Design A School Building Using IS800:2007 & International Standards for Similar Loading Parameters

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Abstract— Technological improvement over the year has contributed immensely to the enhancement of quality of life through various new products and services. One such revolution was the pre-engineered buildings (PEB). Pre-engineered buildings can be adopted to suit a wide variety of structural applications; the greatest economy will be realized when utilizing standard details in structural framework. In this report, comparison is made between IS800:2007 & International standards. The entire range of pre-engineered building is studied while doing this comparison. A school building is designed using IS800:2007 & International standards by keeping the loading parameters similar, all the loads are applied accordance with Indian codes. An attempt is made to study the variation in tonnage as per IS800:2007 & International standards & possible reasons for variation in respective results. Analysis and design of these building frames was carried out using Staad-Pro software & manually also. 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. Considering that the current practice all over the world is based on Limit State Method (LSM) or Load and Resistance Factor Design Method (LRFD), 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 IS800:2007 was thus prepared and published by the Bureau of Indian Standards (BIS) in 2008. As per market study it observed that more than 70% pre-engineered buildings are designed according to American codes. As per the design result obtained during this dissertation work it is noted that the weight of structure is reduced by 23.97% as compared to IS800:2007. Even though most of the pre-engineered buildings are designed accordance to American code it is noted that by using Euro-03 weight of structure is reduced by 27.2% and by using BS5950-2000 weight of structure is reduced by 9.04% respectively as per obtained design results as compared to IS800:2007.

Keywords: PEB, Analysis, Design, LSM, LRFD, AISC-10, IS 800:2007, Euro-03, BS5950

I. Introduction

Technological improvement over the year has contributed immensely to the enhancement of quality of life through various new products and services. One such revolution was the pre- engineered buildings (PEB). Though its origin can be traced back to 1960‟s, its potential has been felt only during the recent years.

With increased emphasis on the on-going green buildings ensuring sustainable construction, the PEB structures are created with a high proportion of recycled content making them lighter by about 30% to 40 % than the conventional steel buildings. They contain higher degree of fire and dust resistant and are maintenance free. As a result today the PEB system is the most preferred choice among the architects, builders, developers and industrialists. The experts in the field are unanimous in their view that the PEB industry in India is currently heading to achieve growth trajectory of about 35% per annum.

A. Concept

Pre-engineered buildings (PEBs) use a predetermined inventory of raw materials that has proven over time to satisfy a wide range of structural and aesthetic design requirements. This flexibility allows PEBs to fulfill an almost unlimited range of building configurations, custom designs, requirements and applications. The pre-engineered steel building is a building shell utilizing three distinct product categories as:

- Built-up “I” shaped primary structural framing members (columns and rafters)
- Cold-formed “Z” and “C” shaped secondary structural members (roof purlin, eave struts and wall grits)
- Roll formed profiled sheeting (roof and wall panels)

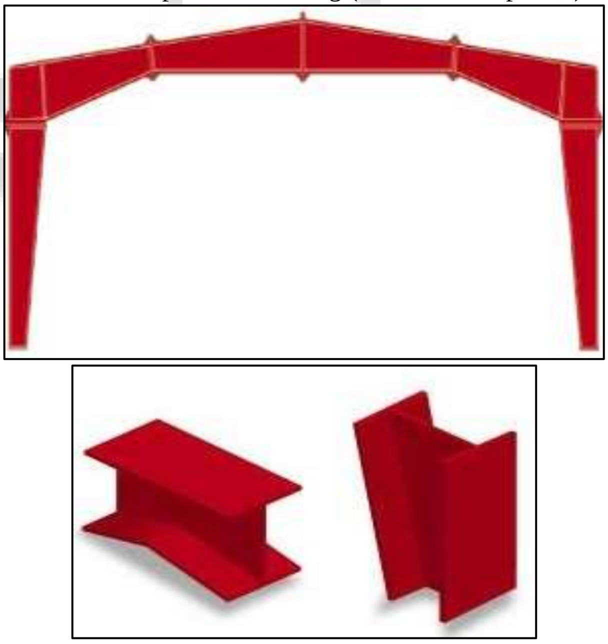


Fig. 1: Built-Up “I” Shaped Primary Structural Framing Members.

Fig. 2: Cold-Formed “Z” And “C”

Fig. 3: Roll Formed Profiled Shaped

B. Need for Pre-Engineered Building

Pre-engineered buildings can be adopted to suit a wide variety of structural applications. The greatest economy will be realized when we will utilize light weight standard details in PEB. An efficiently designed pre-engineered building can be lighter than the conventional steel buildings by up to 30% to 40%. Lighter weight equates to less steel and a potential price savings in structural framework.

Pre-engineered steel buildings are very versatile buildings systems and can be finished internally to serve any functions and accessorized externally to achieve attractive and unique designing styles. It is very advantageous over the conventional buildings and is really helpful in the low-rise building design. Pre-engineered buildings are generally low-rise buildings however the maximum eave height can go up to 25 to 30 meters. Low rise buildings are ideal for offices, houses, showrooms, shop fronts etc. PEB can be constructed in less than half the normal time especially when complemented with the other engineered sub-systems.

C. Comparison between Pre-Engineered Building System and Conventional Building System

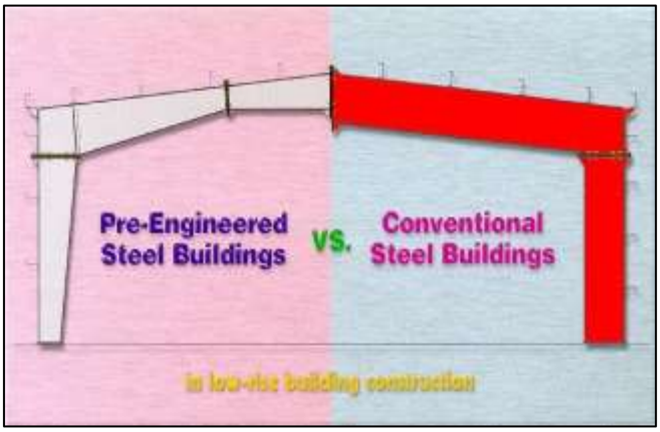


Fig. 4: Comparison of PEB & CSB

Building Type Point	Pre-Engineered Building System (PEBs)	Conventional Building System
1.StructureWeight	Primary framing members are tapered (varying depth), So Pre- Engineered buildings are about 30 to 40 % advantages for the main rigid frame when compare to the use of conventional hot rolled section as primary member.	Primary steel members are selected from standard hot rolled "I" sections, which are in many segments of the members. They are heavier than what is actually required by design. Members have constant cross-sections regardless of varying magnitude of the local stresses along the member length.
2. Delivery	Average 6 to 8 weeks.	Average 20 to 26 weeks.
3. Foundations	Simple design, easy to construct and light weight.	Extensive, heavy foundation required.
4. Seismic Resistance	The low-weight flexible frames offer higher resistance to seismic forces.	Rigid heavy weight structures do not perform well in seismic zones.
5. Erection Simplicity	Since the connections of the components are standard, the learning curve of erection for each subsequent project is faster.	The connections are normally complicated and differ from project to project, resulting in longer learning curves of erection for new projects.
6.Erection Cost and Time	Both costs & time of erection are accurately known based upon extensive experience with similar building	Typically, they are 20% more expensive than PEB. In most of the cases, the erection costs and time are not estimated accurately.
7.Overall Price	Price per square meter may be as much as 30% lower than conventional steel.	Rigid heavy weight structures do not perform well in seismic zones.
8.Architecture	Outstanding architectural design can be achieved at low cost using standard architectural features and interface details. Traditional wall and fascia materials, such as concrete,masonry and wood, can be utilized.	Special architectural design and features must be developed for each project, which often require research and thus resulting in much higher costs.
9.Sourcing and Co-ordination	Building is supplied complete with cladding and all accessories, including erection (if desired) from one single source.	Many sources of supply is required to co-ordinate suppliers and sub- contractors.
10.Cost of Change Orders	PEB manufacturers often stock a large amount of basic raw materials that can be flexibly used in many types of PEB projects.	Substitution of hot rolled sections that are in frequently rolled by mills, It is expensive and time consuming.

11.Building Accessories	Designed to fit the system, with standardized, interchange able parts, including pre-designed flashing and trims. They are mass produced for economy and are available with the building. They have been tried in thousands of existing buildings.	Every project requires special design for accessories and special sourcing for each item. Flashing and trims must be uniquely designed and fabricated.	

Table 1: Comparison of Pre-Engineered Building System & Conventional Building System

II. Problem Statement and Methodology

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 RCC. 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 get 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 2020is highly encouraging. In order to match with this expectation, the other related parameters need to be in line too. Modernizing 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 meantime, 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 3.1, shows design format of steel structures adopted in some of the countries.

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

Table 2: Countries and their Design Format

A. *Methodology of work*

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 Centers in the country. Considering that the current practice all over the world is based on Limit State Method (LSM) or Load and Resistance Factor Design Method (LRFD), 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 IS800:2007 was thus prepared and published by the Bureau of Indian Standards (BIS) in 2008.

In recent years, the introduction of Pre-Engineered Building (PEB) concept in the design of structures has helped in optimizing design. The adoptability of PEB in the place of Conventional Steel Building (CSB) design concept resulted in many advantages, including economy and easier fabrication & faster construction. In this project work, an industrial structure (Pre-engineered Building) with loading as per Indian Standard codes will be analyzed and will be designed according to the various standards, i.e., IS 800-2007 (LSM), IS 800-2007 (ASD), AISC-10 LRFD, BS 5950:2000 and Eurocode-3 & design results will be compared in terms of steel consumption. Here an attempt will be made to highlight the essential contents of IS: 800- 2007 while following Limit State Method, the corresponding stipulations as adopted by other international codes.

The project work will be carried out as,

1) Design of G+3 PEB structure for school building using IS800:2007 & International standards
2) Comparing codal provision.
3) Comparing design results of IS800:2007 with international standards.
4) Comparing % variation in tonnage of structure

III. Theorotical Content

Dead load (DL) is defined as the total weight of the building and its components. This includes main frames, purlins, girts, cladding, bracing, connections, etc.

Following are some standard dead loads (in kN/m^2) Purlin + Panel (0.5mm) = 0.10

Purlin + Panel (0.5mm) + Liner (0.5mm) = 0.15 Purlin + Mark Series Roof = 0.15

Purlin + Tempcon Panel = 0.15

Live load (LL)includes all loads that the structure is subjected to during erection, maintenance and usage throughout the life time of the structure. The live load is specified by the applicable building code for which the structure is designed. The roof live load depends on the tributary area of rigid frames. However, "IS: 875 (Part 2) – 1987" allows the use of 0.75kN/m^2.

Wind load (WL) the application of wind load to a structure varies from one code of practice to another. For wind load design, we use the "IS: 875 (Part3) –1987".

A. *Load Combination*

The following two load combinations are always considered for any building as per (IS; 800-1984).

1) DL + LL
2) DL + WL
3) DL + EL

B. *Planning of PEB*

Planning of the PEB buildings and arranging different building components is a very important step for the designer before proceeding with the design of each component.

The following building configurations are significantly affecting the building stability -

1) Main frame configuration (orientation, type, roof slope, eave height).
2) Roof purlins spacing.
3) Wall girts (connection & spacing).
4) End wall system.
5) Expansion joints.
6) Bay spacing.
7) Bracing systems arrangement.
8) Mezzanine floor beams/columns (orientation & spacing).

C. *Design Constraints*

1) *Built up section*

Geometrical limitation was established to achieve the following targets

1) Ease shop fabrication
2) Limit the reduction of allowable stresses due to high (width / thickness) ratios resulting in non-economical designs.
3) To ensure sound designs and optimize material cutting and minimize material waste. In pre-engineered building system the following limitations have to be checked

   $h_w/t_w \leq 180$

   $t_f/t_w \leq 2.5$ $h_w/w_f \leq 5$.

   Where h_w = Web depth of section. t_w = Web thickness.

   t_f = Thickness of flange. $w_{f=}$ Width of flange.

IV. STRUCTURE & CONFIGURATION

A. *General*

Selected structure is located in Madhya Pradesh, India. Structure having the dimensions length 35m, width 15.2m, eave height 15m, & with flat roof. Structure located in seismic zone II with wind speed 39 m/sec considered life span of structure as 50 years. Complete structure configuration details can be found in Table 5.1 as follows

Location	Bhopal, Madhya Pradesh
Length	35m
width	15.2m
Eave Height	14m
Seismic Zone	III
Wind Speed	39 m/s
Wind Terrain Category	2
Wind Class	C
Life Span	50 Years
Slope of Roof	Flat Roof
Soil Type	Medium
Importance Factor	1.5
Response Reduction Factor	5

Table 3: Description of Building

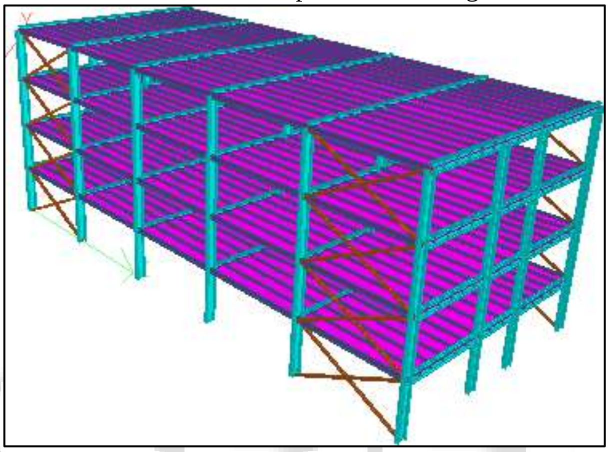


Fig.5 Structure Configuration

B. *Design Assumptions*

The following assumptions are considered for pre-engineered building system design.

– All the column bases are pinned at base.
– The longitudinal stability of the building is provided through the cross braced bays of the building in the roof and side walls.
– The main frame rafters and exterior columns are rigidly connected to each other (using moment type connections).

C. *Applicable Standard Codes*

The building described in the Table is designed according to the IS800:2007 & International standards that have been referred to in the design:

– The loads have been applied on the structure in accordance with:IS-875- PART- I to III - 1987 – Code of Practice for Design Loads for Building and Structures.
– The seismic loads are applied accordance with IS1893-2002 - Indian Standard criteria for Earthquake Resistance design of Structures.
– Hot rolled sections and built-up components have been designed in accordance with: IS800:2007 General construction in steel – Code of practice.
– Hot rolled sections and built-up components have been designed in accordance with: The ninth edition (2010) of the Manual of Steel Construction, Inc. (AISC) 1 East

Wacker Drive, Suite 3100, Chicago, Illinois 60601-2001, USA.

- Hot rolled sections and built-up components have been designed in accordance with: BS5950-1:2000 code of practice for design Rolled and welded sections.
- Hot rolled sections and built-up components have been designed in accordance with: Euro-03 Basis of structural design.

D. Load Combinations

Load combinations include different combinations of loads according to different codes (AISC-10, BS-5950, IS800:2007 & EURO-03) by considering serviceability and strength criteria as follows in Table.

AISC-10	BS-5950	IS 800:2007	EURO-03
Limit State of Serviceability	Limit State of Serviceability	Limit State of Serviceability	Limit State of Serviceability
(DL+LL)	(DL+LL)	(DL+LL)	(DL+LL)
(DL+0.75*WL/EL)	(DL+WL/EL)	(DL+WL/EL)	(DL+WL/EL)
(DL+ WL/EL)	(DL+LL+WL/EL)	(DL+0.8*LL+0.8*WL/EL)	
(0.6*DL+ WL/EL)	(DL+LL+WL/EL)		
Limit State of Strength	Limit State of Strength	Limit State of Strength	Limit State of Strength
(1.2*DL+1.6*LL)	(1.4*DL+1.6*LL)	1.5*(DL+LL)	(1.35DL+1.50LL)
(1.2*DL+0.5*LL+1.6*WL/EL)	(1.0*DL+1.4*WL/EL)	1.5*(DL+WL/EL)	(1.35DL+1.50WL/EL)
(0.9*DL+1.6*WL/EL)	(1.0*DL+1.2*WL/EL)	(0.9*DL+1.5 WL/EL)	
(1.2*DL+1.2*LL+0.6*EL)		(1.2*DL+1.2*LL+0.6*WL/EL)	
(1.2*DL+1.2*LL+1.2*EL)		(1.2*DL+1.2*LL+1.2 *WL/EL)	
(0.9*DL+1.5*EL)		(1.2DL+0.5LL+2.5EL)	
		(0.9DL+2.5EL)	

Table 4: Load Combinations (ref 16-17)

1) *Abbreviations:*

DL= Dead Load LL= Live Load
WL= Wind Load EL= Earthquake Load

E. Deflections Limits

Sr No	Description	AISC-10		BS-5950		IS800:2007		EURO-03	
		Vertical	Lateral	Vertical	Lateral	Vertical	Lateral	Vertical	Lateral
1	Main Frame	L/180	H/60	L/200	H/100	L/180	H/150	L/250	H/100
2	Mezzanine	L/240	-	L/360	-	L/300	-	L/300	-

Table 5: Limiting Deflections

F. Design Specifications

Design specifications include limiting ratios of cross sections and deflection limits according to different codes. Deflection limitations are already discussed in Table shows the classification of sections as per various codes.

Compression		Ratio	Class of section		
			Class 1 (Plastic)	Class 2 (Compact)	Class 3 (Semi-Compact)
Outstanding element of compression flange	Rolled section	b/t_f	9.4ε	10.5ε	15.7ε
	Welded section	b/t_f	8.4ε	9.4ε	13.6ε
Internal element of compression flange	Compression due to bending	b/t_f	29.3ε	33.5ε	42ε
	Axial compression	b/t_f	Not applicable		
Web of an I,H or box section	Neutral axis at mid-depth	d/t_w	84ε	105ε	126ε
	Generally If r_1 is negative	d/t_w	(84ε)/(1+r_1) but ≤ 42ε	(105ε)/(1+r_1)	(126ε)/(1+2r_2) but ≤ 42ε
	If r_1 is positive	d/t_w		(105ε)/(1+1.5r_1) but ≤ 42ε	
	Axial compression	d/t_w	Not applicable		42ε
Web of a channel		d/t_w	42ε	42ε	42ε
Angle, compression due to bending (Both criteria should be satisfied)		b/t	9.4ε	10.5ε	15.7ε
		d/t	9.4ε	10.5ε	15.7ε
Single angle, or double angles with the components separated, axial compression (All three criteria should be satisfied)		b/t	Not applicable		15.7ε
		d/t			15.7ε
Outstanding leg of an angle in contact back-to-back in a double angle member			9.4ε		25ε
d/t outstanding leg of an angle with its back in continuous contact with another component		d/t	9.4ε	10.5ε	15.7ε
Stem of a T-section, rolled or cut from a rolled I-or H- section		D/t_f	8.4ε	9.4ε	18.9ε
Circular hollow tube, including welded tube subjected to: a) Moment		D/t	42ε[2]	52ε[2]	146ε[2]
b) Axial compression		D/t	Not applicable		88ε[2]

NOTES
1. Elements which exceed semi-compact limits are to be taken as of slender cross-section.
2. ε = (250 /f_y)$^{1/2}$.
3. The stress ratio r_1 and r_2 are defined as: r_1 = (Actual average axial stress(negative if tensile)/(Design compressive stress of web alone) r_2 = (Actual average axial stress(negative if tensile)/(Design compressive stress of overall section)

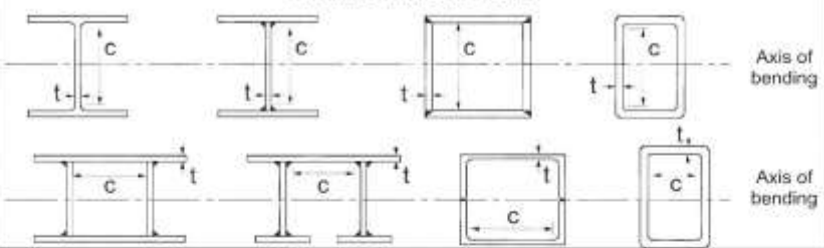
Table 6: Limiting width to thickness ratio according to IS 800-2007-Table2

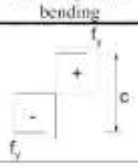
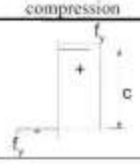
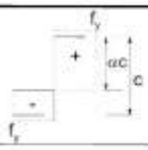
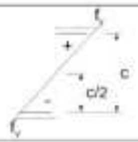
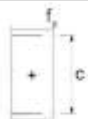
Compression element			Ratio[a]	Limiting value[b]		
				Class 1 plastic	Class 2 compact	Class 3 semi-compact
Outstand element of compression flange		Rolled section	b/T	9ε	10ε	15ε
		Welded section	b/T	8ε	9ε	13ε
Internal element of compression flange		Compression due to bending	b/T	28ε	32ε	40ε
		Axial compression	b/T	Not applicable		
Web of an I-, H- or box section[c]	Neutral axis at mid-depth		d/t	80ε	100ε	120ε
	Generally[d]	If r_1 is negative:	d/t	$\frac{80\varepsilon}{1+r_1}$ but $\geq 40\varepsilon$	$\frac{100\varepsilon}{1+r_1}$	$\frac{120\varepsilon}{1+2r_2}$ but $\geq 40\varepsilon$
		If r_1 is positive:	d/t		$\frac{100\varepsilon}{1+1.5r_1}$ but $\geq 40\varepsilon$	
	Axial compression[d]		d/t	Not applicable		
Web of a channel			d/t	40ε	40ε	40ε
Angle, compression due to bending (Both criteria should be satisfied)			b/t	9ε	10ε	15ε
			d/t	9ε	10ε	15ε
Single angle, or double angles with the components separated, axial compression (All three criteria should be satisfied)			b/t	Not applicable		15ε
			d/t			15ε
			$(b+d)/t$			24ε
Outstand leg of an angle in contact back-to-back in a double angle member			b/t	9ε	10ε	15ε
Outstand leg of an angle with its back in continuous contact with another component						
Stem of a T-section, rolled or cut from a rolled I- or H-section			D/t	8ε	9ε	18ε

[a] Dimensions b, D, d, T and t are defined in Figure 5. For a box section b and T are flange dimensions and d and t are web dimensions, where the distinction between webs and flanges depends upon whether the box section is bent about its major axis or its minor axis, see 3.5.1.
[b] The parameter $\varepsilon = (275/p_y)^{0.5}$.
[c] For the web of a hybrid section ε should be based on the design strength p_{yf} of the flanges.
[d] The stress ratios r_1 and r_2 are defined in 3.5.5.

Table 7: Limiting width to thickness ratio according to BS5950 -Table11

Internal compression parts



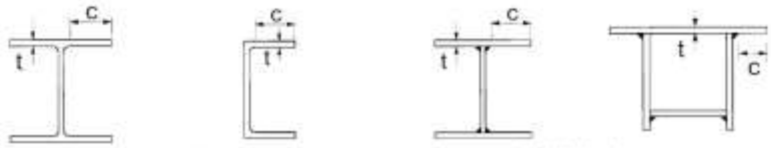
Class	Part subject to bending	Part subject to compression	Part subject to bending and compression
Stress distribution in parts (compression positive)			
1	$c/t \leq 72\varepsilon$	$c/t \leq 33\varepsilon$	when $\alpha > 0{,}5$: $c/t \leq \frac{396\varepsilon}{13\alpha - 1}$ when $\alpha \leq 0{,}5$: $c/t \leq \frac{36\varepsilon}{\alpha}$
2	$c/t \leq 83\varepsilon$	$c/t \leq 38\varepsilon$	when $\alpha > 0{,}5$: $c/t \leq \frac{456\varepsilon}{13\alpha - 1}$ when $\alpha \leq 0{,}5$: $c/t \leq \frac{41{,}5\varepsilon}{\alpha}$
Stress distribution in parts (compression positive)			
3	$c/t \leq 124\varepsilon$	$c/t \leq 42\varepsilon$	when $\psi > -1$: $c/t \leq \frac{42\varepsilon}{0{,}67 + 0{,}33\psi}$ when $\psi \leq -1$*): $c/t \leq 62\varepsilon(1-\psi)\sqrt{(-\psi)}$

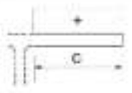
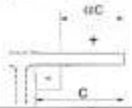
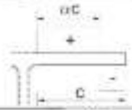
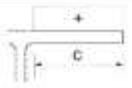
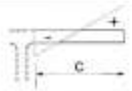
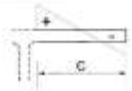
$\varepsilon = \sqrt{235/f_y}$						
	f_y	235	275	355	420	460
	ε	1,00	0,92	0,81	0,75	0,71

*) $\psi \leq -1$ applies where either the compression stress $\sigma \leq f_y$ or the tensile strain $\varepsilon_y > f_y/E$

Table 8: Limiting width to thickness ratio according to EURO-03-Table5.2 (ref 19)

Outstand flanges



Class	Part subject to compression	Part subject to bending and compression: Tip in compression	Part subject to bending and compression: Tip in tension
Stress distribution in parts (compression positive)			
1	$c/t \le 9\varepsilon$	$c/t \le \frac{9\varepsilon}{\alpha}$	$c/t \le \frac{9\varepsilon}{\alpha\sqrt{\alpha}}$
2	$c/t \le 10\varepsilon$	$c/t \le \frac{10\varepsilon}{\alpha}$	$c/t \le \frac{10\varepsilon}{\alpha\sqrt{\alpha}}$
Stress distribution in parts (compression positive)			
3	$c/t \le 14\varepsilon$	$c/t \le 21\varepsilon\sqrt{k_\sigma}$ For k_σ see EN 1993-1-5	

$\varepsilon = \sqrt{235/f_y}$	f_y	235	275	355	420	460
	ε	1,00	0,92	0,81	0,75	0,71

Table 9: Limiting width to thickness ratio according to AISC-341-TableI-8-1 (ref 20)

	Description of Element	Width-Thickness Ratio	Limiting Width-Thickness Ratios λ_{ps} (seismically compact)
Unstiffened Elements	Flexure in flanges of rolled or built-up I-shaped sections [a], [c], [e], [g], [h]	b/t	$0.30\sqrt{E/F_y}$
	Uniform compression in flanges of rolled or built-up I-shaped sections [b], [h]	b/t	$0.30\sqrt{E/F_y}$
	Uniform compression in flanges of rolled or built-up I-shaped sections [d]	b/t	$0.38\sqrt{E/F_y}$
	Uniform compression in flanges of channels, outstanding legs of pairs of angles in continuous contact, and braces [c], [g]	b/t	$0.30\sqrt{E/F_y}$
	Uniform compression in flanges of H-pile sections	b/t	$0.45\sqrt{E/F_y}$
	Flat bars [f]	b/t	2.5
	Uniform compression in legs of single angles, legs of double angle members with separators, or flanges of tees [g]	b/t	$0.30\sqrt{E/F_y}$
	Uniform compression in stems of tees [g]	d/t	$0.30\sqrt{E/F_y}$

Note: See continued Table I-8-1 for stiffened elements.

	Description of Element	Width-Thickness Ratio	Limiting Width-Thickness Ratios λ_{ps} (seismically compact)
Stiffened Elements	Webs in flexural compression in beams in SMF, Section 9, unless noted otherwise	h/t_w	$2.45\sqrt{E/F_y}$
	Webs in flexural compression or combined flexure and axial compression [a], [c], [g], [h], [i], [j]	h/t_w	for $C_a \le 0.125$ [k] $3.14\sqrt{\frac{E}{F_y}}(1-1.54C_a)$ for $C_a > 0.125$ [k] $1.12\sqrt{\frac{E}{F_y}}(2.33-C_a) \ge 1.49\sqrt{\frac{E}{F_y}}$
	Round HSS in axial and/or flexural compression [c], [g]	D/t	$0.044\,E/F_y$
	Rectangular HSS in axial and/or flexural compression [c], [g]	b/t or h/t_w	$0.64\sqrt{E/F_y}$
	Webs of H-Pile sections	h/t_w	$0.94\sqrt{E/F_y}$

[a] Required for beams in SMF, Section 9 and SPSW, Section 17.
[b] Required for columns in SMF, Section 9, unless the ratios from Equation 9-3 are greater than 2.0 where it is permitted to use λ_p in Specification Table B4.1.
[c] Required for braces and columns in SCBF, Section 13 and braces in OCBF, Section 14.
[d] It is permitted to use λ_p in Specification Table B4.1 for columns in STMF, Section 12 and columns in EBF, Section 15.
[e] Required for link in EBF, Section 15, except it is permitted to use λ_p in Table B4.1 of the *Specification* for flanges of links of length $1.6M_p/V_p$ or less, where M_p and V_p are defined in Section 15.
[f] Diagonal web members within the special segment of STMF, Section 12.
[g] Chord members of STMF, Section 12.
[h] Required for beams and columns in BRBF, Section 16.
[i] Required for columns in SPSW, Section 17.
[j] For columns in STMF, Section 12; columns in SMF, if the ratios from Equation 9-3 are greater than 2.0; columns in EBF, Section 15; or EBF webs of links of length $1.6\,M_p/V_p$ or less, it is permitted to use the following for λ_p:

for $C_a \le 0.125$, $\lambda_p = 3.76\sqrt{\frac{E}{F_y}}(1-275C_a)$

for $C_a > 0.125$, $\lambda_p = 1.12\sqrt{\frac{E}{F_y}}(2.33-C_a) \ge 1.49\sqrt{\frac{E}{F_y}}$

[k] For LFRD, $C_a = \frac{P_u}{\phi_b P_y}$

For ASD, $C_a = \frac{\Omega_b P_a}{P_y}$

where
P_a = required compressive strength (ASD), kips (N)
P_u = *required compressive strength* (LRFD), kips (N)
P_y = axial yield strength, kips (N)
ϕ_b = 0.90
Ω_b = 1.67

V. RESULTS & CONCLUSION

A. *General*

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.

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

Parameters	IS 800:2007	BS5950:2000	AISC-2010	EURO-03
Partial Safety Factor				
γ_{mo}	1.1	1.0	1.11	1.1
γ_{m1}	1.25	1.2	1.31	1.25
Φ	-	-	0.9	-
Gross Section Capacity	f_yA_g / γ_{mo}	-	$\Phi.f_yA_g$	f_yA_g / γ_{mo}
Net Section Capacity	$0.9\,A_nf_u / \gamma_{m1}$	f_yA_e	$\Phi.f_uA_e$	$0.9\,A_nf_u / \gamma_{m1}$

Table 10: Tension member

Parameters	IS 800:2007	BS5950:2000	AISC-2010	EURO-03
Effective area of cross section				
Plastic section	$A_e = A_g$	$A_e = A_g$	$A_e = A_g$	$A_e = A_g$
Compact section	$A_e = A_g$	$A_e = A_g$	$A_e = A_g$	$A_e = A_g$

Non-compact section	$A_e = A_g$	$A_e = A_g$	$A_e = A_g$	$A_e = A_g$
Slender section	$A_e = \sum b_{eff}.t$	$A_e = \sum b_{eff}.t$	$A_e = \sum b_{eff}.t$	$A_e = \sum b_{eff}.t$
Plastic capacity of cross section				
Plastic section	f_yA_g/γ_{mo}	f_yA_g	$\Phi_c f_y A_g$	$f_yA_g/\gamma mo$
Compact section	f_yA_g/γ_{mo}	f_yA_g	$\Phi_c f_y A_g$	$f_yA_g/\gamma mo$
Non-compact section	f_yA_g/γ_{mo}	f_yA_g	$\Phi_c f_y A_g$	$f_yA_g/\gamma mo$
Slender section	f_yA_g/γ_{mo}	f_yA_g	$\Phi_c f_y A_3$	$f_yA_g/\gamma mo$
			$\Phi_c = 0.75$	
Effective slenderness ratio				
Plastic section	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
Non-compact section	L_{eff}/r	L_{eff}/r	L_{eff}/r	L_{eff}/r
Slender section	L_{eff}/r	L_{eff}/r	L_{eff}/r	L_{eff}/r

Section capacity based on member buckling				
Plastic section	$xf_yA_g/\gamma mo$ $(x \le 1)$	f''_yA_g	Φ $FcrA_g$	$xf_yA_g/\gamma mo$ $(x \le 1)$
Compact section	$xf_yA_g/\gamma mo$ $(x \le 1)$	f''_yA_g	Φ $FcrA_g$	$xf_yA_g/\gamma mo$ $(x \le 1)$
Non-compact section	$xf_yA_g/\gamma mo$ $(x \le 1)$	f''_yA_g	Φ $FcrA_g$	$xf_yA_g/\gamma mo$ $(x \le 1)$
Slender section	$xf_yA_g/\gamma mo$ $(x \le 1)$	f''_yA_g	Φ $FcrA_g$	$xf_yA_g/\gamma mo$ $(x \le 1)$
	x= depends on L/r	f''_y= depends on L/r	Fcr= depends on L/r	x= depends on L/r
Buckling curve				
Welded I section (z-z) tf≤40	b	b	-	b
Welded I section (y-y) tf≤40	c	c	-	c
Welded I section (z-z) tf>40	c	b	-	c
Welded I section (y-y) tf>40	d	d	-	d

Table 11: Compression member

Bending Resistance under low Shear [$V \le 0.6Vd$] (Comp. Flange Laterally Restrained)	IS 800:2007		BS5950:2000	AISC-2010	EURO-03
Plastic section	$Z_pf_y/\gamma_{mo} \le Z_ef_y/\gamma_{mo}$	1.2	Z_pf_y	$M_p = \Phi Z_pf_y$	Z_pf_y/γ_{mo}
Compact section	$Z_pf_y/\gamma_{mo} \le Z_ef_y/\gamma_{mo}$	1.2	Z_pf_y	$M_p = \Phi Z_pf_y$	Z_pf_y/γ_{mo}
Non-compact section	Z_ef_y/γ_{mo}		Z_ef_y	-	Z_pf_y/γ_{mo}
Slender section	-		$Zeff.\ fy$	-	$Zeff.\ fy/\gamma mo$
	Z_p= Plastic section modulus Z_e= Elastic section modulus Z_{eff}= Effective section modulus				
Bending Resistance under high Shear [$V > 0.6Vd$] (Comp. Flange Laterally Restrained)					
Plastic section	$f_y/\gamma_{mo}.(Z_p\text{-}\beta Z_{pv}) \le 1.2\ Z_ef_y/\gamma mo$		$f_y(Z_p\text{-}\beta Z_{pv})$	$M_p = \Phi Z_pf_y$	$f_y/\gamma_{mo.}(Z_p\text{-}\beta Z_{pv})$
Compact section	$f_y/\gamma_{mo}.(Z_p\text{-}\beta Z_{pv}) \le 1.2\ Z_ef_y/\gamma mo$		$f_y(Z_p\text{-}\beta Z_{pv})$	$M_p = \Phi Z_pf_y$	$f_y/\gamma_{mo.}(Z_p\text{-}\beta Z_{pv})$
Non-compact section	Z_ef_y/γ_{mo}		$f_y(Z_e\text{-}\beta Z_{pv}/1.5)$	-	$f_y/\gamma_{mo.}(Z_p\text{-}\beta Z_{pv})$
Slender section	-		$f_y(Z_{eff}\text{-}\beta Z_{pv}/1.5)$		$f_y/\gamma_{mo.}(Z_{eff}\text{-}\beta Z_{pv})$
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_p= Plastic modulus of effective section excluding shear area Z_v= Plastic modulus of shear area				
β	$(2V/V_d\text{-}1)^2$		$(2V/V_d\text{-}1)^2$	-	$(2V/V_d\text{-}1)^2$

Table 12: Flexure member (Laterally Supported)

B. Design Comparison

If a brief comparison is made between the IS 800:2007 Limit state and other international standards which are presently in practice and based on Limit state method or Load and resistance factor design method, it is noticed that like other codes the basic design concept following the procedure for Limit state is similar for IS 800:2007. The limiting design parameters are vary based on design and other parameters like fabrication and erection. After designing the building by various design codes the following tonnage is obtained, and which is tabulated as below.

1) Design weight of structure as per IS800:2007
   - Frame weight = 13160.0kg x 6 = 78960.0kg
   - Beam weight = 308.0kg x 240 = 73920.0kg
   - Bracing weight = 8523.0kg = 8523.0kg
   - Total weight = 161403.0kg
2) Design weight of structure as per BS5950
   - Frame weight = 11092.0kg x 6 = 66552.0kg
   - Beam weight = 308.0kg x 240 = 73920.0kg
   - Bracing weight = 7556.0kg = 7556.0kg
   - Total weight = 148028.0kg
3) Design weight of structure as per AISC:2010
   - Frame weight = 10440.0kg x 6 = 62640.0kg
   - Beam weight = 250.0kg x 240 = 60000.0kg
   - Bracing weight = 7556.0kg = 7556.0kg
   - Total weight = 130196.0kg
4) Design weight of structure as per EURO:03
   - Frame weight = 9890.0kg x 6 = 59340.0kg
   - Beam weight = 250.0kg x 240 = 60000.0kg
   - Bracing weight = 7556.0kg = 7556.0kg
   - Total weight = 126896.0kg

Description	IS800:2007	BS-5950	AISC-2010	EURO-03
	STRUCTURE WEIGHT			
	(Kg)	(Kg)	(Kg)	(Kg)
Framing	152880	140472	122640	119340
Bracing	8523	7556	7556	7556
Total Wt.	161403	148028	130196	126896
% Reduction	BASE	9.04%	23.97%	27.19%

Table 13: Weight comparison

VI. RESULT

Following graphs shows the design weight of the structure and % reduction in tonnage as per international standards as compared to IS800:2007 in framing & bracing members.

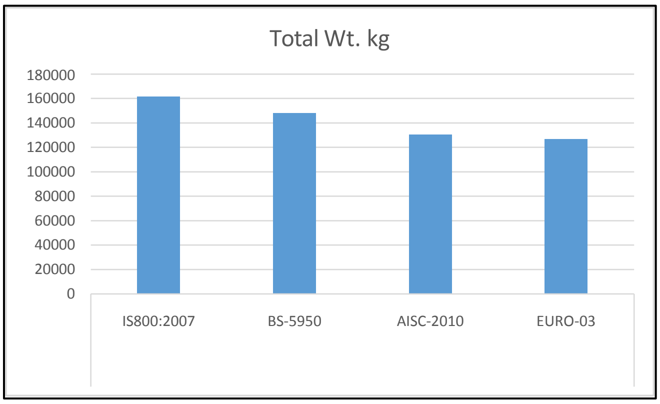


Fig. 6: Design Weight of Structure

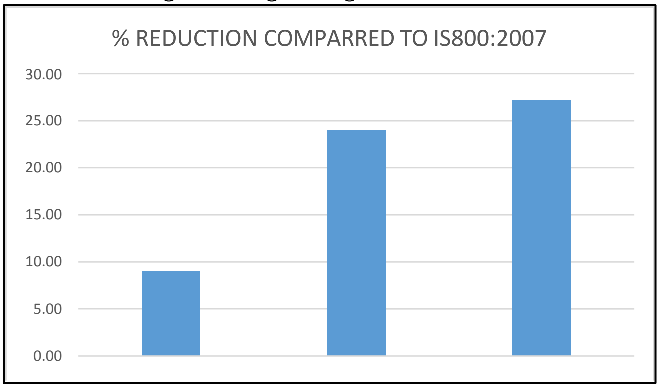


Fig. 7: % Reduction in Tonnage

VII. CONCLUSION

Following are the conclusions which are observed:

1) As per market study it observed that more than 70% pre-engineered buildings are designed according to American codes. As per the design result obtained during this dissertation work it is noted that the weight of structure is reduced by 23.97% as compared to IS800:2007.
2) Even though most of the pre-engineered buildings are designed accordance to American code it is noted that by using Euro-03 weight of structure is reduced by 27.2% and by using BS5950-2000 weight of structure is reduced by 9.04% respectively as per obtained design results as compared to IS800:2007.
3) The reasons to increase in weight in IS800:2007 as compared other international standards are as mentioned below.
   1) As per requirement of design and detailing for earthquake loads, we have to consider additional Load combinations as per limit state of strength.
   2) As per requirement of design and detailing for earthquake loads, we have limited the slenderness value for bracing member to span by 120, which is critical as compare to international standards.
4) 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.
5) The code has been mainly modelled in line with the Eurocodes, with some additional references taken from the existing British Codes also.

6) Another important aspect of IS800:2007 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.
7) As per American code, both ASD and LRFD method of design is equally prescribed, in the case of the IS 800:2007 (LSM) is prescribed mainly & only one chapter included for ASD.

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