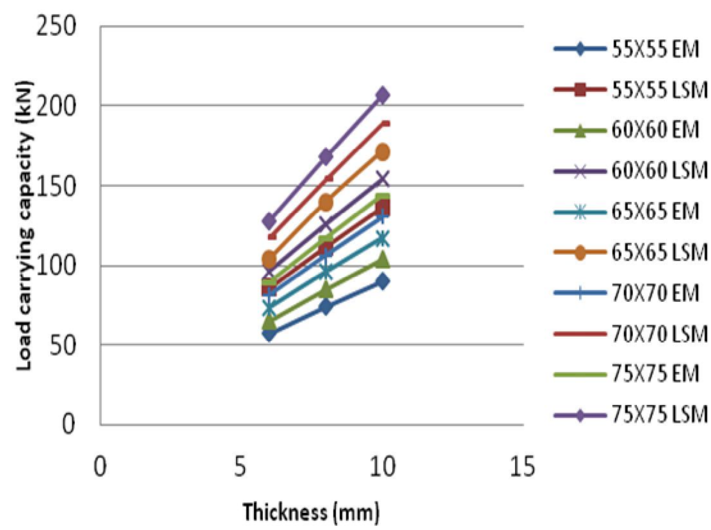

Fig 1 Variation of L.C.C. (kN) Vs thickness (mm) for various sections

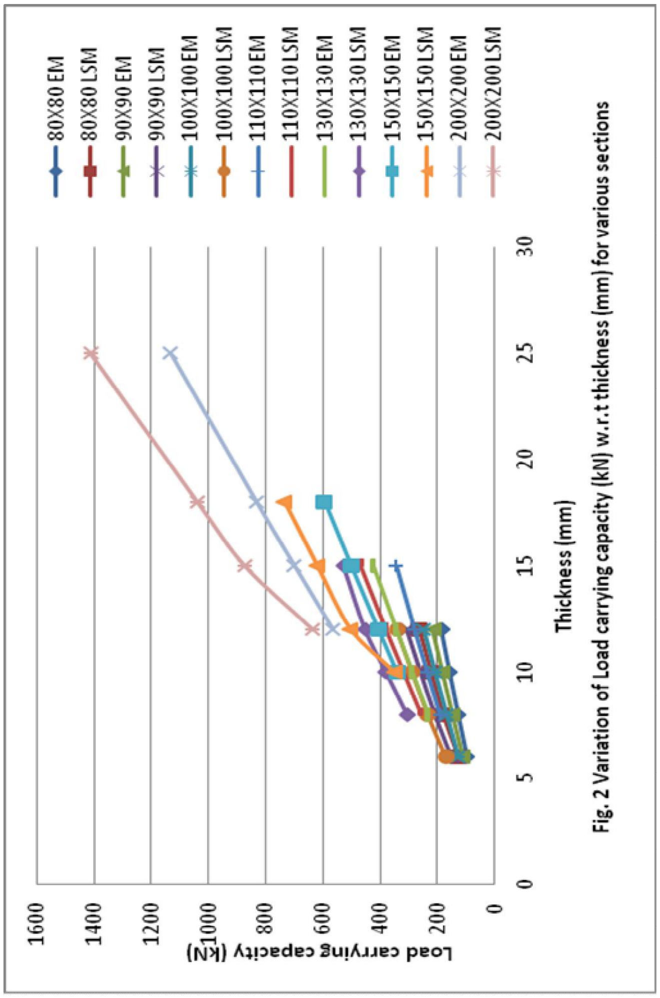

Fig. 2 Variation of Load carrying capacity (kN) w.r.t thickness (mm) for various sections

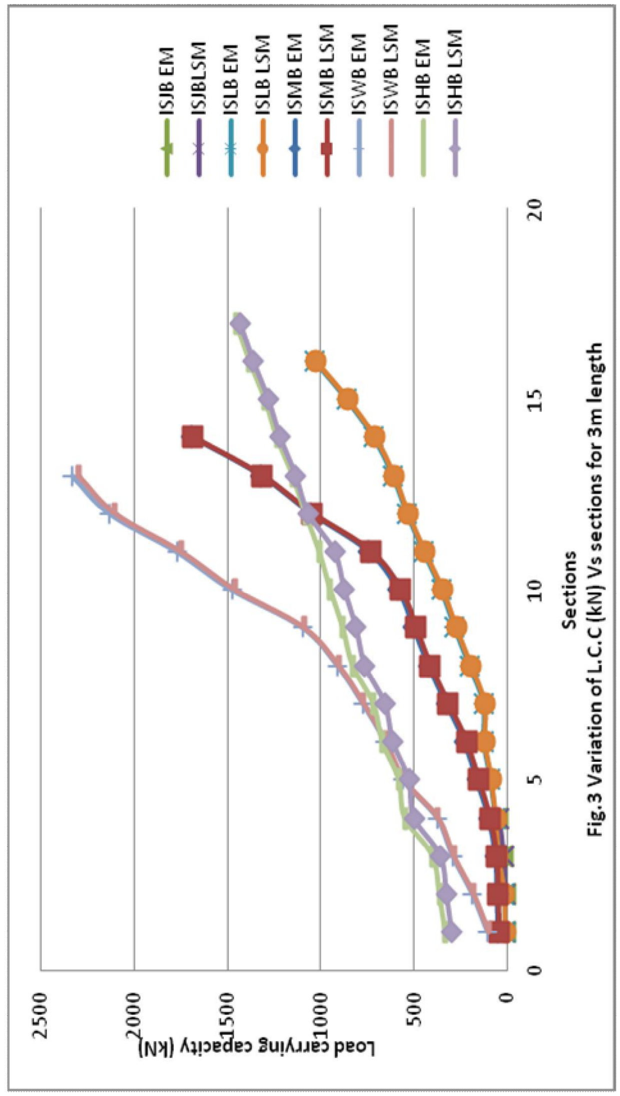

Fig.3 Variation of L.C.C (kN) Vs sections for 3m length

7.2 Comparison of Compression member by both codes

Similarly, L.C.C. of compression members is carried out by by both IS 800-1984 & IS 800-2007 for all I sections for column pinned at both ends for column length of 2m,3m & 4m.This is shown graphically.(Fig.3 to fig.5).

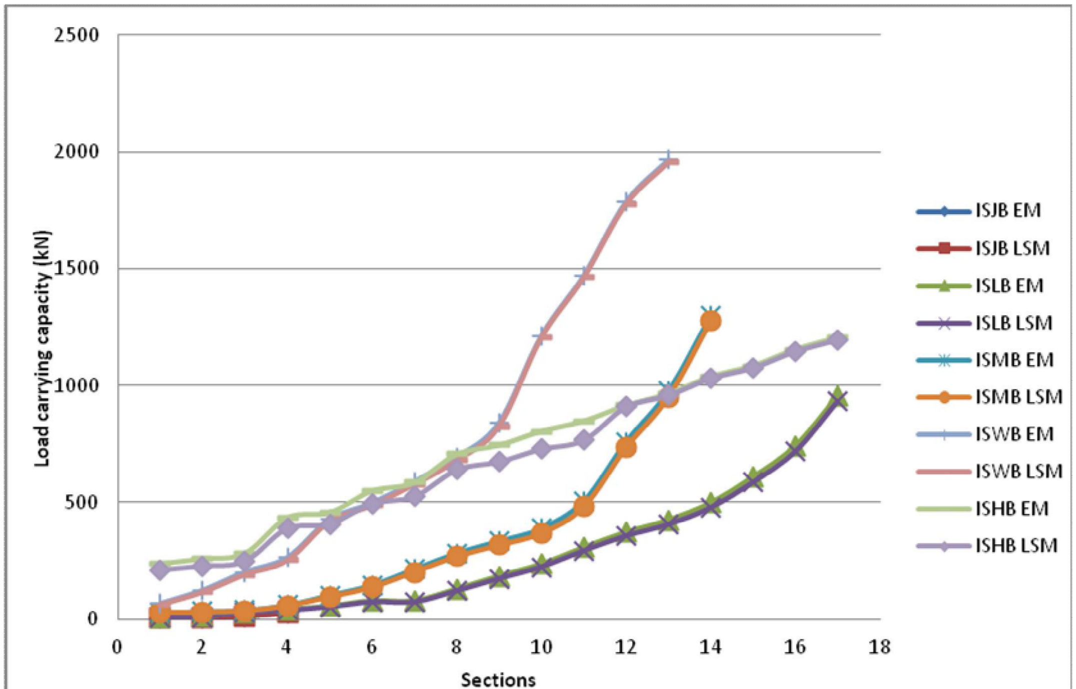

Fig. 4 Variation of L.C.C (kN) Vs sections for 4m length

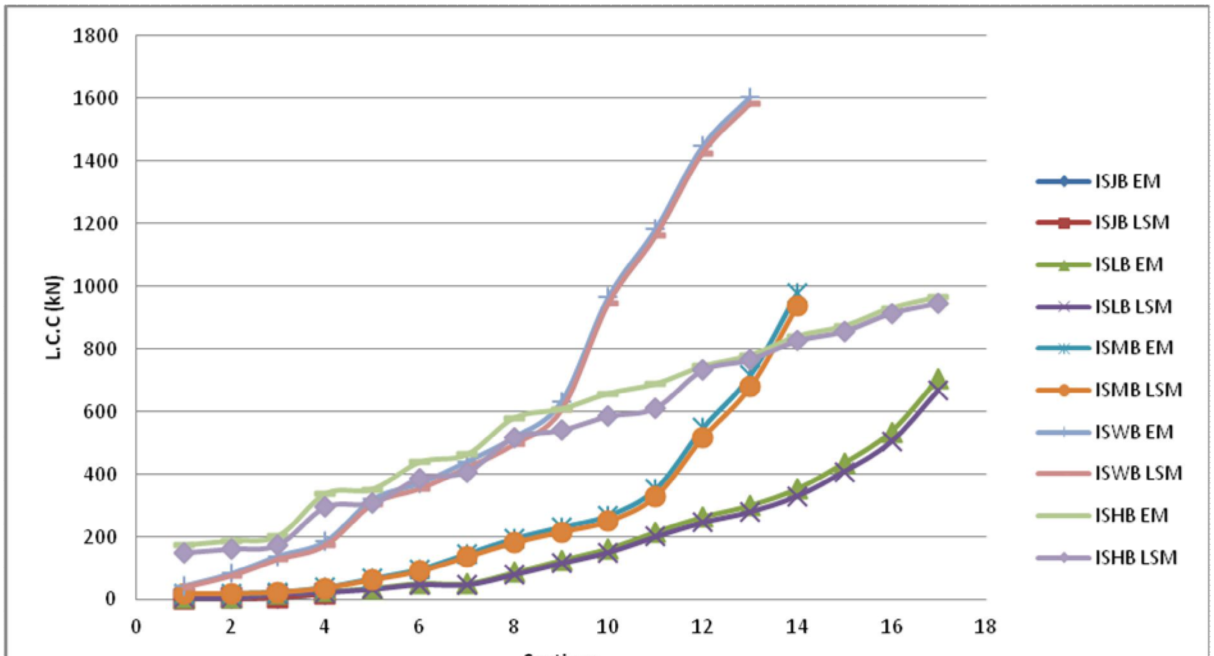

Fig. 5 Variation of L.C.C (kN) Vs Sections for 5m length

8 OBSERVATIONS

8.1 For Tension member

On comparison of the strength of sections calculated using IS 800-1984 & IS 800-2007, the observation made from the graphs (fig.1 & fig.2) are as under:

The Limit State Method (LSM) gives higher values than Working Stress Method (WSM) or Elastic method (EM). For Equal angle, it varies from 12% to 50% for higher sections to smaller sections.

8.2 For Compression member

On comparison of the strength of sections calculated using IS 800-1984 & IS 800-2007 (fig.3 to fig.5), it was found that the strength increases with increase in size of the sections to the maximum of 15% in Elastic method. So the limit state gives lower values than elastic method.

9 CONCLUSION

9.1 For Tension member

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%.

9.2 For Compression member

1.The percentage increase in load carrying capacity as per IS 800-1984 is marginally higher than IS 800-2007. The maximum increase was found to be a maximum of 15%.

2. The section fails if designed by IS 800-2007. So here, the elastic method is economical than limit state method.

10 NOTATIONS

a - connecting leg
A - section area
A_1 - effective cross-sectional area of the connected leg
A_2 - the gross cross-sectional area of the unconnected leg
A_e - effective sectional area
A_g - gross area of cross section
A_{go} - gross area of outstanding leg
A_n - net area of the total cross section
A_{nc} - net area of connected leg of the member
A_{tg} - minimum gross in tension from the hole to the toe of the angle or next last row of bolt in plates, perpendicular to the line of force
A_{tn} - net area in tension from the hole to the toe of the angle or next last row of bolt in plates, perpendicular to the line of force
A_{vg} - minimum gross area in shear along a line of transmitted force
A_{vn} - net area in shear along a line of transmitted force
b_s -shear lag width
E - modulus of elasticity
EM – elastic method
f_{cc} - critical buckling stress
f_{cd} - design compression stress
f_u - characteristic ultimate stress
f_y - characteristic yield strength
σ_{ac} - axial compressive stress
σ_{at} - axial tensile stress
L -Length of the end connection, i.e. distance between the outermost bolts in the joint along the length direction or length of the weld along the length direction
Lc- length of the end connection, i.e. the distance between the outermost bolts in the end joint measured along the load direction or length of the weld along the load direction
LSM – Limit state method
t - thickness of the leg
w- outstand leg width
γ_{mo} - the partial safety factor for failure in tension by yielding
γ_{m1} - partial safety factor for failure at ultimate stress
λ = non dimensional effective slenderness ratio
α = imperfection factor
χ = stress reduction factor for different bucking class , slenderness ratio and yield stress

11 REFERANCE

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