IS: 800 - Indian Code of Practice for Construction in Steel and its Comparison with International Codes

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ABSTRACT

The state-of-the-art design finds its way into practice through specifications and stipulations of relevant codes. In India, several development work has taken place for improving the material properties of steel, yet the design is uneconomical at times due to non-availability of efficient sections. The design codes are being updated and modified incorporating the results from the various researches and developments being carried out at the various R & D Centres in the country.

IS: 800, which was prepared in 1984 and reaffirmed in 1991, was outdated. This code was based on Allowable Stress Design, which was in vogue till the 1960's all over the world. The more modern Limit State Method developed and adapted in advanced countries in the early 1970's is technologically improved and results in significant economy in the completed structures. Considering that the current practice all over the world is based on Limit State Method (LSM) or Load and Resistance Factor Design Method, it was found essential during the year 2002 – 2003 that the code of practice for use of steel in general construction should be modified to LSM while maintaining Allowable Stress Design as a transition alternative. The code was thus prepared and published by the Bureau of Indian Standards (BIS) in 2008.

This paper highlights the essential contents of IS: 800 -2007 while following Limit State Method, the corresponding stipulations as adopted by other International codes, comparison with WSM and the benefits derived thereof. The findings are encouraging as the philosophy is more scientific.

The country is in the threshold of development. The demand of steel in the infra sector and urban are is positive. Survey reveals that a huge untapped demand remains in the rural area. The forecasting of demand is encouraging. To meet up this expectation the other parameters in the supply chain needs to be in place. One of the main agents of change is the development of value rich codes for designs.

KEY WORDS

Allowable Stress Design, Factor of Safety, Limit State Method, Load and Resistancee.Factor Design Method, Serviceability Limit State, Ultimate Limit State.

1. INTRODUCTION

The Indian Construction is often guided by steel, cement as the prime material of construction. Cement requires a healthy partnership with aggregates and steel to form the structural element called concrete. Steel, on the other hand has an advantage of partnering with concrete and also can go alone as an individual structural element.

In order to reap the advantages of steel the whole supply chain needs to be in place. Use of steel as a preferred material for Design Engineers can be increased if the design codes are modified, updated with the scientific researches , user friendly etc. The design Engineers will then be inclined in deciding on using steel. This will increase the consumption in the country.

Early report states that the per capita consumption of the material is though 48Kgs which is below average, but the rise to this value has been steep. The market has a huge potential in the rural sector. In order to tap this untapped source various measures and policies are being framed mainly by the manufacturers. Availability of steel at the doorstep is one such initiative. "Seeing is believing" is the truth behind the success of use of steel. Convincing the rural sector and transforming this belt with steel will serve as an eye opener. The forecasting in demand till 2020 is highly encouraging. In order to match with this expectation, the other related parameters need to be in line too. Modernising codes are one of them.

IS-800, the umbrella code for general structural steel design which was published in 1984 reaffirmed in 1991 was much outdated with outdated philosophy. The working stress method or the Allowable stress method was prepared long back. In the mean time the methodology of design of steel structures had undergone major changes due to two decades of research and the state-of-the-art practiced all over the world. Since an outdated code would be detrimental to the very purpose of the code of practice itself, the basic code for design of steel structures needed updating using recent research findings and practices in developed countries. Thus, the code was revised under the supervision of expert committee constituted by the Bureau of Indian standards (BIS – 2008). The code had ultimately been published in February 24,2008.

Almost all advanced countries are now taking advantage of efficient code stipulations, and the current practice all over the world is based on either Limit State Method (LSM) or Load and Resistance Factor Design (LRFD) method. Table 1, shows design format of steel structures adopted in some of the countries.

Table 1: Countries and their Design Format. (AISC 13th Ed, BS 5950 – 2000)

Australia, Canada, China, Europe, U K, Japan	Limit State Method (LSM)
U S A	Load and Resistance Factor Design (LRFD)
India	Allowable Stress Design (ASD)

Since LSM has become the design philosophy in most of the international design standards due to its rationality and consequent economy achieved in design, it was felt that IS: 800 should also be modified to LSM while maintaining Allowable Stress Design (ASD) as a transition alternative. This would also help the designers to understand both the design methods and utilize the most advantageous one. Even in USA, the codes on design of steel structures, still maintain a dual standards approach, viz. ASD as well as LRFD.

It was also felt that these changes from ASD to LSM in the design Code would render steel design novel and will facilitate accuracy of design.

However, it is important to understand the differing philosophies of Allowable Stress Method of Design and Limit State Method as they apply to design of steel structures.

1.1 Allowable Stress Design (Bandyopadhyay et al 2002, 2003, 2004)

Allowable Stress Design is an approach in which structural members are designed so that unit stresses do not exceed a pre-defined allowable stress. The allowable stress is defined by a limiting stress divided by a factor of safety, so that, in general, it is expressed in the form of:

$f_{actual} \leq f_{allowable}$

and the allowable stress is given by

$f_{allowable} = (f_y/F_s)$

f_y = minimum yield stress and F_s = factor of safety

The factor of safety (F_s) used in the allowable stress design method, however, is fixed. This means that no matter how variable the loads are, in terms of either frequency or magnitude, the factor of safety is always the same. These deficiencies as well as advanced knowledge of strength of material beyond yield point and its plastic plateau led to the development of an alternative to the ASD based on the limit states of a material.

According to a different school of thought, linear elastic method can also take care of the issues related to design of structural members, and may be considered sufficient to address instability, dynamic effects and fatigue, since all these are based on similar variants of the basic slope deflection equation. However, this will call for certain modifications of the existing code stipulations, wherein real advantage of limit state concept can be derived from a totally elastic stress code. This would improve checking of structural design by reducing the number of clauses and complexity involved in limit state concept.

Similarly, a better way than “Effective length” methods can be adopted using Merchant – Rankine approach to find the limiting load of the whole structure, instead of the separate values for different struts (for using different “Column Curves”) such that

$1/P_{limit} = 1/P_{field} + 1/P_{critical}$

Where, P_{limit}, P_{field}, and $P_{critical}$ are the factored limit load of the structure, load at plastic collapse ignoring instability, and the elastic critical load of the structure respectively.

1.2 Limit State Method (Bandyopadhyay et al 2003, 2004, 2005)

The limit state method of design was, in part, developed to address the drawbacks to the allowable stress method of design mentioned earlier. Allowable stress method suffers from the inability of the factor of safety to adequately address the variable nature of loading conditions. Limit state method makes use of the plastic range of material for the design of structural members and incorporates load factors to take into account of the variability of loading configurations.

Thus, a rational but variable factor of safety in different structural performance enables to use steel efficiently and economically in different structural systems to withstand tension, compression etc. Limit State Method of design considers the good performance of steel in tension compared to compression and specifies variable factors. The main advantage of the limit state method is that it takes into account this variance by defining limit states, which address strength and serviceability.

According to this method a structure or part of it is considered unfit for use when it exceeds the limit states, beyond which it infringes one of the criteria governing its performance or use.

The two limit states are classified as the Ultimate Limit State and Serviceability Limit State. The limit states take care of the safe operation and adequacy of the structure from strength point of view. The criteria which are used to define the ultimate limit state are yielding, plastic strength, fatigue, buckling etc. Serviceability limit state takes care of the performance and behaviour of the structure during its service period. Deflection, vibration, drift etc. are considered as serviceability criteria.

Limit state method considers the critical local buckling stress of the constituent plate element of a beam. This enables to enhance resistance of plate elements to local buckling by suitably reducing the slenderness ratio. Hence it is possible to develop the full flexural moment capacity of the member or the Limit State in Flexure. In Limit State Method, based on slenderness ratio of the constituent plate elements, a beam section can be classified as Slender, Semi-Compact, Compact and Plastic. This section classification becomes essential as the moment capacities of each of these sections takes different values, whereas in the existing allowable stress design based on IS: 800-1984, the extreme fibre stress is restricted to $0.66f_y$ irrespective of slenderness ratio of the constituent plate elements.

In LSM, the factored loads, in different combinations, are applied to the structure to determine the load effects. The latter are then compared with the design strength of the elements.

This is expressed mathematically as:
The effects of

$$\gamma_L.Q_k \leq \left[\frac{1}{\gamma_f \gamma_{m1} \gamma_{m2}}\right] \text{[Function of } \sigma_y \text{ and other geometric variables]}$$

Where,

γ_L = partial factor for loads.

γ_f = factor that takes account of inaccuracies in assessment of loads, stress distribution and construction.

γ_{m1}, γ_{m2} = factors that take into account, uncertainty in material strength and quality, and manufacturing tolerances respectively.

Q_k = specified nominal load.

σ_y = yield strength of the material.

2. A BRIEF OVERVIEW OF PROVISIONS OF CODES OF PRACTICE FOR STEEL MEMBERS (BIS – 2006, BS 5950 – 2000)

A steel member may be either in compression, tension, bending or under the combined effect of bending & compression or bending & tension. However the basic stresses applied to a member are either compressive, tensile or shear stresses and the primary forces are compressive & tensile forces or the bending moments. With the advent of the modern State-of-the-Art design methodology in the form of the Limit States Method or the LRFD method, rationality and overall economy has become the key word in the design of steel structures. IS: 800, which has recently been revised to the LSM concept has adopted various design practices as are widely accepted and practiced in various other countries, and has laid down stipulations which match the modern international scenario as far steel design is concerned.

If a brief comparison is made between the Limit States version of IS: 800-2007 and other international codes which are presently in practice, it may be worthwhile to notice that, like other codes though the basic design concept following the Limit States procedure are same for IS: 800, the limiting values of various parameters vary according to design and fabrication / erection practices existing in India. For example, in India though automation in fabrication and erection is developing fast, it is still much behind the normal fabrication / erection procedure as practiced in the developed countries. As such parameters governing the tolerances due to fabrication / erection as well as material strength are more conservative in IS: 800 compared to other international codes.

A comparison of various design provisions for different types of members have been given below.

Table: 2 Tension Members

Parameters	**IS 800 (2007)**	**BS 5950 (2000)**	**Eurocode (1993)**	**AS 4100 (1998)**	**AISC 360 (2005)**
Partial Safety Factors					
γ_{mo}	1.1	1.0	1.1	≈ 1.11	≈ 1.11
γ_{m1}	1.25	1.2 (In effective area)	1.25	≈ 1.31	≈ 1.31
ϕ	-	-	-	0.9	0.9
Fabrication Factor					
For Punched Hole, $\boldsymbol{d_h}$	$d_h + 2mm$	d_h	d_h	d_h	$d_h + 2mm$
For Drilled Hole, $\boldsymbol{d_h}$	d_h	d_h	d_h	d_h	$d_h + 2mm$
Gross Section Capacity	$f_y A_g / \gamma_{mo}$	-	$f_y A_g / \gamma_{mo}$	$\phi . f_y A_g$	$\phi . f_y A_g$
				$(\phi . = 0.9)$	$(\phi . = 0.9)$
Net Section Capacity					
	$0.9 A_n f_u / \gamma_{m1}$	$f_y . A_e$	$0.9 A_n f_u / \gamma_{m1}$	$\phi . 0.85 . . f_u A_n$	$\phi . f_u A_e$
					$(\phi . = 0.75)$
Plates with bolted connection	- do -	- do -	- do -	- do -	- do -
Plates with welded connection	- do -	- do -	- do -	- do -	- do -
	$0.9 A_{nc} f_u / \gamma_{m1}$ $+ \beta A_{go} f_y / \gamma_{m0}$		$U A_n f_u / \gamma_{m1}$	$\phi . 0.85 . k_t f_u A_n$	- do -
Single angle – bolted connection	- do -	$f_y (A_e - 0.5 a_2)$	- do -	$k_t = 0.85$	- do -
Double angle – Connected both side of gusset bolted connection	- do -	$f_y (A_e - 0.25 a_2)$	- do -	$k_t = 1.0$	- do -
Double angle – Connected same side of gusset bolted connection	- do -	$f_y (A_e - 0.5 a_2)$	- do -	$k_t = 0.85$	- do -
Single angle – welded connection	- do -	$f_y (A_e - 0.3 a_2)$	- do -	$k_t = 0.85$	- do -
Double angle – Connected both side of gusset welded connection	- do -	$f_y (A_e - 0.15 a_2)$	- do -	$k_t = 1.0$	- do -
Double angle – Connected same side of gusset welded connection	- do -	$f_y (A_e - 0.3 a_2)$	- do -	$k_t = 0.85$	- do -

Table: 2 Tension Members (Contd.)

Parameters	IS 800 (2007)	BS 5950 (2000)	Eurocode (1993)	AS 4100 (1998)	AISC 360 (2005)
Shear Lag Factor U					
U (General)	$\left[\dfrac{0.9A_{nc}\,{}^{f_u}\!/_{\gamma_{ml}} + \beta A_{go}\,{}^{f_y}\!/_{\gamma_{m0}}}{A_n\,{}^{f_u}\!/_{\gamma_{ml}}}\right]$	$\dfrac{f_y\left(A_e - 0.5A_{go}\right)}{A_n f_u}$ where, $A_e = \dfrac{f_u}{1.2 \cdot f_y} A_n < A_g$	-	k_t	$1 = \dfrac{x}{L}$
Angle (n = 1)	0.60	-	$2(e_2 - 0.5d_o)/A_n$	0.85	0.60
Angle (n = 2)	0.60	-	$0.4 + \dfrac{0.3}{2.5d_o}\left(p - 2.5d_o\right)$ < 0.70	0.85	0.60
Angle (n = 3)	0.70	-	$0.5 + \dfrac{0.2}{2.5d_o}\left(p - 2.5d_o\right)$ < 0.70	0.85	0.60
Angle (n = 4 or more)	0.80	-	$0.4 + \dfrac{0.2}{2.5d_o}\left(p - 2.5d_o\right)$ < 0.70	0.85	0.80
Unequal angle connected by shorter leg	-	-	Width of outstanding leg is reduced to width of shorter leg in calculation of $\boldsymbol{A_n}$	0.75	-
Other shapes (n = 2)	0.60	-	-	0.85	-
Other shapes (n = 2)	0.80	-	-	0.85	-
Block Shear Capacity (Case – 1)					
Shear Plane Capacity	$A_{vg} . f_y / \left(\sqrt{3}\gamma_{mo}\right)$	$0.6\ A_{vg} f_y$	-	-	$\phi\ 0.6\ A_{nv}\ F_y$
Tension Plane Capacity	$0.9A_{tn} . f_u / \gamma_{m1}$	$0.6\ K_e\ A_{tn} f_y$	-	-	$\phi\ U_{bs}\ A_{gt}\ F_u$
					U_{bs} = 1 for uniform tensile stress U_{bs} = 0.5 for non uniform tensile stress

Table: 2 Tension Members (Contd.)

Parameters	IS 800 (2007)	BS 5950 (2000)	Eurocode (1993)	AS 4100 (1998)	AISC 360 (2005)
Block Shear Capacity (Case – 2)					
Shear Plane Capacity	$0.9 A_{vn} . f_u / \left(\sqrt{3} \gamma_{m1} \right)$	-	-	-	$\phi\, 0.6\, A_{gv}\, F_y$
Tension Plane Capacity	$A_{tg} . f_y / \gamma_{mo}$	-	-	-	$\phi\, U_{bs}\, A_{nt}\, F_u$

where

n = Number of bolts

d = Diameter of fasteners

d_h = Diameter of fastener hole

x = Connection eccentricity

A_n = Net area

A_e = Effective area

A_{vg} = Gross shear plane area

A_{vn} = Net shear plane area

A_{tg} = Gross tension plane area

A_{tn} = Net tension plane area

a_2 = Area of outstanding leg

f_u = Ultimate tensile stress

f_y = Yield stress

L = Length of connection

Table: 3 Compression Members

Parameters	IS 800 (2007)	BS 5950 (2000)	Eurocode (1993)	AS 4100 (1998)	AISC 360 (2005)
Effective Area of Cross Section					
Plastic Section	$A_e = A_g$	$A_e = A_g$	$A_e = A_g$	$A_e = \Sigma b_{e.}\ t = A_g$	$A_e = A_g$
Compact Section	$A_e = A_g$	$A_e = A_g$	$A_e = A_g$	$A_e = \Sigma b_{e.}\ t = A_g$	$A_e = A_g$
Non-Compact Section	$A_e = A_g$	$A_e = A_g$	$A_e = A_g$	$A_e = \Sigma b_{e.}\ t = A_g$	$A_e = A_g$
Slender Section	$A_e = \Sigma b_{eff} .\ t$	$A_e = \Sigma b_{eff} .\ t$	$A_e = \Sigma b_{eff} .\ t$	$A_e = \Sigma b_{e.}\ t$	$A_e = \Sigma b_{eff} .\ t$
Plastic Capacity of Cross Section					
Plastic Section	$f_{y,} A_g / \gamma_{mo}$	$f_{y,} A_g$	$f_{y,} A_g / \gamma_{mo}$	$\phi\, k_{f.}\, f_y , A_n = \phi f_{y,}\, A_g\ (k_f = 1)$	$\phi_c f_{y,} A_g$
Compact Section	$f_{y,} A_g / \gamma_{mo}$	$f_{y,} A_g$	$f_{y,} A_g / \gamma_{mo}$	$\phi\, k_{f.}\, f_y , A_n = \phi f_{y,}\, A_g\ (k_f = 1)$	$\phi_c f_{y,} A_g$
Non-Compact Section	$f_{y,} A_g / \gamma_{mo}$	$f_{y,} A_g$	$f_{y,} A_g / \gamma_{mo}$	$\phi\, k_{f.}\, f_y , A_n = \phi f_{y,}\, A_g\ (k_f = 1)$	$\phi_c f_{y,} A_g$
Slender Section	$f_{y,} A_e / \gamma_{mo}$	$f_{y,} A_e$	$f_{y,} A_g / \gamma_{m0}$	$\phi\, k_{f.}\, f_y , A_n = \phi\, f_{y,}\, A_e\ (k_f \neq 1)$	$\phi_c f_{y,} A_3$
				$k_f = A_e / A_g\ \&\ A_n = A_g$	$\phi_c = 0.75$

Table: 3 Compression Members [Contd.]

Parameters	**IS 800 (2007)**	**BS 5950 (2000)**	**Eurocode (1993)**	**AS 4100 (1998)**	**AISC 360 (2005)**
Effective Slenderness Ratio λ					
Plastic Section	L_{eff} / r	L_{eff} / r	L_{eff} / r	L_{eff} / r	L_{eff} / r
Compact Section	L_{eff} / r	L_{eff} / r	L_{eff} / r	L_{eff} / r	L_{eff} / r
Non-Compact Section	L_{eff} / r	L_{eff} / r	L_{eff} / r	L_{eff} / r	L_{eff} / r
Slender Section	L_{eff} / r	$L_{eff} / r\ (A_{eff} / A_g)^{0.5}$	L_{eff} / r	L_{eff} / r	L_{eff} / r
Section Capacity considering Member Buckling					
Plastic Section	$\chi . f_{y,} A_g / \gamma_{mo}\ (\chi \leq 1)$	$f'_y . A_g$	$\chi . f_{y,} A_g / \gamma_{mo}\ (\chi \leq 1)$	$\phi\ \alpha_c . f_{y,} A_g\ (\alpha_c \leq 1)$	$\phi_c F_{cr} A_g$
Compact Section	$\chi . f_{y,} A_g / \gamma_{mo}\ (\chi \leq 1)$	$f'_y . A_g$	$\chi . f_{y,} A_g / \gamma_{mo}\ (\chi \leq 1)$	$\phi\ \alpha_c . f_{y,} A_g\ (\alpha_c \leq 1)$	$\phi_c F_{cr} A_g$
Non-Compact Section	$\chi . f_{y,} A_g / \gamma_{mo}\ (\chi \leq 1)$	$f'_y . A_g$	$\chi . f_{y,} A_g / \gamma_{mo}\ (\chi \leq 1)$	$\phi\ \alpha_c . f_{y,} A_g\ (\alpha_c \leq 1)$	$\phi_c F_{cr} A_g$
Slender Section	$\chi . f_{y,} A_e / \gamma_{mo}\ (\chi \leq 1)$	$f'_y . A_e$	$\chi . f_{y,} A_e / \gamma_{mo}\ (\chi \leq 1)$	$\phi\ \alpha_c . f_{y,} A_e\ (\alpha_c \leq 1)$	$\phi_c F_{cr} A_g$
	$\chi = =$ *depends on L/r*	$f'_y =$ *depends on L/r*	$\chi = =$ *depends on L/r*	$\alpha_c =$ *depends on L/r*	$F_{cr} =$ *depends on L/r*
Buckling Curve					
Rolled I – Section (z – z) $t_f \leq 40$	a	a	a	-	-
Rolled I – Section (y– y) $t_f \leq 40$	b	b	b	-	-
Rolled I – Section (z – z) $t_f > 40$	b	b	b	-	-
Rolled I – Section (y– y) $t_f > 40$	c	c	c	-	-
Rolled H – Section (z – z) $t_f \leq 40$	b ($t_f \leq 100$)	b	b ($t_f \leq 100$)	-	-
Rolled H – Section (y– y) $t_f \leq 40$	c ($t_f \leq 100$)	c	c ($t_f \leq 100$)	-	-
Rolled H – Section (z – z) $t_f > 40$	d ($t_f > 100$)	c	d ($t_f > 100$)	-	-
Rolled H – Section (y– y) $t_f > 40$	d ($t_f > 100$)	d	d ($t_f > 100$)	-	-
Welded I – Section (z – z) $t_f \leq 40$	b	b	b	-	-
Welded I – Section (y– y) $t_f \leq 40$	c	c	c	-	-
Welded I – Section (z – z)) $t_f > 40$	c	b	c	-	-
Welded I – Section (y– y) $t_f > 40$	d	d	d	-	-
Welded Box–Section (z – z) $t_f \leq 40$	c	b	c	-	-
Welded Box–Section (y – y) $t_f \leq 40$	c	b	c	-	-
Welded Box–Section (z – z) $t_f > 40$	c	c	c	-	-
Welded Box–Section (y– y) $t_f > 40$	c	c	c	-	-
Hollow Section (Hot Rolled)	a	a	a	-	-

Table: 3 Compression Members [Contd.]

Parameters	IS 800 (2007)	BS 5950 (2000)	Eurocode (1993)	AS 4100 (1998)	AISC 360 (2005)
Buckling Curves (Contd.)					
Hollow Section (Cod Formed)	b	c	b	-	-
Channel, Angles, tees	c	c	c	-	-
Two Rolled Section (Built –up)	c	c	c	-	-
Imperfection Factor (Curve a)	0.21	≈ 0.21	0.21	-	-
Imperfection Factor (Curve b)	0.34	≈ 0.34	0.34	-	-
Imperfection Factor (Curve c)	0.49	≈ 0.49	0.49	-	-
Imperfection Factor (Curve d)	0.76	≈ 0.76	0.76	-	-

Table: 4 Flexure Members (Laterally Supported)

Parameters	IS 800 (2007)	BS 5950 (2000)	Eurocode (1993)	AS 4100 (1998)	AISC 360 (2005)
Bending Resistance under low Shear [V $\leq$ 0.6V$_d$] (Comp. Flange Laterally Restrained)					
Plastic Section	$Z_p f_y / \gamma_{m0}$ $\leq 1.2\ Z_e.f_y / \gamma_{mo}$	$Z_p f_y$	$Z_p f_y / \gamma_{m0}$	$\phi Z_p f_y$ $\leq 1.5\ \phi\ Z_e.f_y$	$M_p = \phi Z_p f_y$
Compact Section	$Z_p f_y / \gamma_{m0}$ $\leq 1.2\ Z_e.f_y / \gamma_{mo}$	$Z_p f_y$	$Z_p f_y / \gamma_{m0}$	$\phi Z_p f_y$ $\leq 1.5\ \phi\ Z_e.f_y$	$M_p = \phi Z_p f_y$
Non-Compact Section	$Z_e f_y / \gamma_{m0}$	$Z_e f_y$	$Z_e f_y / \gamma_{m0}$	$\phi f_y \left[Z_e + \left\{ \left(\frac{\lambda_{sy} - \lambda_s}{\lambda_{sy} - \lambda_{sp}} \right) (Z_c - Z_e) \right\} \right]$	-
Slender Section	-	$Z_{eff.} f_y$	$Z_{eff.} f_y / \gamma_{m0}$	$\phi\ f_y.Z_e\ (\lambda_{sy} - \lambda_s)$	-
	Z_p = *Plastic Section Modulus* Z_e = *Elastic Section Modulus* Z_{eff} = *Effective Section Modulus*			λ_{sp} = *Plastic Limit of slenderness* λ_{sy} = *Yield Limit of slenderness* λ_s = *section slenderness*	
Bending Resistance under high Shear [V > 0.6V$_d$] (Comp. Flange Laterally Restrained)					
Plastic Section	$f_y / \gamma_{m0}.(Z_p - \beta.Z_{pv})$ $\leq 1.2\ Z_e.f_y / \gamma_{mo}$	$f_y.(Z_p - \beta.Z_{pv})$	$f_y / \gamma_{m0}.(Z_p - \beta.Z_{pv})$	-	$M_p = \phi Z_p f_y$

Table: 4 Flexure Members (Laterally Supported) [Contd.]

Parameters	IS 800 (2007)	BS 5950 (2000)	Eurocode (1993)	AS 4100 (1998)	AISC 360 (2005)
Bending Resistance under high Shear [V > 0.6V$_d$] (Comp. Flange Laterally Restrained)					
Compact Section	$f_y / \gamma_{m0} . (Z_p - \beta . Z_{pv})$ $\leq 1.2\ Z_e . f_y / \gamma_{mo}$	$f_y . (Z_p - \beta . Z_{pv})$	$f_y / \gamma_{m0} . (Z_p - \beta . Z_{pv})$	-	$M_p = \phi Z_p f_y$
Non-Compact Section	$Z_e . f_y / \gamma_{mo}$	$f_y . (Z_e - \beta . Z_{pv} / 1.5)$	$f_y / \gamma_{m0} . (Z_e - \beta . Z_{pv})$	-	-
Slender Section	-	$f_y . (Z_{eff} - \beta . Z_{pv} / 1.5)$	$f_y / \gamma_{m0} . (Z_{eff} - \beta . Z_{pv})$	-	-
Z_{pv} (section with equal flanges)	$Z_p - Z_f$	Z_v	Z_v	-	
Z_{pv} (section with unequal flanges)	$Z_p - Z_f$	$Z_p - Z_f$	$Z_p - Z_f$	-	
	Z_f = plastic modulus of effective section excluding shear area Z_v = plastic modulus of the shear area			-	
β	$(2\ V / V_d - 1)^2$	$(2\ V / V_d - 1)^2$	$(2\ V / V_d - 1)^2$	-	

Table: 5 Flexure Members (Laterally Un-supported)

Parameters	IS 800 (2007)	BS 5950 (2000)	Eurocode (1993)	AS 4100 (1998)	AISC 360 (2005)
Buckling Resistance Moment					
Plastic Section	$\chi_{LT} . Z_p . f_y / \gamma_{m0}$	$f_b . Z_p$	$\chi_{LT} . Z_p . f_y / \gamma_{m0}$	$\alpha_m . \alpha_s\ \phi Z_p f_y$ $\leq\ \alpha_m . \alpha_s\ 1.5\ \phi\ Z_e . f_y$	
$L_p < L_b \leq L_r$	–	-	–	–	$\phi C_b \left[M_p - (M_p - 0.7 f_y . Z_e) \left(\frac{L_b - L_p}{L_r - L_p} \right) \right]$
$L_b > L_r$	–	-	–	–	$\phi F_{cr} . Z_e$
Compact Section	$\chi_{LT} . Z_p . f_y / \gamma_{m0}$	$f_b . Z_p$	$\chi_{LT} . Z_p . f_y / \gamma_{m0}$	$\alpha_m . \alpha_s\ \phi Z_p f_y$ $\leq\ \alpha_m . \alpha_s\ 1.5\ \phi\ Z_e . f_y$	
$L_p < L_b \leq L_r$	-	-	-	-	$\phi C_b \left[M_p - (M_p - 0.7 f_y . Z_e) \left(\frac{L_b - L_p}{L_r - L_p} \right) \right]$
$L_b > L_r$	-	-	-	-	$\phi F_{cr} . Z_e$

Table: 5 Flexure Members (Laterally Un-supported) [Contd.]

Parameters	IS 800 (2007)	BS 5950 (2000)	Eurocode (1993)	AS 4100 (1998)	AISC 360 (2005)
Buckling Resistance Moment					
Non-Compact Section	$\chi_{LT}.Z_{e}.f_y / \gamma_{m0}$	$f_b.Z_e$	$\chi_{LT}.Z_{e}.f_y / \gamma_{m0}$	$\alpha_m \alpha_s \phi f_y \left[Z_e + \left\{ \left(\frac{\lambda_{sy} - \lambda_s}{\lambda_{sy} - \lambda_{sp}} \right) (Z_c - Z_e) \right\} \right]$	
$L_p < L_b \leq L_r$	–	-	–	-	$\phi C_b \left[M_p - (M_p - 0.7 f_y.Z_e) \left(\frac{L_b - L_p}{L_r - L_p} \right) \right]$ $\leq \phi \left[M_p - (M_p - 0.7 f_y.Z_e) \left(\frac{\lambda - \lambda_{pf}}{\lambda_{rf} - \lambda_{pf}} \right) \right]$
$L_b > L_r$	–	-	–	-	$\phi F_{cr}.Z_e \leq 0.9 E k_c Z_e / \lambda^2$
Slender Section	-	$f_b.Z_{eff}$	$\chi_{LT}.Z_{eff}.f_y / \gamma_{m0}$	$\alpha_m.\alpha_s \phi f_y.Z_e (\lambda_{sy} - \lambda_s)$	
$L_p < L_b \leq L_r$	-	-	–	–	Same as Non-Compact
$L_b > L_r$	-	-	–	–	- do -
	χ_{LT} & f_b = *Depends on Equivalent Slenderness*			α_m= *Moment mod. factor* α_s =*Slenderness red.. factor*	

Table: 5 Flexure Members [Contd.]

Parameters	**IS 800 (2007)**		**BS 5950 (2000)**		**Eurocode (1993)**	**AS 4100 (1998)**	**AISC 360 (2005)**
Equivalent Slenderness Ratio	$\lambda_{LT} = \sqrt{\beta_b Z_p f_y / M_{cr}}$		$\lambda_{LT} = u \upsilon \lambda \sqrt{\beta_W}$		$\lambda_{LT} = \sqrt{\beta_b Z_p f_y / M_{cr}}$	-	–
Imperfection Factor (Rolled Section	0.21		≈ 0.21		0.21	-	–
Imperfection Factor (Welded Section	0.49		≈ 0.49		0.49	-	–
Effective Length Contd.)	**Normal**	**Destabilizing**	**Normal**	**Destabilizing**			
Warping Restraint	0.70 L	0.85 L	0.70 L	0.85 L	–	–	–
Both flanges fully restrained	0.75 L	0.90 L	0.75 L	0.90 L	–	–	–
Compression flange fully restrained	0.80 L	0.95 L	0.80 L	0.95 L	–	–	–
Both flanges partially restrained	0.85 L	1.00 L	0.85 L	1.00 L	–	–	–
Compression flange partially restrained	1.00 L	1.20 L	1.00 L	1.20 L	–	–	–
Warping not restrained in both flanges	0.70 L	0.85 L	0.70 L	0.85 L	–	–	–
	Compression flange Laterally restrained against Torsion						
Partially restrained by bottom flange support connection	1.0 L + 2D	1.2 L + 2D	1.0 L + 2D	1.2 L + 2D	-	-	–
Partially restrained by bottom flange bearing support	1.2 L + 2D	1.4 L + 2D	1.2 L + 2D	1.4 L + 2D	-	-	–
	Warping not restrained in both flanges						

Table: 5 Flexure Members [Contd.]

Table: 5 Flexure Members [Contd.]

Parameters	**IS 800 (2007)**	**BS 5950 (2000)**	**Eurocode (1993)**	**AS 4100 (1998)**	**AISC 360 (2005)**
Permissible Shear					–
V_d	$A_v.f_y/(\sqrt{3}.\gamma_{mo})$	$0.6 f_y. A_v$	$A_v.f_y/(\sqrt{3}.\gamma_{mo})$		$0.6\ \phi\ f_y.A_w C_v$
$d_w / t_w \leq 82 / (f_y / 250)^{0.5}$				$\phi\ 0.6 f_y.A_v$	–
$d_w / t_w > 82 / (f_y / 250)^{0.5}$				$\alpha_v.\phi\ 0.6 f_y.A_v$	
					$\phi = 0.9 – 1.0$ $C_v = Parameter \leq 1.0$
Shear Area of Sections					–
Hot Rolled I & H section (Major axis Bending)	$h\ t_w$	$h\ t_w$	$A\text{-}2b\ t_f+(t_w+2r)t_f$	$h\ t_w$	$h\ t_w$
Rolled Channel section (Major axis Bending)	$h\ t_w$	$h\ t_w$	$A\text{-}2b\ t_f+(t_w+ r)t_f$	$h\ t_w$	$h\ t_w$
Welded I, H & Box section (Major axis Bending)	$\Sigma (d\ t_w)$	$\Sigma (d\ t_w)$	$\Sigma (d\ t_w)$	$\Sigma (d\ t_w)$	$\Sigma (d\ t_w)$
Rolled & Welded I, H & Box Section (Minor Axis Bending)	$2\ b\ t_f$	$1.8\ b\ t_f$	$A - \Sigma (d\ t_w)$	$2\ b\ t_f$	$2\ b\ t_f$
RHS loaded parallel to depth (h)	$A\ h / (b + h)$	$0.9\ A\ h / (b + h)$	$A\ h / (b + h)$	$A\ h / (b + h)$	–
RHS loaded parallel to width (b)	$A\ b / (b + h)$	$0.9\ A\ b / (b + h)$	$A\ b / (b + h)$	$A\ b / (b + h)$	
CHS	$2\ A / \pi$	$0.6\ A$	$2\ A / \pi$	$0.6\ A$	–
Plates and solid bars	A	$0.9\ A$	A	A	–

3. CONCLUSION:

IS 800-2007 (LSM) as prepared (BIS – 2006) is mostly based on international standards as is evident from the comparative charts shown above, with load factors and partial safety factors suiting Indian conditions. The code has been mainly modeled in line with the Eurocodes, with some additional references taken from the existing British Codes also. Another important aspect of this IS code is that this code does not totally do away with the existing Allowable Stress Design (ASD) method of analysis. As a matter of fact, one chapter in this code has been totally dedicated to design concepts based on the ASD method, with certain modification from the existing Indian Standard (IS) Code. Though in American code, both ASD and LRFD method of design is equally prescribed, in the case of the IS 800 (LSM), the ASD method with minor modification has been included to help in making a smooth and proper transition of design practice in India from ASD philosophy to LSM philosophy.

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5. ACKNOWLEDGEMENT

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