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Evaluation Of Pre-Engineering Structure Design By IS-800 As Against Pre-Engineering Structure Design By AISC

Abstract

Technological improvement over the year has contributed immensely to the enhancement of quality of life through various new products and services. In structural Engineering, apart from structural and aesthetic design requirements, the major hurdle was the rate of construction and the safety norms. Development of Pre-Engineering Structure (PES) accelerated the rate of construction maintaining all the safety factors reducing the erection time of the structure. PES has also been satisfying a wide range of aesthetic and structural design requirements. Thus PES fulfils wide range of building configurations, custom designs, requirements and applications.

India being one of the fastest growing economies, infrastructure development is inevitable. Thus there is wide scope of PES in India. As compared to other countries Indian codes for building design are stringent but safer. Thus, PES being an upcoming field in construction industry in India, it becomes necessary to study the PES design using IS 800 over AISC, which is discussed further.

Introduction

In the USA, where the PES concept was originally conceived during the early years of this century, nearly 70% of all single storey non-residential construction now utilizes pre-engineered Structures. Applications range from small car parking sheds to 90 m (+), wide clear span aircraft hangars to low-rise multi-storey buildings. Almost every conceivable building use has been achieved using the pre-engineered structure approach.

Until 1990, the use of pre-engineered structure was confined mostly to North America and the Middle East. Since then, the use of pre-engineered structures has spread throughout Asia and Africa where the PES construction concept has now been widely accepted and praised. A growing number of prominent international contractors and designers, who previously specified conventional structural steel buildings exclusively, have recently started using the pre-engineered building approach. They now enjoy significant cost savings and benefits from the faster construction cycle resulting from this concept. From excavation to occupancy no other building system matches the pre-engineered building system when it comes to speed and value. The advantages of pre-engineered steel buildings are numerous and are the major reason for the spectacular growth of the PES industry during the past 50 years. These advantages include: Low Initial Cost, Superior Quality, Fast Project Construction, Functional Versatility, Architectural Flexibility, Low Maintenance and Operating Costs.[1]

- [1]Source: Z. Steel Tech. manual

Pre engineered steel buildings can be fitted with different structural accessories including mezzanine floors, canopies, fascias, interior partitions etc. and the building is made water proof by use of special mastic beads, filler strips and trims. This is 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 upto 25 to 30 metres. Low rise buildings are ideal for offices, houses, showrooms, shop fronts etc. The application of pre engineered buildings concept to low rise buildings is very economical and speedy. Buildings can be constructed in less than half the normal time especially when complemented with the other engineered sub systems.[2]

- [2]Source: Civil engineering portal (http://www.engineeringcivil.com)

Stability Approach: Pre-engineered building (PEB)

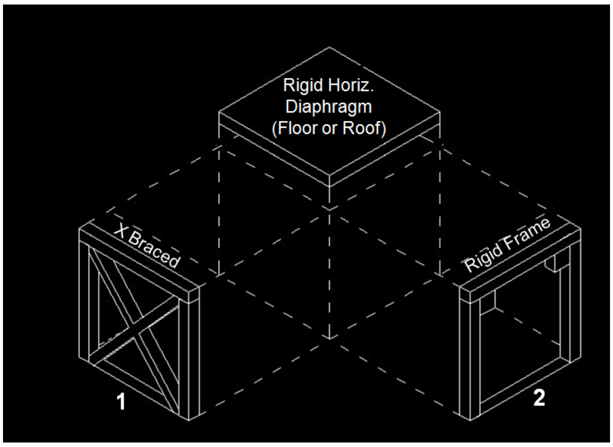
Metal Building, A System

- In PEB, the components such as walls, roof, main and secondary framing, and bracing are designed to work together. That’s why it is also called as metal building system as it satisfies the classical definition of a system as an interdependent group of items forming a unified whole.
- A building’s first line of defense against the elements consists of the wall and roof materials. These elements also resist structural loads, such as wind and snow, and transfer the loads to the supporting secondary framing.
- The secondary framing—wall girts and roof purlins—collects the loads from the wall and roof covering and distributes them to the main building frames, providing them with valuable lateral restraint along the way.
- The main structural frames, which consist of columns and rafters, carry the snow, wind, and

other loads to the building foundations. The wall and roof bracing provides stability for the whole building Even the fasteners are chosen to be compatible with the materials being secured and are engineered by the manufacturers.

Stability approach

As loads on the building are applied in both vertical as well as in lateral longitudinal direction, we have to make building stable in all directions. Vertical support for the whole building is provided by Main frame. It also provides lateral stability for the building in its direction while lateral stability in other direction is achieved by a bracing system.



Design Codes

American codes

- Code which governs load calculation is, MBMA (Metal Building Manufacturers Association), Low Rise Building Systems Manual
- Code which governs the design of hot rolled section & build up component is, AISC (American Institute Of Steel Construction), Manual Of Steel Construction, Allowable Stress Design.

Indian codes

- Design load calculation by IS 875(PART I TO V) and IS 1893.
- IS 875: Code Of Practice For Design Loads (Other Than Earthquake) For Buildings and Structures.
    - Part 1 Dead load
    - Part 2 Imposed load
    - Part 3 Wind Load
    - Part 4 Snow load
    - Part 5 Special Loads and Other Load Combination
- IS1893 Part I Criteria for Earthquake Resistant Design Of Structures. Part I. General Provisions and Buildings.
- Design of structural steel i.e. built up and hot rolled section is govern by IS800: Code of Practice for General Construction in Steel

Structural loads

Different structural loads that the building typically must carry are
- Dead load
- Collateral load
- Live load
- wind load
- Seismic load

Forces that act vertically are gravity loads like dead load, collateral load, live load. Forces that act horizontally, such as stability, wind and seismic events require lateral load resisting systems to be built into structures. As lateral loads are applied to a structure, horizontal diaphragms (floors and roofs) transfer the load to the lateral load resisting system.

Building Parameter

Building under consideration for the captioned project is as follows:

- Clear span Building
- Building dimensions
    - ✓ Width 25.8m
    - ✓ Length 56.0m
    - ✓ Clear ht 7.0m
    - ✓ Bay spacing 7.0m
    - ✓ 2.5m brick wall along the periphery of building.
    - ✓ 1:10 slope
- Wind speed 39 m/sec
- Seismic zone II

Load calculation by IS 875 & IS 1893

Dead Load Calculation: Along with self weight, we have to add Imposed dead load due to secondary elements like roof sheeting, purlins etc.
Consider dead load for 0.5 mm Panel and supporting purlin = 0.15 KN/m2
We must also add general collateral load i.e. only for Lighting = 0.05 KN/m2

Dead Load = (0.15+0.05) x 7.0 (Tributary = 7.0 m)
= 1.40 kn/m

Live load calculation: (IS: 875 (Part 2) -1987)
Live load includes all loads that the structure is subjected to during erection, maintenance and usage throughout the life time of the structure.
From Table 2 of IS: 875 (Part 2)

- for flat, sloping or curved roof
- with slopes up to and including 10 degrees
- when Access not provided except for maintenance

Live Load = 0.75 KN/m2
= 0.75 x 7.00 (Tributary = 7.0 m)
= 5.3 kn/m

Wind loads calculation: (IS : 875 (Part 3) – 1987)
Basic wind speed (Vb) = 44 m/sec

Design wind speed (Vz) = Vb x K1 x K2 x K3
(Clause 5.3) where,
K_1 Probability factor (risk coefficient)
K_2 Terrain, height, and structure size factor
K_3 Topography factor

Probability factor / Risk coefficient (K1)

- Class of structure - All general buildings & structures
- Mean probable design life of structures - 50 yrs
- Basic wind speed- 44 m/sec

K1 = 1.0 (Table 1 of IS : 875 (Part 3))

Terrain, height, and structure size factor (K2)
K_2 depends upon terrain category, class of structure and height of structure

Terrain category (Clause 5.3.2.1)

The building under consideration falls under – Category 3

Class of structure (Clause 5.3.2.2)
Depends upon diamension i.e. greatest horizontal or vertical dimension of Structures and/or their components
Class A Diamension < 20m
Class B Diamension = 20m-50m
Class C Diamension > 50m
Dimension represents maximum horizontal or vertical dimension of structure and /or their components.

The building under consideration falls under:
Class C (as 56.0 m > 50 m)

Height of structure: E_{ave} ht. = 8.0 mm (< 10 m)
Hence, Height = 10.0 m

$K_2 = 0.82$ (Table 2 of IS : 875 (Part 3))

Topography factor (K_3) (Clause 5.3.2.1)

Upwind slope <=3 $K_3 = 1.0$
Upwind slope >3 $K_3 = 1.0$ to 1.36

$K_3 = 1.0$

Design wind speed,
$V_z = V_b \times K_1 \times K_2 \times K_3$
$V_z = 44 \times 1.0 \times 0.82 \times 1.0$
$V_z = 36.08$ m/sec

Design Wind Pressure,
$Pz = 0.6\ Vz^2$ (Clause 5.4)
$Pz = 0.6\ (36.08)^2$
Pz = 0.718

Wind load on individual members,
$F=(C_{pe}-C_{pi})*\ A*\ P_d$ (Clause 6.2.1)
where
C_{pe} = external pressure coefficient,
C_{pi} = internal pressure coefficient
A = surface area of structural element
P_d= design wind pressure

Now we have to find C_{pi} and C_{pe} :

Internal Pressure Coefficients (C_{pi})

- ✓ Enclosed = 0.2 (Clause 6.2.3.1)
- ✓ Partially enclosed = 0.5(area bet 5 to 20%)
  = 0.7(area more than 20%)
  (Clause 6.2.3.2)

Internal Pressure Coefficients (C_{pi}) = 0.2

External Pressure Coefficients (C_{pe})

- ✓ H/W = 8 / 25.8 = 0.31 (H/W < ½)
- ✓ L/W = 56 / 25.8 = 2.17 (3/2 < L/W < 4)
- ✓ Roof angle = 5.71

Coefficients for wall
(Table 4-IS: 875 (PART 3))
Wind angle = 0^0

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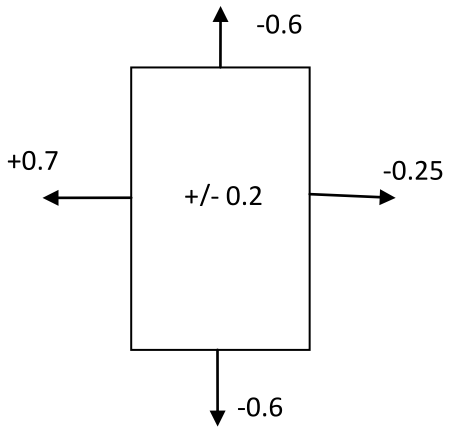
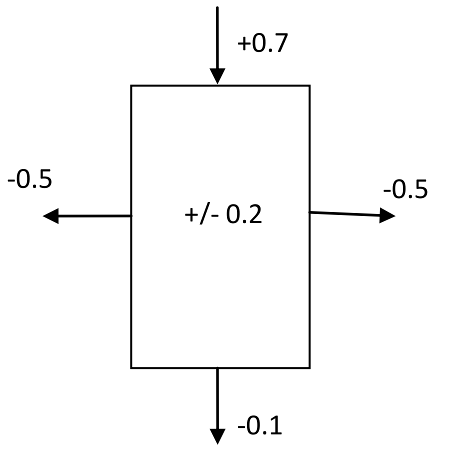
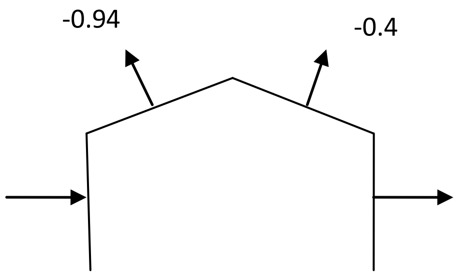


Wind angle = 90^0

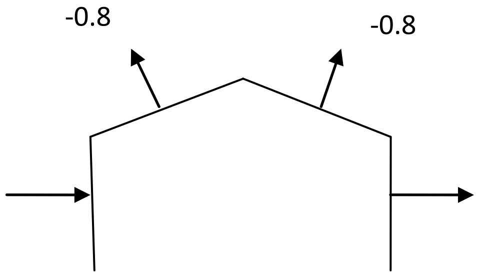


Coefficients for roof (Table5 of IS: 875 (PART 3))

Wind angle = 0^0



Wind angle = 90^0



Different wind load cases

WL1

WL1

Wind angle = 0
+ 0.2 internal pressure coefficient
wind from left.

WL2

Wind angle = 0
+ 0.2 internal pressure coefficient
wind from right

WL3

Wind angle = 0
- 0.2 internal pressure coefficient
wind from left.

WL4

Wind angle = 0
- 0.2 internal pressure coefficient
wind from right

WL5

Wind angle = 90
+ 0.2 internal pressure coefficient
wind in +ve z- direction

WL6

Wind angle = 900
+ 0.2 internal pressure coefficient
wind in -ve z- direction

WL7

Wind angle = 90
-0.2 internal pressure coefficient
wind in +ve z- direction

WL8

Wind angle = 90
- 0.2 internal pressure coefficient
wind in -ve z- direction

Final wind coefficients for different wind cases (Cpe-Cpi):

	WL1	WL2	WL3	WL4	WL5	WL6	WL7	WL8
Left Column	0.90	-0.05	0.50	-0.45	-0.30	-0.30	-0.70	-0.70
Left Rafter	-0.74	-0.20	-1.14	-0.60	-0.60	-0.60	-1.00	-1.00
Right Rafter	-0.20	-0.74	-0.60	-1.14	-0.60	-0.60	-1.00	-1.00
Right column	-0.05	0.90	-0.45	0.50	-0.30	-0.30	-0.70	-0.70

Final wind pressure for different wind cases

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F=(Cpe-Cpi) A Pd

	WL1	WL2	WL3	WL4	WL5	WL6	WL7	WL8
Left Column	4.92	-0.27	2.73	-2.46	-1.64	-1.64	-3.83	-3.83
Left Rafter	-4.06	-1.09	-6.25	-3.28	-3.28	-3.28	-5.47	-5.47
Right Rafter	-1.09	-4.06	-3.28	-6.25	-3.28	-3.28	-5.47	-5.47
Right column	-0.27	4.92	-2.46	2.73	-1.64	-1.64	-3.83	-3.83

Seismic load calculation (IS 1893 (Part 1): 2002)

Zone Factor (Table 2 of IS 1893 (Part 1))

The building under consideration falls under seismic zone II

Zone Factor = 0.10

Response Reduction Factor (Table 7 of IS 1893 (Part 1))

We are using cross angle bracing which is concentric bracing thus for Steel frame with concentric braces.

Response Reduction Factor = 4.0

Importance Factor depends upon the functional use of the structures, post-earthquake functional needs and historical value.

The captioned building under consideration falls under all other buildings Class.

Importance Factor = 1.0

Height of Structure (h) (clause 4.11): It is the difference in levels, in metres, between its base and its highest level.

As peak height of the structure is 9.29 m.

Height of structure, h = 9.29 m

Fundamental Natural Period:

$T_a = 0.085\, h^{0.75}$ (for steel frame building)

Where, h = Height of building, in meters

$T_a = 0.085\, h^{0.75}$

$= 0.085 \times (9.29)^{0.7}$

T_a **= 0.452 sec**

Structural Response Factors (S_a/g): Depending on type of soil, average response acceleration coefficient S_a/g is calculated corresponding to 5% damping by using formulae in clause 6.4.5 of IS 1893 (Part 1) :2002.

We are considering medium soil, for the captioned project.

natural time period T is as follows:

O.1O<T<O.55

Thus, $S_a/g = 2.5$

Now design horizontal seismic coefficient (Ah) for a structure shall be determined by the following formula,

$$(A_h) = \frac{z}{2} \times \frac{I}{R} \times \frac{Sa}{g}$$

$$(Ah) = \frac{(0.1)\,(1.0)\,(3.5)}{(2)\quad(4.0)}$$

$(Ah) = 0.0438$

Design Seismic Base Shear (Vb): It is the total design lateral force at the base of a structure. It is determined by using following expression:

$Vb = A_h W$

where,

Ah = Design horizontal acceleration spectrum and

W = Seismic weight of the

This design base shear (Vb) shall be distributed along the height of the building as per the following expression:

Design Lateral Force Qi =Vb.(Wi.Hi2)/(ΣWi.Hi2)

Using above calculated V_b & by calculating seismic wt. corresponding lateral force is calculated.

Load calculation by MBMA

Dead load calculation:

Consider dead load for 0.5 mm Panel and supporting purlin.

Dead load = 0.15 KN/m2

=0.15 x 7.0 (tributary = 7.0 m)

=1.05 kn/m

Collateral load calculation:

Consider general collateral load i.e. only for Lighting.

Collateral load = 0.05 KN/m2

=0.05 x 7.00 (tributary = 7.0 m)

=0.35 kn/m

Live load calculation:

Live Load = 0.57 KN/m2 (section 3 table 3.1 of MBMA=0.57 x 7.00 (tributary = 7.0 m)

Live load =3.99 kn/m

WIND LOADS CALCULATION

Calculation by using section 5 of MBMA

A basic wind speed is specified from which a velocity pressure is calculated. This velocity pressure and a peak combined pressure coefficient are used to determine the design wind pressure according to the following equation

$$q = 2.456 \times 10^{-5} \times V \times H^{2/7} \quad \text{where,}$$

q = velocity pressure in kilonewton per square meter (kN/m).

V = specified basic wind speed in kilometers per hour (km/h).

H = mean roof height above ground in meters (m). (H must be greater than or equal to 4.6 m.)

Note: Eave height may be used instead of mean roof height if roof slope is not greater than 10°

$$q = 2.456 \times 10^{-5} \times 39 \times 8^{2/7}$$

$$q = 0.8737 kN/m^2$$

PEAK COMBINED PRESSURE COEFFICIENT (GCP)

Table 5.4 (a) and 5.4 (b) – I-5-7

We are considering the building where, $0^0 <= \theta^0 >= 10^0$

WL1	WL2	WL3	WL4	WL5	WL6	WL7	WL8
0.25	-0.55	0.65	-0.15	-0.70	-0.70	-0.30	-0.30
-1	-0.65	-0.6	-0.25	-1.00	-0.65	-0.60	-0.25
-0.65	-1	-0.25	-0.6	-0.65	-1.00	-0.25	-0.60
-0.55	0.25	-0.15	0.65	-0.70	-0.70	-0.30	-0.30

Design wind pressure $p = I_w \times q \times (GCp)$ where,

p = Design wind pressure

q = Velocity pressure

GCp=Peak combined pressure coefficient

I_w= Importance Factor

Wind force = p x tributary

Here, q = 0.8737 KN/m

$I_w = 1.0$

Tributary = bay spacing = 7.0m

WL1	WL2	WL3	WL4	WL5	WL6	WL7	WL8
1.9	-4.3	5.1	-1.2	-5.4	-5.4	-2.3	-2.3
-7.8	-5.1	-4.7	-1.9	-7.8	-5.1	-4.7	-1.9
-5.1	-7.8	-1.9	-4.7	-5.1	-7.8	-1.9	-4.7
-4.3	1.9	-1.2	5.1	-5.4	-5.4	-2.3	-2.3

FINAL WIND LOADS

Seismic force calculation:

Peak acceleration coefficient(Aa) = 0.05

For Aa=0.05

Seismic coefficient, Ca = 0.08

For lateral Direction: Interior Frame - Ordinary Moment Resisting Frame, R = 4.5

For Longitudinal Direction:

Concentric Braced Frame, R = 5

Seismic design coefficient (Cs) =2.5*Ca/R (equation 7-2)

For lateral direction (Cs) = 2.5*0.08/4.5

(Cs) =0.044

For Longitudinal Direction (Cs) = 2.5*0.08/5

(Cs) =0.04

Seismic force V=CS*W

Conclusion

Following are some of the major differences in IS code methodology and AISC methodology observed during the study are:

1. *Live load is 0.75 KN/sq m as per IS code whereas it is 0.57 KN/sq m as per MBMA.*
   Thus, live load by IS code (IS 875-part II) is greater than live load by MBMA.

2. Calculation of % of opening for wind load calculation:
   As per MBMA, "Windows, doors, and other building accessories, designed to resist the wind pressures set forth in Section 5.5 need not be considered as openings."
   Thus, ***In MBMA, framed openings like doors, rolling shutter are not considered as open area as they are not permanently open. Whereas as per IS, we take them into account while calculating % of openings.***

3. Calculation of wind coefficient:
   MBMA gives final wind coefficient for enclosed, partially enclosed and open building. Whereas IS 875 part III gives external wind coefficient and (+/-) internal wind coefficient. One has to calculate final wind coefficient using external and (+/-) internal wind coefficient. Thus, ***calculation of wind coefficient using MBMA is much simplified as compared to IS code.***

4. Calculation of opening condition:
   Internal wind coefficient, as discussed earlier depends upon the % of opening.

Internal pressure coefficient,
cpi = 0.2 if % of opening
cpi = 0.5 if % of opening is between 5 % to 20
cpi = 0.7 if % of opening is more than 20%

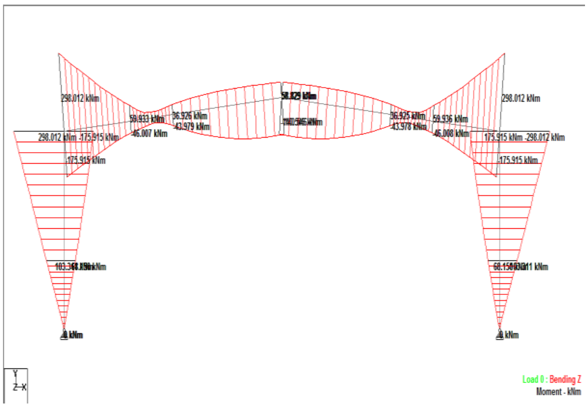
Thus, when % of opening is less than 5%, the building is called as enclosed building. When % of opening is in range of 5% to 20%, the building is called as partially enclosed building. When the % of opening is more than 20%, the building is called as open building. The percentage of opening area with respect to the gross sheeted area determines the opening condition of the building.

Whereas in MBMA,

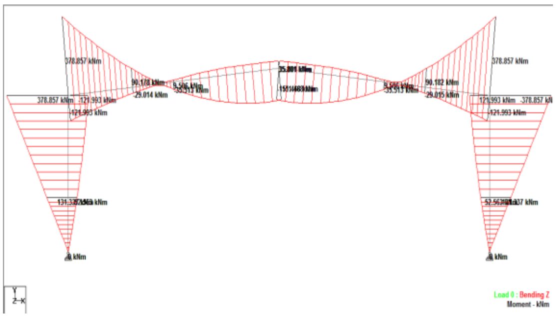
- **Open building** is a structure having all walls at least 80 percent open.
- **Partially Enclosed Building** is a building in which the total area of openings in a wall that receives positive external pressure exceeds the sum of the areas of openings for the balance of the building envelope (walls and roof) and exceeds 5 percent of the area of that wall; and the density of the openings in the balance of the building envelope does not exceed 20 percent**.**
- **Enclosed Building** *is* a structure that encloses a space and does not have openings that qualifies under the definitions of a partially enclosed or open building.

Building with only roof sheeting & all walls open comes under enclosed building category as per MBMA. Whereas, it is considered as open building as per IS codes.

4. In IS code, wind pressure depends upon various parameters like, terrain category, class of structure, horizontal and vertical dimensions of the structure, mean probable design life of structure and basic wind speed. Regardless of any other parameter, wind pressure in AISC depends only upon wind speed and mean height of building.
5.



Bending moments on typical portal frame by AISC



Bending moments on typical portal frame by IS

By observing bending moment diagrams on both the frames it can be concluded that **load calculated by IS code is higher than load as per MBMA.**

6. Load Combination :

Load combinations for strength as per IS codes are as follows-

- DL+LL
- 0.75(DL+WL)
- 0.75 (DL+SEISMIC)
- 0.75 (DL+LL+WL)
- 0.75 (DL+LL+SEISMIC)

Factors applied to forces in load combination in order to increase permissible stresses should not be taken into consideration while measuring deflection thus all force factors are 1.0 while measuring deflection as per IS. Therefore, load combination for deflection as per IS codes are as follows:

- DL+LL
- DL+WL
- DL+SEISMIC
- DL+LL+WL
- DL+LL+SEISMIC

Whereas as per AISC, there is no need for different load combinations for strength and deflection. Thus common load combination for both strength and deflection as per AISC are as follows

- DL + CL + LL
- 0.75(DL+WL)
- 0.75(DL + 0.5 WL)
- $((1.1+0.5A_v)DL)$+seismic
- ((0.9-0.5Av)DL)+seismic

7. Serviceability criteria:

MBMA says that *"Whether or not a structure or element has passed a limit state is a matter of judgment. In the case of strength limits, the judgment is technical and the rules are laid down by building codes. In the case of serviceability limits, the judgments are frequently non-technical. They involve the perceptions and expectations of building owners and building users. Serviceability limits have in general not been codified in the past in part because they concern the contractual relations with the owner rather than the protection of the public at large. Because of the nature of serviceability limits, it is proper that they remain outside the building codes."*
AISC just provides guidelines for deflection limit but ultimate decision is of customers.

PEB companies following MBMA codes use deflection limit-

- vertical deflection = span(L) /180 and
- Horizontal deflection = height (H) /90.

Deflection limit as per IS codes are –

- vertical deflection = span(L) /325 and
- Horizontal deflection = height (H) /325.

But, IS code also says that, "this limit may be exceeded in cases where greater deflection would not impair the strength or efficiency of the structure or lead to damage to finishing.

Thus, PEB companies following IS codes, use deflection limit-

- vertical deflection = span(L) /180 and
- Horizontal deflection = height (H) /150,

which are still higher than deflection limit by MBMA. **Deflection limits by IS code are higher than deflection limits by MBMA.**

Because of above mentioned differences, it can be stated as **" IS code gives more conservative design of portal frame as compared to AISC"**

Biliography:

- MBMA : Metal Building Manufacturers Association, Low Rise Building Systems Manual
- AISC : American Institute Of Steel Construction, Manual Of Steel Construction, Allowable Stress Design.
- IS 875 : Part 1 to 5 Code Of Practice For Design Loads (Other Than Earthquake) For Buildings and Structures
- IS1893 Part I Criteria for Earthquake Resistant Design Of Structures – part I. General Provisions And Bldgs
- IS800 : Code Of Practice For General Construction In Steel
- Z. Steel Tech. manual
- Civil engineering portal (http://www.engineeringcivil.com)