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DESIGN AND ANALYSIS OF SPECIAL STEEL CONNECTIONS ON PRE-ENGINEERED STEEL BUILDINGS

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ABSTRACT

Steel industry is growing rapidly in almost all the parts of the world. The use of steel structures is not only economical but also eco friendly at the time when there is a threat of global warming. Long Span, Column free structures are the most essential in any type of industrial structures, and Pre-Engineered Buildings (PEB) fulfills this requirement along with reduced time and cost as compared to conventional structures. The work will involve the detailed design and Analysis of connections in Pre-Engineered Buildings (PEB). Further, Comparison between connections of PEB and Conventional Steel Buildings will be done.

***Keywords*: Connections,Pre Engineered Building , reduced time and cost, steel structure**

I. INTRODUCTION

Steel Industry is growing rapidly in all the parts of the world. To meet the rising demand of construction, alternative way construction is to be incorporated. In structural engineering, a pre-engineered building (PEB) is designed by a manufacturer to be fabricated using a pre-determined inventory of raw materials and manufacturing methods that can efficiently satisfy a wide range of structural and aesthetic design requirements. The primary framing structure of a pre-engineered building is an assembly of I-shaped members, often referred asI beam. Also the sections used are Tapered sections. In PEB, I section beams used are usually formed by welding together steel plates to form of I section. I section beams are then field-assembled (e.g. bolted connections) to form the entire frame of the pre-engineered building. Cold formed Z and C-shaped members may be used as secondary structural elements to fasten and support the external cladding. To design a pre-engineered building, clear span between bearing points, bay spacing, roof slope, live loads, dead loads, collateral loads, wind uplift, deflection criteria, internal crane system and maximum practical size and weight of fabricated members are considered. In pre-engineered building concept the complete designing is done at the factory and the building components are brought to the site in CKD (Completely knock down condition).

Aijaz Ahmad Zende et al, [1] The work involves the comparative study of static and dynamic analysis and design of Pre Engineered Buildings (PEB) and Conventional steel frames.

C. M. Meera,[2]The concept includes the technique of providing the best possible section according to the optimum requirement. This paper is a comparative study of PEB concept and CSB concept. Matthew Stuart, [3] In this course various types of pre-engineered buildings are designed and examined. Process of assembling of primary members and secondary members in PEB is explained. Sai Kiran Gone et al ,[4] In this study,an industrial structure (Ware House) is analyzed and designed according to the Indian standards, IS 800-1984, IS 800-2007 and also by referring MBMA-96 and AISC-89. F. Kavoura et al ,[5] The objective of this paper is to study the rotational stiffness of column base-plate connections in low-rise metal building systems. This papergives a comparative study of Pre-Engineered Building (PEB) concept and Conventional Steel Building (CSB) concept. Sagar Wankhade and P. S Pajgade ,[6] This concept has many advantages over the Conventional Steel Building (CSB) concept of buildings with roof truss. This paper is a comparative study of PEB concept and CSB concept. Mansi and Tausif,[7] The objective of this paper is to analyse and designs a Pre-Engineered Building (PEB) using cold formed steel 'Z' purlin section and compare it with Conventional Steel Building (CSB) with fink type truss.Chris Burnett et al[8], It explains how the soft storey effect can be reduced by providing specially designed moment resisting pre-engineered frame. Se Woon and Hyo Seon ,[9]This paper presents the minimum column-to-beam moment ratio of steel moment resisting frame (SMRF) with various connection models. Tsioupanis kyriakos,[10]Types of bolted beam to column connections, simple or shear beam to column connections, various graphs and failure patterns are also explained in this project.

II. METHODOLOGY

1].Technical parameters related to Pre-Engineered Buildings:-

Width or span of building: The center to center length from one end wall column to the other end wall column of a frame is considered breadth or span of the building. The basic span length starts from 10 to150 meters or above with intermediate columns.

Roof slope: This is the angle of the roof with respect to the horizontal. The most common roof slopes are 1/10 and 1/20 for tropical countries like India.

Design loads: Design loads for pre-engineered buildings are broadly classified into two groups: Dead Loads and Live Loads. Other loads considered are wind loads, earthquake loads, roof load, collateral loads, and auxiliary loads.

Bay spacing: The distance between the two adjacent frames of a building is called as a Bay spacing. The most economical bay spacing is 7.5m to 8.0m.

Types of frames: A frame is a combination of Columns and inclined beams. There are various type of frames: Clear span, arched clear span, Multi span, arched multi span, Single slope, Multi gable.

2].Modelling of Pre-engineered Building

For basic understanding of the concepts, Model of a warehouse is prepared in Staad pro. Also for getting plastic moment the model has been done in staad pro. Further this model is designed and analysed in SAP2000 software. The total height of the building is 9.5m. The bay width is of 5m and there are 8 bays.

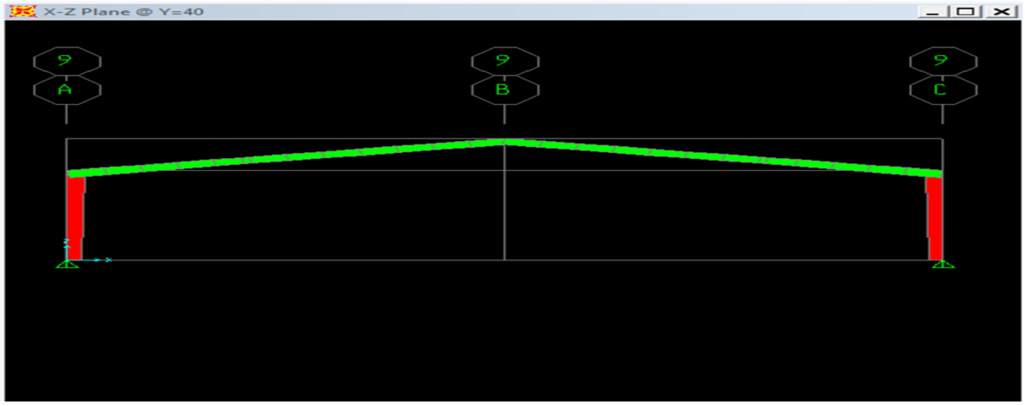

Fig. 1 Front view of warehouse. (pre-engineered).

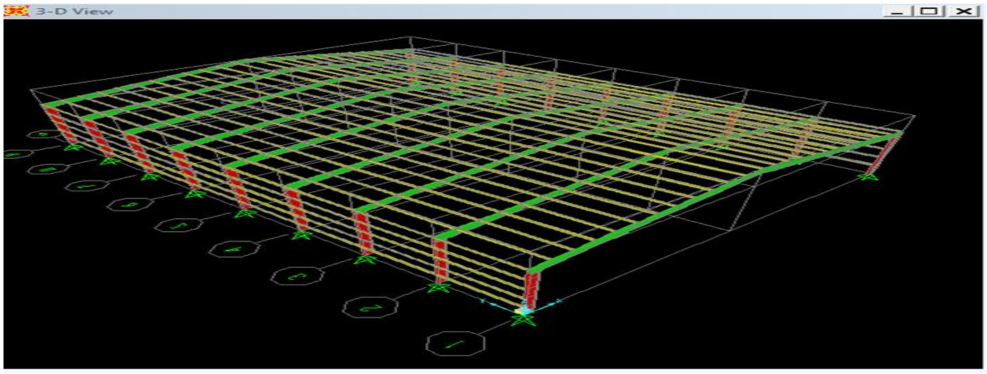

Fig. 2 3D view of warehouse. (pre-engineered).

3].Modelling of Conventional Building

In case of conventional model, a basic warehouse is modelled. The model has same dimensions as that of the Pre-engineered one. Roof truss is the additional element in the model. The roof truss which is provided is Flat Pratt Truss. It has medium pitch and can be used for large spans of the structures. The depth of these trusses is usually span/5 to span/6.

After the basic modelling, all the loads are applied. Types of applied are : Dead load, Live Load, Wind load and load combinations.

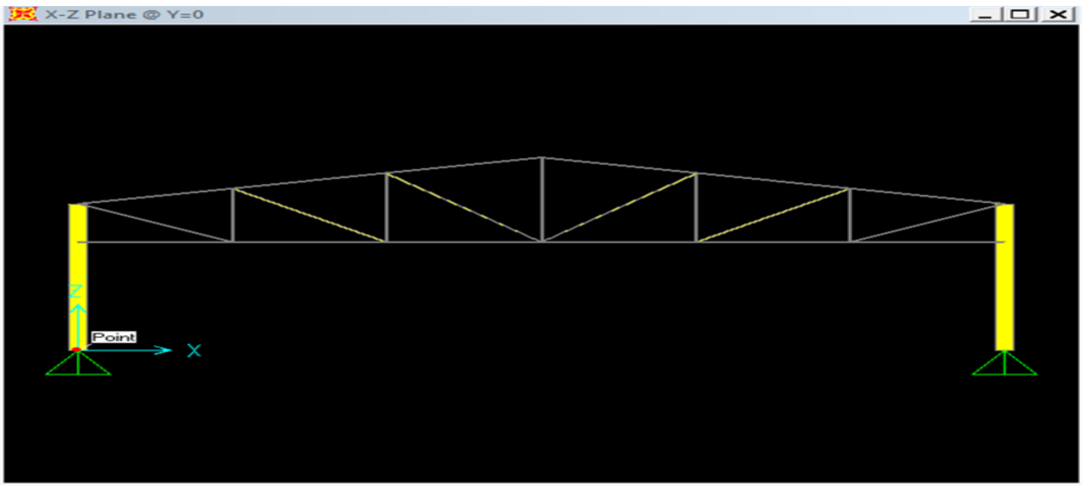

Fig.3: Front view of warehouse. (conventional).

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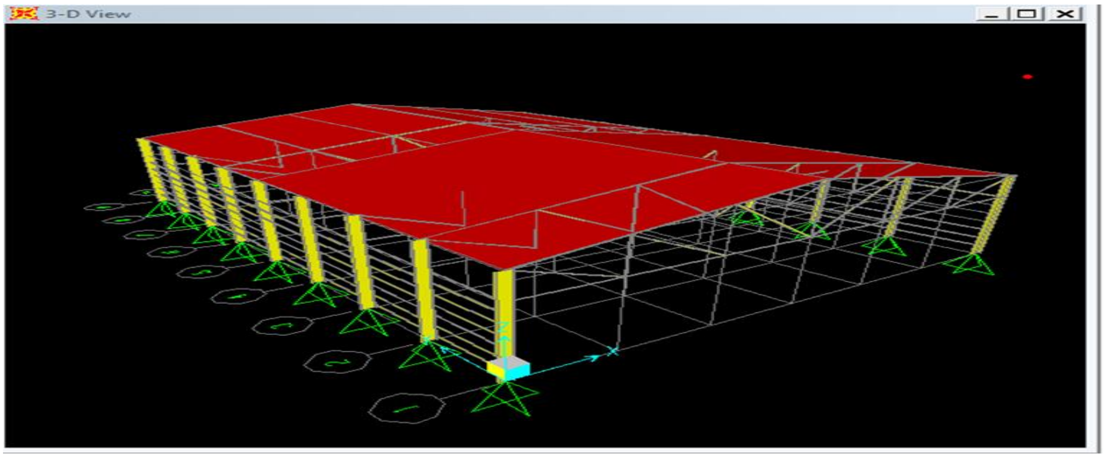

Fig.4: 3D view of warehouse.(conventional)

The loads applied are:

a] Design Dead Load :-

Weight of roof covering(galvanized sheeting) =150 N/m2

Weight of purlins =100 N/m2

Weight of wind bracing =15N/m2

b]Design Live Load :-

For model the Roof slope is <10 degrees**.**

For this case we provide access.Live Load= 1.5kN/m2 of plan area. (IS 875).

c]Design Wind Load :-(IS 875 Part3)

Design wind load is applied to walls and roof differently by referring to IS 875 Part 3.

For walls:- From table 4 IS875 part 3

Table. 1 Co-efficients for walls

	A	B	C	D
W_{lx}	+0.3965	-0.317	-0.555	-0.555
	+0.713	0	-0.237	-0.237
W_{lz}	-0.555	-0.555	+0.396	-0.317
	-0.237	-0.237	+0.713	0
W_{l-x}	-0.317	+0.3965	-0.555	-0.555
	0	+0.713	-0.237	-0.237
W_{l-z}	-0.555	-0.555	-0.317	+0.3965
	-0.237	-0.237	0	+0.713

For roof: from table 5 IS875 part 3

Table. 2 Co-efficients for roof

	A	B	C	D	Cpi
W_{lx}	-1.167	-1.167	-0.4	-0.4	+0.2
					-0.2
W_{lz}	-0.8	-0.378	-0.8	-0.378	+0.2
					-0.2
W_{l-x}	-0.4	-0.4	-1.167	-1.167	+0.2
					-0.2
W_{l-z}	-0.8	-0.378	-0.8	-0.378	+0.2
					-0.2

Various load combinations are applied to the models. The models are then analysed and various results such asshear , axial force and moments are taken as reference for designing of special moment connections.

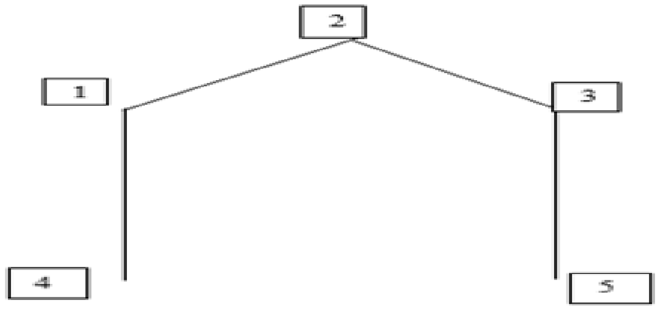

Fig.5: Frame Skeleton

Considering the maximum values of shear force, axial force and moment around the frame for pre-engineered building. For joint 1) axial force= 317.23 kN ,Shear force= 327.67 kN Moment 3-3 = 1717.85 kNm.

For joint 2)axial force= 237.46 kN , Shear force= 18.23 kN, Moment 3-3 = 80.78kNm.

For joint 3) Axial force= 317.28 kN , Shear force= 327.61 kN, Moment 3-3 = 1717.85 kNm.

Considering the maximum values of shear force, axial force and moment around the frame for Conventional building. For joint 1) axial force= 2177.37 kN ,Shear force= 339.56 kN Moment 3-3 = 725.21 kNm.

For joint 2)axial force= 476.036 kN,Shear force= 0.24 kN, Moment 3-3 = 0.16 kNm.

For joint 3) Axial force= 2711.37 kN , Shear force= 255.08 kN, Moment 3-3 = 840.38 kNm.

III. RESULTS AND DISCUSSIONS

Types of connections: For designing of special moment connections in pre-engineered buildings following designs are done:

A] Special moment connections referring IS Codes:

Light moment connections: Bolted Clip Angle Connection :These connections are subjected to small end moments and large end shears are called Light moments connections.

Heavy Moment Connections: The moment carrying capacity of clip angle connections is limited. When the connections are subjected to heavy moments following connections are provided: The split beam connection ,The Bracket connection B] Special Moment Connections referring FEMA-350 : Prequalified Connections are generally provided by referring FEMA-350. Prequalified connection details are permitted to be used for moment frame connections for the types of moment frames and ranges of the various design parameters indicated in the limits. Prequalified Welded Fully Restrained Connections. Prequalified Bolted Fully Restrained Connections.

B] Special Moment connections referring to IS codes are designed:

1] Clip Angle Connection:

Size of clip angle assumed is 70 x 70 x 10 after design the thickness computed was calculated as 10.68mm . And a minimum of 2 bolts are provided over the clip angle outstanding leg. And the maximum tension resisted by the connection will be twice the value of the bolt in tension.

2] The Split Beam Connection:

Split beams are made by cutting I-sections at the mid of the web. The bending moment in split beam connection is resisted by the bolts on split beams and the end shear is resisted by the bolts in web clip angles. Also clip seats are provided if the end moment produces a pull greater than the value of bolt in tension. ISMB 200 is assumed for split beam connection. Thickness computed is 7mm.

3] The Unstiffened Seat Connection:

In Unstiffened seat connection an angle is provided below the beam flange and is designed to transfer the end reaction of beam to the column through connections. In conventional design it is assumed that this type of connection does not restrain the rotation at the beam end in the vertical plane and the end reaction is the only force to be considered. This type of connection is provided as bolted as well as welded connections.

For conventional Model:

Unstiffened Seat Connection(bolted):-

A nominalcleatangle ISA150 X150 X10 mmoverthe top of the beamflange. Connectthe legs ofthis angle with flanges of beamand column with 2, 20 mmdia bolts. For Connection of seatanglelegwithcolumnflange 20 mmdiameterbolts ofgrade 4.6, 7 in numbers, in two rows ata pitch of60 mm.

Unstiffened Seat Connection(welded):-

Seat angle of 150 X 150 X10 mm is provided. For connection between seat angle and column flange fillet weld of 6mm is provided. For connection between seat angle and beam flange by 2 bolts of 20mm diameter.

For Pre-engineered Model:

Unstiffened Seat Connection(bolted):-

A nominal cleat angle of 75 X 75 X 10 mm over the top of the beam flange is provided. Connect the legs of thisangle with the flanges of beam and column with 2, 20mm diameter bots of grade 6 in numbers in 2 rows. For Connection of seatanglelegwithcolumnflange 20 mmdiameterbolts ofgrade 4.6, 6 in numbers, in two rows ata pitch of60 mm.

Unstiffened Seat Connection(welded):-

Seat angle of 75 X 75 X 8 mm is provided. For connection between seat angle and column flange fillet weld of

6mm is provided. For connection between seat angle and beam flange by 2 bolts of 20mm diameter.

4] The Stiffened Seat Connection:

In stiffened seat connection, the outstanding leg is stiffened by angle, thus the seat does not remain flexible. The outstanding leg of seat angle is stiffened when the reaction to be transferred to the column is very large or when the seating leg of 100 mm cannot provide the required bearing area. Also, due to a large reaction the number of bolts required to join the connecting leg with the column maybe so large that more than two or three rows of bolts will be required.

For conventional Model:

Seat angle of 200 X 150 X 10mm is provided with seatinglegof 200mm connected to the flange of beamwith2,24mmdia.Bolts. 90 X 60 X 8 mm of stiffener angle is provided. 5 bolts in 2 vertical rows are provided.

For Pre-engineered Model:

Seat angle of 150 X 150 X 10mm is provided with seatinglegof 150mm connected to the flange of beamwith2,24mmdia.Bolts. 90 X 60 X 8 mm of stiffener angle is provided. 4 bolts in 2 vertical rows are provided.

5] Bracket Connection:

Bracket type of connections are made whenever two members to be secured together do not intersect. Structurally, this is not a desirable type of connection because a pronounced eccentricity is introduced both in the connection and in one of the members to be jointed.These type of joints are subjectedto direct shear and torque/ bending moment due to eccentric shear.

For conventional Model:

For this connection double J groove weld is provided with the throat thickness of 15 mm. Depth of bracket plate is 400 mm with 8mm fillet weld.

For Pre-engineered Model:

For this connection double J groove weld is provided with the throat thickness of 10 mm. Depth of bracket plate is 300 mm with 8mm fillet weld.

6] Column Base Design: Bolted Gusseted Base with concrete pedestal.

For conventional Model:

2 gussetplates one on each, on the two flanges of column sections. two gussetangles=ISA150 X150 X15 mm. Gusset Plate thickness is 16mm. Base plate 870 X280 X 30 mm in size. Numberof bolts required to connectcolumn flanges are 18. 9, 24mmdiameterbolts on each flange in two rows. Provide gussetplate 288 X280 X16mmin size.

For Pre-engineered Model:

2 gussetplates one on each, on the two flanges of column sections. two gussetangles=ISA150 X150 X15 mm. Gusset Plate thickness is 8mm. Base plate 850 X60 X 30 mm in size. Numberof bolts required to connectcolumn flanges are 4, 24mmdiameterbolts on each flange in two rows. Provide gussetplate 288 X60 X16mmin size.

7] Welded Moment Connection on column flange with Haunch:

This moment Connection is done by referring to AISC and FEMA 350. This type of Prequalified connection are applied Special Moment Frame system. The web of the beam is removed in a single cut in the area adjacent to the column flange, and is replaced with a heavy Haunch plate. This connection is applicable for Pre-engineered buildings. Cleat angle of dimension of 80 X 80 X 12 mm is provided with the depth of 500 mm. top cover plate of 260 X 150 X 20 mm is provided. Haunch plate of 180 X 25 mm is provided.

Connection of beam column and angle weld= 10mm

Connection between beam and cover plate=14mm

Connection between column stiffen plate and bottom cover plate=16mm.

IV. CONCLUSION

Pre-engineered steel structures building offers low cost, strength, durability, design flexibility, adaptability and recyclability. Steel is the basic material that is used in the materials that are used for Pre-engineered steel building. For longer span structures, Conventional buildings are not suitable with clear spans. Pre-engineered building are the best solution for longer span structures without any interior column in between as seen in this present work. With the advent of computerization, the design possibilities became almost limitless. Saving of material on low stress area of the primary framing members makes Pre-engineered buildings more economical than Conventional steel buildings especially for low rise buildings spanning up to 90.0 meters with eave heights up to 30.0 meters. PEB structures are found to be costly as compared to Conventional structures in case of smaller span structures. Also from the below table we can conclude that the PEB sections are lesser in size and the required number of bolts is also very less.

		Conventional Building	Pre-engineered Building
Unstiffened Seat Connection (Bolted)	Cleat Angle	150 X 150 X 10 mm.	75 X 75 X 10 mm
	Number of bolts for seat angle	7, 20 mm dia. Bolts in 2 rows.	6, 20 mm dia. Bolts in 2 rows.
	Number of bolts for cleat angle	2, 20mm dia. Bolts.	2, 20mm dia. Bolts.
Unstiffened Seat Connection (welded)	Seat angle	150 X 150 X 10mm.	75 X 75 X 8mm.
	Connection seat angle and column flange	6mm fillet weld.	6mm fillet weld.
	Connection seat angle and beam flange	2, 20mm dia.	2, 20mm dia.
Stiffened Seat Connection	Seat angle	200 X 150 X 10mm	150 X 150 X 10mm.
	Stiffener angle	90 X 60 X 8mm.	90 X 60 X 8mm.
	Number of bolts	5 bolts in 2 vertical rows.	4 bolts in 2 vertical rows.
Bracket Connection	Depth of bracket plate	15mm.	10mm.
	Weld thickness	400mm.	300mm.
Column Base	Gusset plate thickness	16mm.	8mm.
	Base plate	870 X 280 X 30mm.	850 X 60 X 30mm.
	Gusset plate	288 X 280 X 16mm.	288 X 60 X 16mm.
	Number of bolts	9, 24mm dia. in 2 rows.	4, 24mm dia. in 2 rows.

Fig.12: Comparison between Pre-engineered and Conventional Building.

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