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# A Comparative Study of PEB Frames TCCS & TCMS1

Ajay Gopal Mishra<sup>1</sup>, Mohd. Ahtasham<sup>2</sup>, Dr. J.M Bandy<sup>3</sup>

Design Head, Department of Design and Drafting, Apex Buildsys, Noida, India<sup>1</sup>

Post Graduate Structural Engineer, Department of Design and Drafting, Apex Buildsys, Noida, India<sup>2</sup>

Associate Professor, Department of Civil Engineering, N.I.T Srinagar J & K, India<sup>3</sup>

**ABSTRACT:** Pre-Engineering Building is the recently trend for construction of industrial building, residential building, aircraft hangers, metro stations, malls, warehouse, etc. in India. Now a days, a large scope of PEB buildings with many advantages like light weight, short erection time period, easy maintenance, weather proof, provision of future expansion and also good control over quality. Another advantage of PEB, a wide space can be utilized without any obstruction or intermediate column and can be provided desirable section as per optimum requirement. In this paper, a comparative study of Pre-Engineering Building (PEB) with 324m length, 40m width and clear height 9.5m and slope 5.71 degree, location Kolkata is considered to analyse and designed for 2D frame. There are two frames are analyzed and designed namely tapered column clear span (TCCS) & tapered column multi span (TCMS1). TCMS1 frame is analyzed with HSTC & CFST columns. This PEB structure is analyzed and design on Stadd.Pro to understand the behavior of PEB. An intermediate column is modelled to analyse with circular hollow steel tubular and composite column to ascertain the effect of intermediate column with respect to weight as well as strength. In the present study, An innovative idea is developed of concrete filled steel tubular (CFST) column, which is used as intermediate column in TCMS1 frame. The strength of concrete filled steel tube (CFST) is calculated manually with the help of British standard. The design is done by IS 800:2007, "Code of practice for general construction in steel structures" and latest draft code IS 875 part 3 for wind load. A 2D model of PEB frame is modelled on Stadd. Pro and various loads like dead load, live load, earthquake load, and wind load and their load combinations are applied to analyse and design.

**KEYWORDS:** PEB frames TCCS & TCMS1, Composite column, Tapered sections, Steel tube, BS & IS Standard, Stadd pro.

### I. INTRODUCTION

Pre Engineered metal buildings use the combination of built-up members, hot rolled, cold form elements which make the basic steel frame work and other accessories canopy, fascia, clip, trim, deck sheet for mezzanine floor, ridge vent, bracing, sag rod etc. Built up members are used for primary members (Rafter and Column) as per optimum requirement with the help of bending moment diagram, thus reducing wastage of material and self-weight of the structure, due to reducing self-weight the reaction at support will be reduced and foundation will be light thus structure become economical. Z & C sections are used as secondary members (Purlin and Girt). All these components of PEB are fabricated in factories after designing and assemble on site for erection. Now a days, PEB buildings have become very popular in India because these buildings are most economical, low cost, short erection time period, light weight, seismic and wind resistant, water proof & wall covering structure etc. one distinct advantage of PEB buildings have become bolted is it can be dismantled and relocate. Three types of frames are used in PEB structure, rigid frame, post end beam and semi rigid frame. Basically, main frame (Column & Rafter) of PEB structure is rigid steel frame and combination taper column and taper rafter. These taper sections are fabricated in plant using advanced technology wherein taper flange welded to the taper web while end wall frame of PEB building may be designed as a main frame or post end beam frame. While post end beam system framing consists of columns (Post) with pinned ends and supporting beam known as end-wall. In post beam system consists bracing to resisting lateral load to maintain longitudinal as well as lateral stability. Generally mezzanine framing is connected to the main frame column and main

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beam at equal distance to support mezzanine slab with the help of deck sheet, this system provide good stiffness to the structure. Mezzanine beam consists of joist, which is tapered section can be provided for long span to make economical of the structure. Pre-engineering buildings are generally single story; however the maximum heights can go upto 30 meters and clear width upto 100 meter.

## II. LITERATURE REVIEW

**Swati Wakchaure, N.C Dubey (2016)<sup>2</sup>** Compare the Pre- Engineering building (PEB) and conventional steel building (CSB) with weight. The construction of PEB in place of CSB design concept resulted in many advantages as members are as per bending moment diagram and thus reducing steel as per requirement. In this study, PEB and CSB structure are analyzed and designed as per IS: 800-2007, IS: 800-1984. The economy of the structure is discussed in terms of weight comparison, between Indian code IS: 800-2007 and IS: 800-1984 and in between PEB & CSB building structure.

**K.K.Mitra – Gen. Manager Lloyd Insulations (India) Limited (2009)<sup>2</sup>** has studied about the latest trend in building construction. The Pre-Engineered steel building is the combination of hot rolled, cold form, and built-up members. It can be fitted with various structural accessories including mezzanine floors, canopy, fascia, gutter down take pipe and crane system etc. Pre-Engineered building can be erected up to 25m to 30m height and 100 m clear width. Now a day, there is a wide scope of PEB building in India. Solar power is the conversion of energy from sunlight to electricity for generation of this electricity a large space is required on earth and on roof. For which PEB structure can be used for installed the solar system on roof easily. The concept is designed to provide a complete building envelope system which is air tight, energy efficient, optimum in weight, cost and above all.

**C.M Meera (2013)<sup>1</sup>** this paper present the comparison of Pre Engineered building and Conventional steel building concept. The study is achieved by designing a typical frame of a proposed Industrial Warehouse building using both the concepts and analyzing the designed frames using the structural analysis and design software Staad.Pro. PEB structure has many advantages over conventional steel building, lower weight, low cost, fast erection, durability and designed with various countries code.

## III. METHODOLOGY

In this research paper, a Pre- Engineering Building 324m length, 40m width, clear height 9.5m from ground level with constant bay spacing 9m, 3m brickwork and slope is 1:10 is located in Kolkata, for this PEB structure two frames are analyzed. TCCS & TCMS1. TCCS & TCMS1 are analyzed and designed on Staad Pro. Software. TCMS1 is analyzed with circular hollow steel tubular column & concrete filled steel tubular (CFST) column at ridge. Support condition for these PEB frames is fixed supported and analyzed as an enclosed building. The support condition of intermediate circular column is pinned. In this PEB building an intermediate composite column (CFST) is used for knowing the behavior, strength and weight effect. The strength of concrete filled steel tubular column (CFST) is calculated by British standard BS-5400 part 5 for taking effect of confinement of concrete. Wind load is confirmed by latest draft code IS: 875-part 3 (third revision) for considering importance factor (K4) for cyclonic region. Earthquake loads are considered as per IS 1893-2002 part 1.

### 3.1 Structural Configuration

This PEB configuration consists two frames tapered column clear span (TCCS) and tapered column multi span one (TCMS1). Tapered column clear span & tapered column multi span one are analyzed and designed on Staad. software. These picture, which are showing below (fig.1) are taking from Staad. In TCCS & TCMS1 frames, all member (column and rafter) are assigned as tapered but in TCMS1 an intermediate column is assigned as circular hollow steel tubular column (HSTC).

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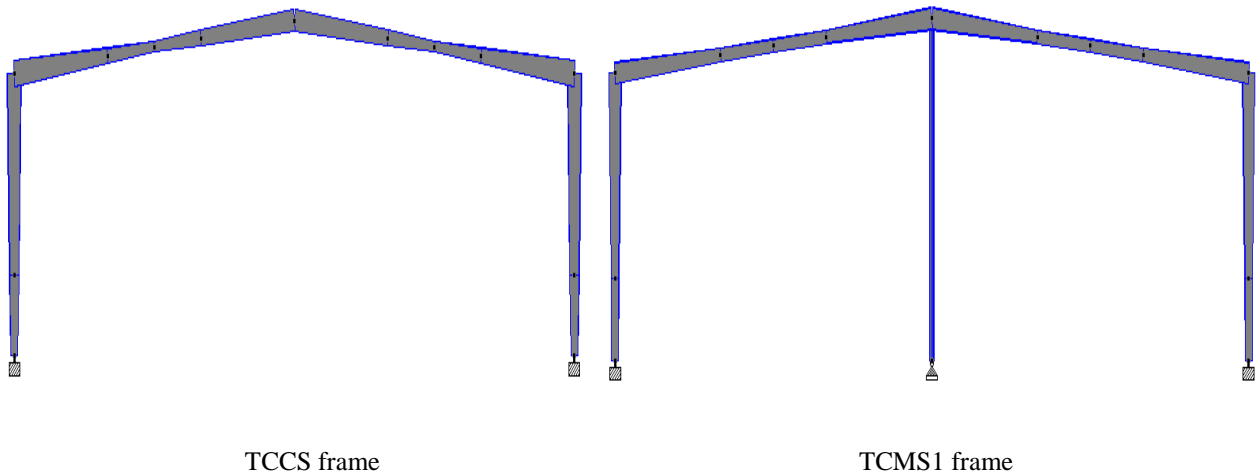


Figure1 PEB frames TCCS & TCMS1

## IV. LOAD CALCULATION, COMBINATION AND DEFLECTION CRITERIA

### 4.1.0 Design Detail Specification

Location of building = Kolkata  
 Length of building = 324 m  
 Width of building = 40m  
 Intermediate column at = 20m  
 Bay spacing = 9 m  
 Eave Height (clear) = 9.5m  
 Seismic Zone = III  
 Wind Speed = 50 m/s  
 Terrain category = Category 2  
 Slope = 1:10  
 Soil type = Medium  
 Response reduction factor = 4  
 Importance factor = 1.

#### 4.1.1 Dead Load

Dead Load =  $.15 \text{ kN/m}^2$  As per IS 875 Part1  
 Total dead load =  $.15 * 9$  (Bay Spacing)  
 =  $1.35 \text{ kN/m}$

#### 4.1.2 Live Load

Live Load =  $.75 \text{ kN/m}^2$  As per IS 875 Part2  
 Total Live Load =  $.75 * 9$  (Bay Spacing)  
 =  $6.75 \text{ kN/m}$

#### 4.1.3 Earthquake Load

Dead Load =  $.15 \text{ kN/m}^2$  As per IS 875 Part2  
 Live load =  $.1875 \text{ kN/m}^2$  (25% live load considered as per IS 1893 (part1):2002)  
 Total load =  $.3375 \text{ kN/m}^2$   
 Earthquake load on rafter =  $.3375 * 9$  (bay spacing)  
 =  $3.0375 \text{ kN/m}$

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## 4.1.4 Wind load calculation

Basic wind speed = 50 m/sec  
 Risk coefficient (k1) = 1  
 Terrain height & size factor (k2) = 1  
 Topography factor (k3) = 1  
 Importance factor (k4) = 1  
 Design wind speed (Vz) = Vb x K1 x K2 x K3 x K4  
 = 50 m/s  
 Design wind pressure (pz) = 0.6 x (Vz)<sup>2</sup>  
 pz = 1.5 kN/m<sup>2</sup>  
 Design wind pressure (Pd) = Kd \* Ka \* Kc \* pz > 0.7 pz  
 Wind directionality factor (Kd) = 1  
 Area averaging factor (Ka) = 0.9  
 Combination factor (Kc) = 1  
 Design wind pressure (Pd) = 1.35 kN / m<sup>2</sup>

Wind load is applied as per IS 875 part 3. The wind load is applied as uniformly distributed load acting away from the structure over roof. For side wall, the wind load is applied as uniformly distributed load acting away and toward to the structure according to the wind load cases.

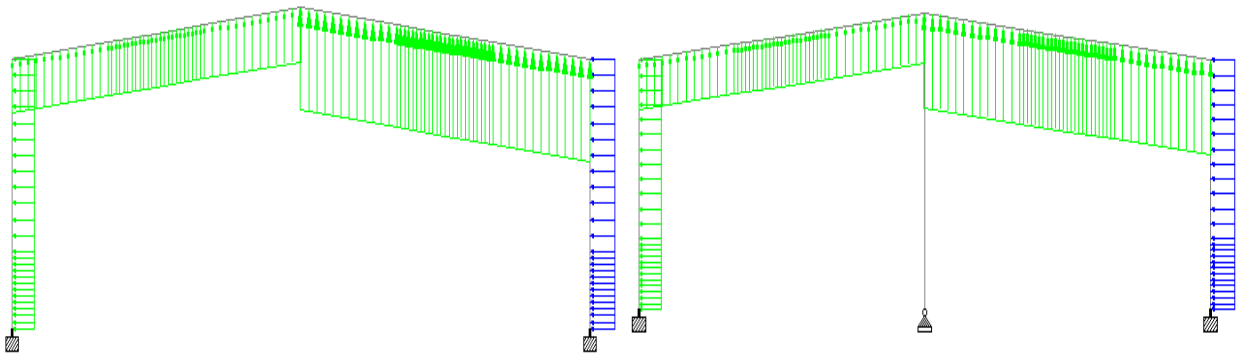


Figure 2 Wind load on TCCS & TCMS1 frames

## 4.1.5 Parameters for Intermediate concrete filled steel tubular (CFST) column

### Limiting values for CFST as per BS-5400 part 5

1. The wall thickness of concrete filled steel tube should not be less than  $D_e \sqrt{\frac{f_y}{8E_s}}$  for circular section.
2. The concrete should be of normal density (Not less than 23 kN/m<sup>3</sup>) with characteristic 28 day cube strength of not less than 20 N/mm<sup>2</sup> for concrete filled tube.
3. The ratio of effective length to its least lateral dimension should not exceed 55 for concrete filled circular section.

In table 1, the parameters are considered for this PEB frames analyses are calculated under permissible values. Minimum grade of concrete, wall thickness, effective length and slenderness ratio are used for concrete filled steel tubular column as per British Standard under permissible values.

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**Table 1 Limiting values for intermediate CFST column**

Parameters	Calculated value	Permissible value
Slenderness	48.875	55
Wall thickness	2.5	2.5
Grade of concrete	20	20
Outer dia.	200	200
Effective length	9775	9775

Circular hollow tube is used as an intermediate column for taking axial load because it is pin supported at mid of building. In above table effective length 9.775m, wall thickness 2.5mm, yield strength 250 N/mm<sup>2</sup> these parameters are used for analysis CFST column as per BS-5400.

#### 4.1.6 Analysis of CFST intermediate column by British Standard Equation

Axially load column formed from concrete filled circular hollow steel tube. The axial load is calculated by BS-5400 Squash load equation of CFST column by BS-5400 part 5

$$N_u = 0.95 * f_y' * A_s + 0.45 * f_{cc} * A_c$$

Where

$f_{cc}$  = is an enhanced characteristic strength of tri-axially contained concrete under axial load

$$f_{cc} = f_{cu} + \frac{C_1 * t * f_y}{D_e}$$

$D_e$

$f_y'$  = is a reduction nominal yield strength of steel casing

$$f_y' = C_2 * f_y$$

$f_y$  Yield strength of steel tube material (250 N/mm<sup>2</sup>)

$A_s$  Cross sectional area of steel tube (mm<sup>2</sup>)

$A_c$  Cross section area of concrete in tube (mm<sup>2</sup>)

$f_{cu}$  is the characteristic 28 day cube strength of the concrete (20 N/mm<sup>2</sup>)

$E_s$  is the modulus elasticity of steel (2 \* E + 005 N/mm<sup>2</sup>)

**Table 2 Values of constants C<sub>1</sub> & C<sub>2</sub> for axially loaded CFST circular column**

L <sub>e</sub> /D <sub>e</sub>	C <sub>1</sub>	C <sub>2</sub>
0	9.47	0.76
5	6.40	0.80
10	3.81	0.85
15	1.80	0.90
20	0.48	0.95
25	0	1.0

#### 4.1.7 Concrete Contribution Factor

The concrete contribution factor lies between the following limit

For concrete filled hollow steel sections 0.1 <  $\alpha_c$  < 0.8

Where  $\alpha_c = \frac{0.45 * A_c * f_{cu}}{N_u}$

$N_u$  = Squash load

$\alpha_c$  = Concrete contribution factor

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#### 4.1.8 Pre-Engineering Building by Staad. Pro.

Staad pro. is the most popular tool for analysis and design of 2D & 3D structure modeling with various properties. The procedure for design of structure modeling, specification to structure, support, loading and load combination, of analyzing and design of the structure. Staad pro software is not only for building analysis but also facilities available for bridge analysis. In staad pro utilization ratio indicates the suitability of the member as per code, the value above 1 indicates not suitable for given load, and the value below 1 indicates the member capacity available. Staad pro also gives the other useful information about the structure that it fail in compression, tension, slenderness, flexural and shear. In staad Pro. is the powerful tool by which, structure can be designed with various material, properties, and any desirable properties can be generate.

#### 4.1.9 Load combination and deflection limit as per IS code

Load combinations include different combination of loads according to IS 800-2007 by considering serviceability and strength criteria.

**Table 3 Load Combination as per IS: 800-2007**

S.No.	Limit state of serviceability	Limit state of strength
1	DL+LL	1.5(DL+LL)
2	DL+WL	1.5(DL+WL)
3	DL+EQ	1.5(DL+EQ)
4	DL+0.8LL+0.8WL	0.9DL+ 1.5WL
5	DL+0.8LL+0.8EQ	0.9DL+1.5EQ
6		1.5DL+1.05LL
7		1.5DL+1.05LL
8		1.2DL+1.2LL+0.6WL
9		1.2DL+1.2LL+0.6EQ
10		1.2DL+1.05LL+0.6WL
11		1.2DL+1.05LL+0.6WL
12		1.2DL+0.5LL+2.5EQ
		0.9DL+2.5EQ

In table3, the load combinations for limit state of serviceability & limit state of strength are applied to the TCCS & TCMS1 as per IS800-2007. Higher factor to the load combination is also the reason to increase the weight. In table 4 deflection limit is applied to the all frames for every member.

**Table 4 Deflection Limit as per IS 800:2007**

S.No.	Description	Limit (IS 800:2007)	
		Horizontal	Vertical
1	Main frame	H/150	L/180
2	Main frame with crane < 50t	-	L/750
3	Purlin	-	L/150
4	Girt	-	L/150
5	Rafter	-	L/150
6	Wind column	H/120	-
7	Mezzanine beam		L/240

## V. RESULTS AND DISCUSSIONS

In this paper, this Pre-Engineering Building is analyzed with two type of frame and compare the weight. 1. Tapered column clear span (TCCS) 2. Tapered column multi span (TCMS1). Circular HSTC & CFST columns are used in TCMS1 frame. Pre-Engineering frames TCCS & TCMS1 are analyzed and designed for various loads and load

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combination and compare the weights by using Staad pro. And British Standard BS-5400 part 5 is used for calculating load of pin ended intermediate column.

**Table 5 Load calculated of Intermediate HSTC by Staad.**

HSTC Shape	$f_y(N/mm^2)$	Wall thickness $t_w(mm)$	De Outer dia. (mm)	Axial load (kN)Staad.	TCMS1 Frame wt. (ton)	TCCS Frame wt. (ton)	I.C column wt. (ton)
Circular	250	3	300	284.78	6.66	4.35	.247

The most important parameter in this study, Intermediate circular column, once TCMS1 frame is analyzed with circular hollow steel tubular column (HSTC) and second TCMS1 frame is analyzed with concrete filled steel tubular column (CFST) and compare the weight between frames and intermediate columns. For CFST column capacity, M20 grade of concrete is filled in steel tube for taking the effect of confinement of concrete and axial load capacity by using BS-5400 part 5.

**Table 6 Load calculation by BS-5400 part 5**

CFST column shape	$f_y(N/mm^2)$	$f_c(N/mm^2)$	Wall thickness $t_w$	Slenderness ratio	De outer dia. (mm)	Axial Load (kN) Staad	Calculated Load by BS code (kN)	CFST I.C wt.(ton)
Circular	250	20	2.5	48.875	200	284.78	635	.140

CFST column or composite columns the advanced application in Pre-Engineering Building due to which a significant weight can be reduced. In table 6, And axial load for circular concrete filled steel tubular column is calculated by BS-5400 part 5, CFST column is more capable to take axial load higher than HSTC because concrete strength and confinement of concrete are play the important role to increasing the strength of CFST column. In short column, tri axial strength is the most important factor, CFST column is more capable to take the large axial load than circular hollow steel tube due to tri-axial strength.

**Table 7 Weight comparison**

Staad/ BS-5400	$f_y(N/mm^2)$	$f_c(N/mm^2)$	$E_s(N/mm^2)$	$t_s(mm)$	Outer dia. $D_e$ (mm)	Steel area $A_s$ (mm <sup>2</sup> )	TCCS frame weight I.C (Ton)	TCMS1 Frame weight (Ton)	Hollow steel I.C (Ton)	CFST I.C (Ton)
Staad	250	-	2*E+005	3	300	2797.74	6.66	4.35	.247	-
BS-5400	250	20	2*E+005	2.5	200	1550.37	-	-	-	.140

In above results, concrete filled steel tubular column and hollow steel tubular column are used as intermediate columns for knowing the behavior of frame, frame weight. Results shows above, CFST column is more capable to take the higher load than HSTC column with lesser weight, economical, and more efficient. In this paper, the support condition for TCCS frame and TCMS1 frame is fixed, TCCS frame weight much higher than TCMS1 frame due to higher moments are generated at fixed supports, negative moments at column rafter end and deflection at mid span. In TCMS1, two different type of intermediate column are used hollow steel tubular & concrete filled steel tubular column. Axial load in intermediate circular hollow steel tubular column is taking from staad.

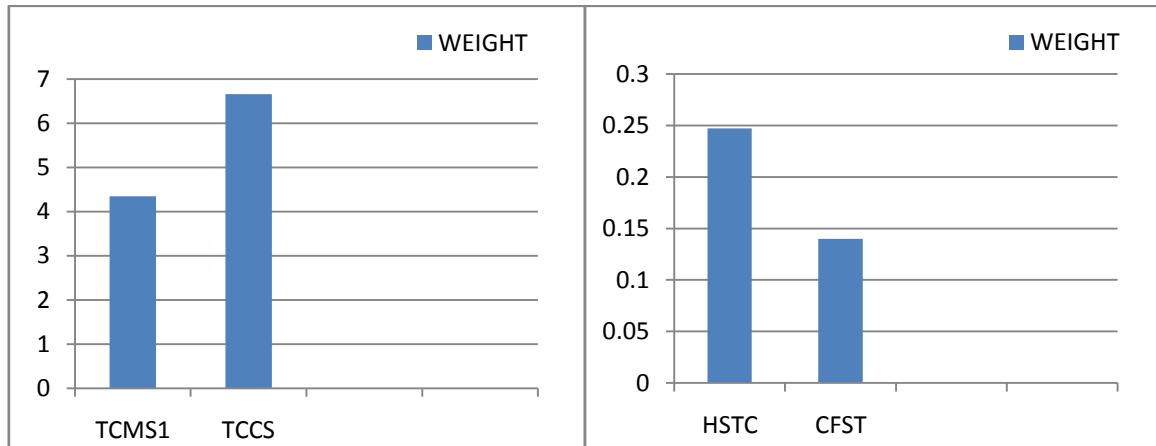


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Weight comparison between TCMS1& TCCS      Weight comparisons between HSTC & CFST  
**Figure 3 Weight comparison**

In above graph, in fig.3 weight comparison between tapered column multi span one and tapered column clear span frame. The weight of TCMS1 with circular hollow steel tubular and concrete filled steel tubular column is less than TCCS frame. In next fig. the weight, strength, and buckling capacity of concrete filled steel tubular column is more efficient than HSTC.

## VI. CONCLUSION

1. Tapered column clear span (TCCS) frame is almost 34% heavier than tapered column multi span one (TCMS1) with hollow steel tubular column at ridge.
2. Tapered column clear span (TCCS) frame is almost 36% heavier than tapered column multi span one (TCMS1) with concrete filled steel tubular (CFST) column at ridge.
3. Hollow steel tubular column is 43% heavier than concrete filled steel tubular column (CFST) in TCMS1 frame.
4. In TCMS1, consumption of steel in CFST column much lesser than hollow steel tubular column. Not only lesser steel consumption but also provide higher load carrying capacity, confinement of concrete, good ductility and low cost.
5. Overall TCMS1 frame with CFST column at ridge is proved more efficient and economical, good ductility higher load capability than other frames.
6. Steel quantity depends on primary members & purlins. As bay spacing of frames is increased steel consumption decreased for primary member and increased for secondary members up to certain limit.

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### BIOGRAPHY



**MOHD AHTASHAM** has received his B.Tech. in Civil Engineering from B.B.D N.I.T.M Lucknow & M.Tech. in Structural Engineering from N.I.T Srinagar J & K. He is presently working in Apex Buildsys, Noida, India. His research interests include Bridge Engineering, RCC Design & Steel Structures. He is a chartered Engineer from Institution of Engineers, India. He is the associate member of Indian association of Structural Engineers (IStructE), Indian Buildings Congress (IBC) & IAENG.