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ANALYSIS AND DESIGN OF PRE - ENGINEERED STEEL BUILDING FOR AIRBUS A-380 HANGAR USING IS CODES

Moiz Mohammed [1]
Ahmed Hussain Mohammed

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A B S T R A C T

The pre-engineered steel framed structure (PEB) introduced in 1960's includes a structural frame, roofing system and wall supports; for the construction of industrial structure like ware houses, car showrooms, workshops, function halls, stadiums, aircraft hangars etc. is found to be economical, light weight and fast erection process. The PEB's are built to perform some important functions, provide enough space for storing goods; aircrafts etc.. and protecting the storage items against natural disasters, wind forces, and rain. In this research work a hangar for airbus A-380 has been designed considering its dimensions; for maximum span of 120M and width of 115M and a height of 30M as a pre-engineered framed structure. For designing the structural members staad pro (V8i) software is used. This structural design is in accordance with the specification of the general construction in steel confirming to IS:800-2007 (limit state design) and wind application as per latest code confirming to IS:875-2015 (part-III) and earthquake analysis has been done as per IS-1893-2016 (part-IV). For the first time a hangar for A-380 has been designed for using above IS Codes, structural design details, connection details have been produced and found that the total steel is 3502.43 Metric Tons.

1. INTRODUCTION

In this world of population it is seen that many national, international and domestic aiports requires the building for aircrafts servicing.Therefore for servicing and maintaining the aircrafts a building called as a hangar is required so, for the construction of an aircraft hangar more space is required because aircraft hangar consumes more space for its errection and required experinced structural designers. Space for erecting the hangar is the major criteria for some airports where space matters for its maintenance because in an airport other aminities are required to be adjusted for different purposes and need permissions from compitent airport authorities otherwise it is highly difficult for aircrafts to be maintained in good condtion because in every arrivals to the airports the aircrafts need to get serviced for smooth travelling and they need to be parked in closed structure, so that it can be safe form whether conditions. Many researchers given designing and detailing for aircraft hangars for different sizes consisting of spans starting from 30m to 60m and 60m to 90m. Whenever hangars are planned for airports it is to see that construction of hangars should be economical

[1] Corresponding author: Moiz Mohammed
Email: moizmohammed93@gmail.com

because the cost would be estimated as on area basis that is,it would be in per square meters or some times it would be in per square feets or some times its cost would be in per tonnage of steel as all the hangars are usually made of steel only. If area is more cost would also be morebecause if area of hangar increases obviously the quantity of steel will also increase due to which structure will not be economical. (Muhammad Umair Saleem et al., 2018)

Therefore in this research work a large span hangar for air bus A-380 for a maximum dimensions of 120M X 115M and a maximum clear height 30M has been identified as complex issue because for designing long span hangar it takes more time in software to pass the section properties. In india no aiport is maintaining a hangar of the above dimensions as in india air bus A-380 is not available in future if it is in service then this design will be very helpful to erect the larger hangar for the maintenence of air bus A-380.

2. LITERATURE REVIEW

(Animesh et al., 2020), conducted a Parametric Study on Design of P.E building Using IS-800-2007 steel code and AISC 360-2010, 13th edition. It was found that pre-engineered building sysem has become very popular due to following reasons,first one is speedy construction and control over the quality, suitable for single storey building system, as compared to conventional steel structures. In this research a pre-engineered steel building structure for ware house was analysed and designed by practicing IS- 800-2007 code of practice and american code AISC360-2010 by maintaining loading parameters similar. A comparative study is made by calculating the quantity of steel using both codes using structural analysis and design software, STAAD-Pro. In this research it is identified that 27% of quantity of steel can be safed by designing the ware houseas an indistrial building. the major reason in increasing the weight is of bay spacing , serviceability criteria, deflection limts is higher in IS:800-2007 compared to AISC360-2010, and limiting ratios in sections.In IS:800-2007 the value of imposed load is being considered as 0.75 KN/M^2 whereas it is 0.57 KN/M^2 in AISC:360-2010.

(Balamurali et.al., 2019), did a Comparative Study by designing a two Storey Car Showroom Using P.E.B Concept Based on B.S and E.C systems. By using staad STAAD pro software by practicing british standards and euro codes by considering wind and seismic loads.

In software two models were created using two different codes. The members has been assigned as a tapered frame in british standards whereas universal standard section frame has been assigned for Euro code system. After analysing and designing for both the structure the following differences were found.The wind pressure obtained is 1.78 KN/M^2 based on British Standards. EQ analysis was also done by T-H method. The total quantity of steel were estimated as 1125.43KN in british code whereas in Euro code it was estimated as 1214.31 kN (7.9% heavier). Comparision of dynamic analysis showed that results for Euro Codes are lower than BS codes.

It was found that Pre-engineered building are favored for industrial sheds due to its better quality and durability as compare to Reinforced cement concrete structures and P.E.B provides extra internal space as the gap between two columns is more.

(Humanaaz et al., 2020), did a Comparative analysis of Pre Engineered and Conventional Steel Building. The design of steel structure using P.E.B system is a current technology that provides low-budget, eco-friendly and sustainable frames. Prior to the establishment of the PEB system the C.S.B system used to construct which was time-consuming and costly design. In the C.S.B the dimensions of the members from top to bottom are uinform through out which leads to high density of material and also excess quantity of steel. Thus,based on the loading effect built-up sections are used in PEB and only bolted connections are provided at the construction site. In this research work, a G+3 floor industrial warehouse is designed and analyzed as per Indian standard code IS 800-2007 (limit state method).The analysis and design of warehouse building structure was configured by using STADD-pro software. The authors found the following parameters Displacement, Support Reaction, Axial shear Forces and Bending Moment, Steel Quantity, Wind Resistance, Purlin for both the systems and compared them. It was found that PEB takes less time and provides lightweight design when compared to C.S.B structures when the span is large and PEB provides column-free space.

(Nihar shah et al., 2021), did a comparative study of PEB by designing a P.E.B & C.S.B using IS-codes & American codes and found that the design of PEB and CSB structure using an AISC code gives 3% to 10% light weight sections as compared to IS-codes.AISC code has less factor of safety compared to IS- code. Being a less factor of safety, AISC code resulting a light weight sections which is not suitable for india to erect the pre-engineered building.

3. METHODOLOGY

This study includes the designing of an airfraft hangar for airbus A-380 as a pre-engineered steel framed building using indian standard code (IS-code) willing to errect this structure in future if the airbus A-380 is bring to india as a own indian aircraft for indians travelling from own country to other countries. Hence in this research worka design has been carried out for an aircraft hangar of maximum dimensions for a span length of 120M, and width as 115M and a clear height of 30M by considering wind analysis and seismic analysis. In this research work total 17 pre-ennginееred tapered steel frames are being used and 16 total number of bays are obatained by maintaining 7.188M as a bay spacing.The structural design in the attached calculations is in accordance with the specifications of the General construction in steel IS: 800-2007 (Limit State Design), (Mayuri Patil 2019) and wind load applications as per IS: 875 -2015(Part –III) and Earth Quake Analysis per IS-1893(Part-4)-2016.

4. PRE-ENGINEERED BUILDING (PEB)

Pre-enginnered buildings are the structures that are constructed for the purpose of work shops,garriages, storage rooms,servicing centres etc. For constructing thsese structures we required designing software and based on the customers need all the members of the frame are desined. (Anisha Goswami et al., 2018).

All the components are made in steel plant itself for structural and aesthetic requirements. These are tapered sections which are combinations of Built-up section. (Saranya and Shallini 2019) Manufacturing process like cutting, welding and painting is done at the plant itself. Manufactured materials are transported to customer site under completely knocked down condition (CKD). The pre-engineered building members are erected at site through high strength grip nut and bolts system. Under same loading Conditions these are shifted to the selected place. Restoration of buildings happens in case of Pre Engineering system. PEB is entirely a concept of Superstructure. In pre-engineered building the main Member is tapered section and Secondary members are “Z” and “C” section. Delivery of all members takes 6 to 8 weeks approximately; Foundation design is very simple for these types of buildings. Time for Erection and estimated budget will be known before construction. In PEB installation procedure is easy, fast, with the help of lifting machines. Majority of pre-engineered building are used due to low weight and offer higher stresses to natural forces. (Shahid Wasim Chaudhary et al., 2019)

The pre-engineered building system can be applied to the following steel structures.

- Industrial Buildings
- Ware Houses
- Air Craft Hangars
- Commercial Complexes
- Celebration halls
- School Buildings
- Metro Stations
- Parking Lots
- Stadiums
- Railway Platforms
(Anisha Goswami et al., 2018).

4.1 Aircraft hangar

An aircraft hangar is a closed structure which is constructed for the use of servicing and maintenance of various aircraft as a protective space because whenever an aircraft arrival be seen after a long journey it has to be taken under that hangar where all the equipment’s are available for it servicing. In an aircraft hangar more space is required for its storage and extra space for its maintenance. Majority of the hangars are design as a pre-engineered steel building due to its light weight and higher resistance over wind and seismic loads.

5. DESIGN CODES

The following design codes have been used in this design of pre-engineered building for an aircraft hangar for airbus A-380.

Table 1. Design codes.

S. No	Name of the IS Code	Code Number
1.	IS Code of Practice	IS-800-2007
2.	IS Code of Practice for Cold Formed Light Gauge Structures	IS-801-1975
3.	IS Code of Practice Design Loads for Part-1	IS: 875-1987
4.	IS Code of Practice for Design Loads Part-2	IS: 875-1987
5.	IS Code of Practice for Design Loads Part-3	IS: 875-2015
6.	IS Code of Practice for Earth Quake	IS 1893-2016 (Part-IV)

6. MATERIALS IDENTIFICATIONS

The below are the standards and identification for materials through which the structural members have designed.

Table 2. Materials specifications.

S. No	Materials	Specifications	Min. Strength
1.	**Primary Members**		
a.	Beams & Columns	IS 2062: 2006 Grade E-350	F_y = 34.5 Kn/cm^2
b.	Tubes	IS 4923: 2017	F_y = 21.0 Kn/cm^2
c.	ISMC & ISMB	2062: 2011 Grade E250	F_y = 25.0 Kn/cm^2
S. No	**Materials**	**Specifications**	**Min. Strength**
2.	**Secondary Members – Zee & Cee Sections.**		
a.	Material Finish	G.I – IS 277_2018	F_y = 34.5 Kn/cm^2
3.	**Sheeting**		
a.	Bare / Colour coated	Comprising of 55% aluminum	

	Galvalume steel	+ 43.5% zinc + 1.5% silicon as per ASTM A-755/A-792M	F_y = 55.0 Kn/cm^2
4.	**Gutters & Downspouts**		
a.	Gutters will usually be made from the materials used for Wall sheeting.		
5.	**X-Bracing Members**		
a.	Rods	IS 2062: 2011 Grade E250	F_y = 25.0 Kn/cm^2
b.	Angles	IS 2062: 2011 Grade E250	F_y = 25.0 Kn/cm^2
6.	**Anchor Bolts**	IS 2062: 2011 Grade E250 Bolts with One coat of Epoxy primmer	F_y = 25.0 Kn/cm^2 F_u = 40.0 Kn/cm^2
7.	**High Strength Bolts (For Primary Connections)**	ASTM A 325	F_u = 83 Kn/cm^2
8.	**Connection Bolts**	IS 1367 CL 4.6	F_u = 40 Kn/cm^2

7. DESIGN ASSSUMPTIONS

Standard assumptions which are usually used in designing of PEB buildings as per codes are also used in designing the hangar for A.380 in the study.

8. STRUCTURE CONFIGURATION DETAILS

Table 3. Structure configuration details.

S.no	Particulars	Details
1.	Building Type	Aircraft Hangar for Airbus A-380
2.	Width	120M
3.	Length	115M
4.	Roof Slope	1:10
5.	Peak Rafter Height	30.0 Meter From F.F.L
6.	Bay Spacing	1@7.1875mO/C+14@7.1875mC/C+1@7.1875mC/O
7.	Roof Cover	0.50 mm thick TCT (Bare Galvalume Sheet).
8.	Wall Cover	0.50 mm thick TCT (Pre-Painted Galvalume Sheet).
9.	Sheeting Condition	
a.	Side Walls	Axis A / (1-17): 3.0m Self-supporting brick wall and above sheeted.
		Axis Y/ (1-17): 3.0m Self-supporting brick wall and above sheeted.
b.	End Walls	GL - 1: 3.0m Self-supporting brick wall and above sheeted.
		GL - 17: 3.0m Self-supporting brick wall and above sheeted from GL-(A-C) and 0.5m sheeted from eave and open for access from GL-(C-V) and 3.0m Self-supporting brick wall and above sheeted from GL-(V-Y).

9. DESIGN PROCESS AND PRINCIPLES

For designing aircraft hangar for airbus, A-380 as a pre-engineered steel building we required a design software called Staad-pro which would help us to design the members of the frames. In this software the design process and principle is firstly we need an auto-cad software drawings in plan so that we can mark the center to Centre distance after marking the distances we double click the software then software will show one dialogue box in that we have to provide center to Centre distances, in software we follow the node system or else we can merge the drawing from AutoCAD software to design software and we will assign the supports by using support commands and it will be considered as fixed, then we can go for member properties and for pre-engineered building system we provide tapered section with the help of node systems we use add beam and add column commands and we assigned the section details. After that we go for loads system and we will create different loading and then we will assign all the loads system to the frame and then we provide the details for all the remaining frame then we have to run the analysis and need to check for any errors are occurring or not, if it is there then we have to modify the member properties and again we do run analysis till we the degree of precision (Sunil Kumar et al., 2019)

10. STAAD PRO

The STAAD- Pro software is a design software used to design the various structures in civil engineering such as reinforced cement concrete structures such as building beams and columns, dams, road bridges etc. by using this software we can perform modeling, analyzing and we can design the structure. This software supports standards of various countries and it consists of various codes Indian standard code, American institute of steel construction, Euro – codes. This software provides various commands in analysis and design of beams and columns. This software would save our time for doing vast calculations for analyzing and designing a three-dimensional model and helps in multi-material designs.

11. LOADS CALCULATIONS

Primary Loads
D.L: self-weight
L.L: imposed load
WL: W.L with internal coefficient +/- 0.18
E.L: Seismic Load
Dead Load:
Dead load has been considered as 0.1 Kn/m^2 due to weight of sheeting +Purlins and
Roof insulation + Self weight of frame.
Live Load:

Live load on roof has been considered as - 0.75 Kn/M^2

Collateral loads:

Light load – 0.15kn/m

Wind loads:

V = 44 m/sec,
K1 = 1.00(for 50years)
K2 = 1.095 as per IS 875(Part-III)-2015
K3 = 1.0
K4 =1.0
$V_z = V_b \times K_1 \times K_2 \times K_3$
$P_z = 0.6(V_z)^2 = 1.4$ Kn/m2.
P_d = Ka x Kd x Kc x Pz
P_d = 0.8 x 0.9 x 0.9 x 1.4
P_d = 0.90 KN/M^2
Internal pressure coefficient = +/-0.5

Wind application on staad members for High bay

H/W = 25/ 120 = 0.209
L/W = 115/120 = 0.959
Wind Speed = 44 m/sec
K1 = 1
K2 = 1.095
K3 = 1
Vz = 44 x 1 x 1.095 x 1
= 48.18 m/sec
Pz = 0.6xVz^2 = 1393/1000=0.908 Kn/m^2
C1 = 0.7
C2 = -0.2
C3 = -0.95
C4 = -0.4
Cpi = 0.5
Ka =0.8
Kd = 0.9
Kc = 0.9
Design Wind Pressure
Pd= KaxKdxKcxPz
Pd= 0.8x0.9x0.9x1.4
Pd = 0.908kn/m^2

Earthquake load:

Earthquake load as per IS 1893(Part-IV) – 2016
Zone-II = 0.10
Imp. factor = 1.5
Res. Red. factor = 4.0

Minimum Thickness Criteria

Secondary Members: 2.5 mm thick

Serviceability Criteria

Main Frame
Vertical deflection : Span / 150
Lateral deflection : Height / 100
Purlins & Girts : Span / 150

12. ANALYSIS AND DESIGN

12.1 Dead Load

= 0.1Kn/m2
= 0.1x7.1875
= 0.719Kn/m

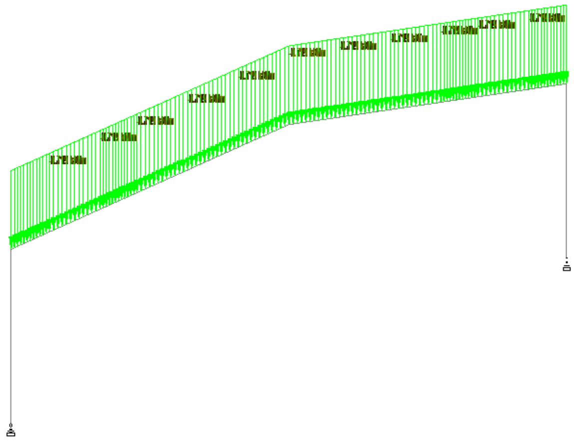

Figure 1. Dead loading diagram

12.2 Live Load

= 0.75Kn/m2
= 0.75 x 7.1875
= 5.391kn/m

12.3 Collateralload

= 0.15Kn/m2
= 0.15 x 7.1875
= 1.07kn/m

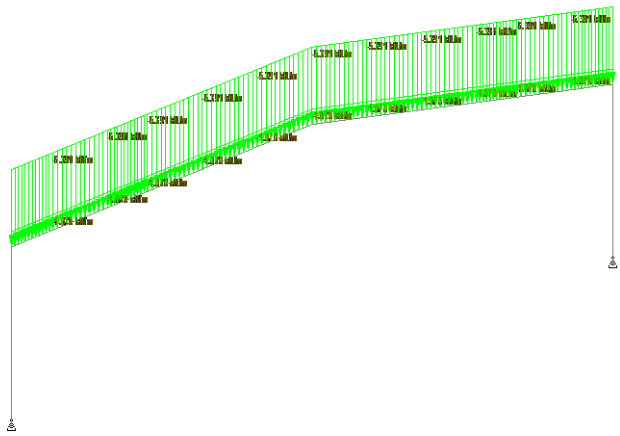

Figure 2. Live loading diagram

12.4 WLL-P (Wind Load Left Pressure)

12.4.1 Presure On Column

(0.7 -0.5) x 7.1875 x 0.908 = 1.304kn/m
(-0.2 -0.5) x 7.1875 x 0.908 = -4.564kn/m

12.4.2 Pressure On Rafter

(-0.95 -0.5) x7.1875x0.908 = -9.455kn/m
(-0.4 -0.5) x7.1875x0.908 = -5.868 kn/m

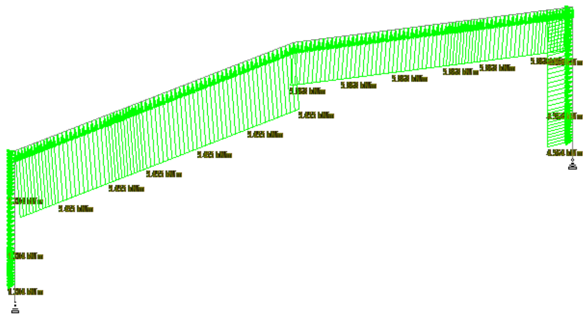

Figure 3. Wind load left pressure diagram

12.5 WLR-P (Wind Load Right Pressure)

12.5.1 Suction Column

(0.7 + 0.5) x 7.1875x0.908 = 7.825 Kn/m
(-0.2 + 0.5) x 7.1875x0.908 = 1.956Kn/m

12.5.2 Rafter

(-0.95 + 0.5) x 7.1875x0.908 = -2.934Kn/m
(-0.4 + 0.5) x 7.1875x0.908 = 0.652Kn/m

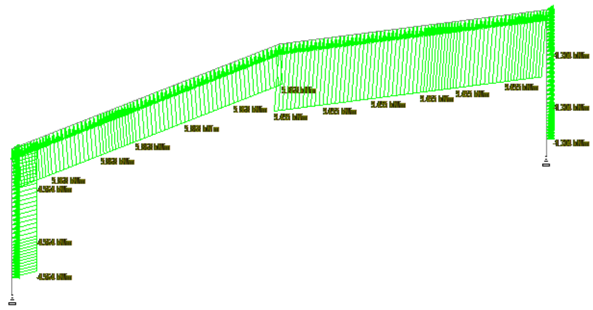

Figure 4. Wind load right pressure diagram

12.6 WLL-S (Wind Load Left Suction)

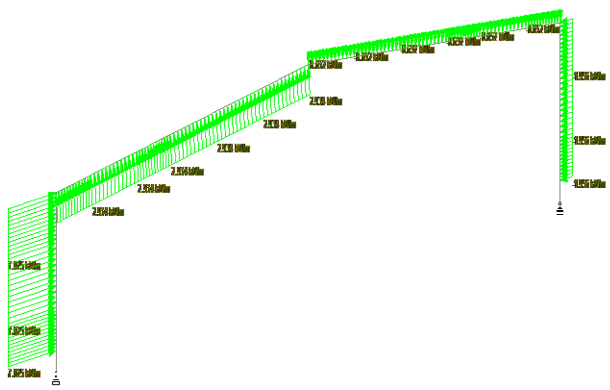

Figure 5. wind load left suction diagram

12.7 WLR-S (Wind Load Right Suction)

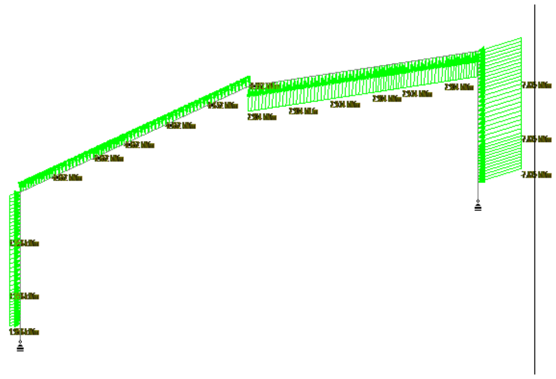

Figure 6. Wind load right suction diagram

12.8 WL Longitidinal 90

12.8.1 Long – 90 For Column

(-0.5 - 0.5) x 7.1875x0.908 = -6.521 Kn/m
(-0.5 - 0.5) x 7.1875x0.908 = -6.521 Kn/m

12.8.2 Rafter

(-0.8 - 0.5) x7.1875x0.908 = -8.477 Kn/m
(-0.8 - 0.5) x7.1875x0.908 = -8.477 Kn/m

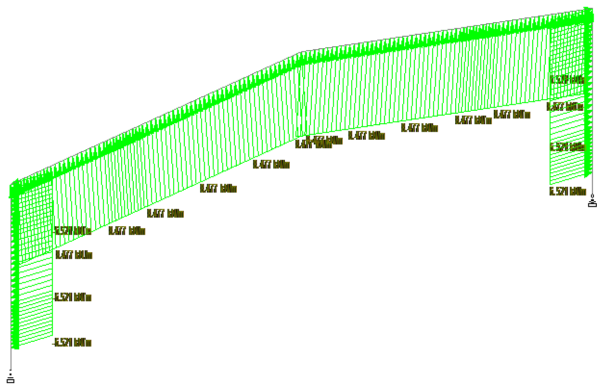

Figure 7. Wind load longitudinal 90 diagram

13. NODE DISPLACEMENT SUMMARY

The below is the node displacement summary in the tabular form.

All | Summary

			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	257	122	109.838	-0.832	-1.437	109.850	-0.000	0.002	0.001
Min X	253	123	**-109.848**	-0.832	-1.438	109.861	-0.000	-0.002	-0.001
Max Y	70	103	-12.758	**77.912**	-103.845	130.448	-0.011	-0.000	0.000
Min Y	233	101	0.002	**-643.827**	72.669	647.915	0.009	0.000	0.000
Max Z	799	102	12.007	-0.107	**271.860**	272.125	-0.003	0.000	-0.000
Min Z	799	109	-0.576	-0.602	**-284.610**	284.611	0.006	-0.001	0.000
Max rX	22	124	-0.554	-1.779	112.075	112.091	**0.035**	0.000	-0.000
Min rX	840	109	0.000	0.000	0.000	0.000	**-0.029**	0.008	-0.000
Max rY	848	109	0.000	0.000	0.000	0.000	-0.025	**0.022**	0.000
Min rY	844	109	0.000	0.000	0.000	0.000	-0.025	**-0.022**	-0.000
Max rZ	877	101	-20.656	-39.977	31.982	55.206	-0.019	-0.003	**0.043**
Min rZ	886	101	20.730	-39.980	31.973	55.231	-0.019	0.003	**-0.043**
Max Rst	233	101	0.002	-643.827	72.669	**647.915**	0.009	0.000	0.000

13.1 Maximum deflection = 643.827mm (vertical).
Limiting deflection (V/180) = 120.0m/180.
= 666.66mm

Hence safe in Deflection.

13.2Maximum deflection =109.838mm (horizontal).
Limiting deflection (H/150) = 25.0m/150.
=166.66mm

Hence safe in Deflection.

14. BEAM DESIGN SUMMARY

The below is the beam design summary in the tabular form.

Postprocessing: Displacements Reactions Beam Results Plate Results Solid Results Dynamics

All Summary Envelope

	Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kN-m	My kN-m	Mz kN-m
Max Fx	232	121	70	3566.697	287.432	-3.530	-0.672	28.839	846.388
Min Fx	17	121	3	-3289.593	-194.132	-0.019	-0.720	30.821	-1246.446
Max Fy	845	101	697	-445.212	949.970	0.679	-2.000	-6.346	9597.897
Min Fy	819	101	671	-459.132	-893.013	0.126	0.397	3.126	9748.343
Max Fz	10597	101	877	-0.140	-18.125	499.421	-0.002	-0.211	1.887
Min Fz	10606	101	886	-0.150	-18.118	-499.429	0.002	0.211	1.886
Max Mx	752	114	602	197.936	54.339	44.694	13.199	-266.910	-4418.297
Min Mx	751	114	602	204.798	-14.472	-44.732	-13.085	267.010	-4418.297
Max My	751	114	602	204.798	-14.472	-44.732	-13.085	267.010	-4418.297
Min My	752	114	602	197.936	54.339	44.694	13.199	-266.910	-4418.297
Max Mz	411	101	218	905.990	-612.642	-3.118	-0.538	-9.089	15305.275
Min Mz	415	101	249	906.051	612.841	-3.119	0.537	-9.096	-15306.427

15. DESIGN DETAILINGS AND DRAWINGS

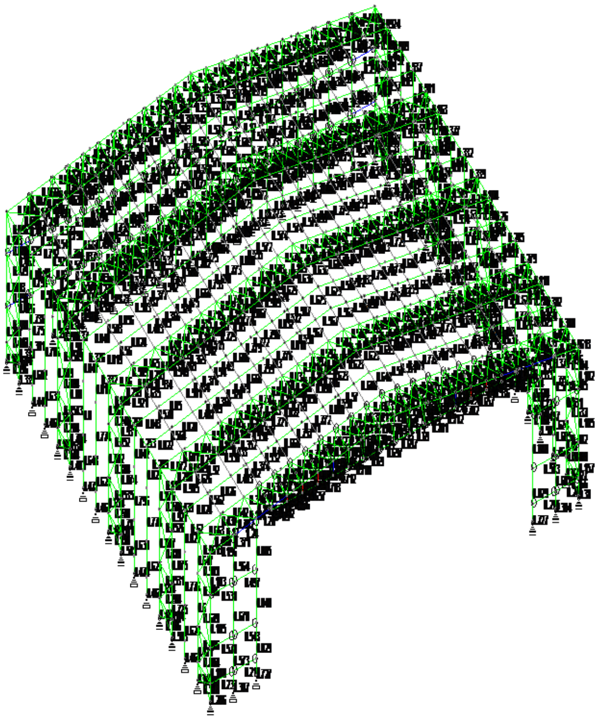

Figure 8. Utility check diagram

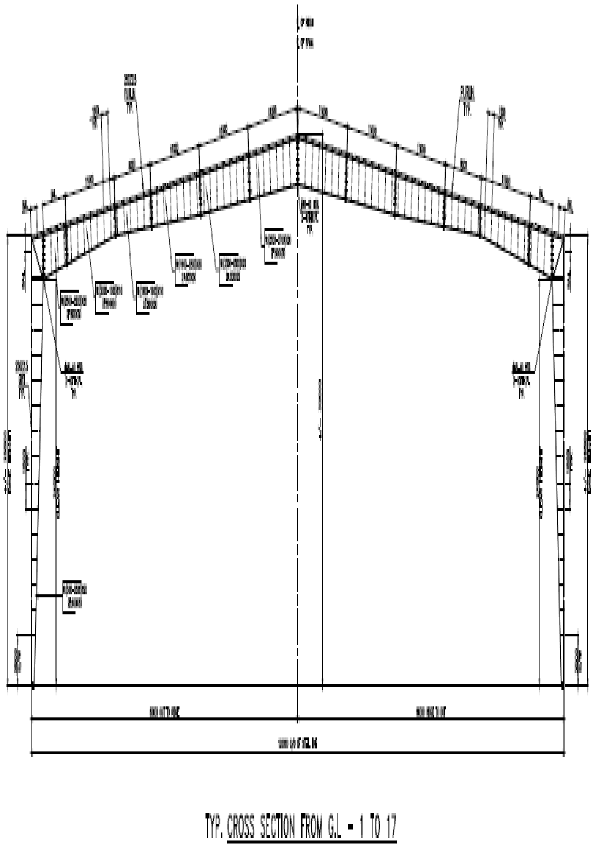

Figure 9. Sectional elevation

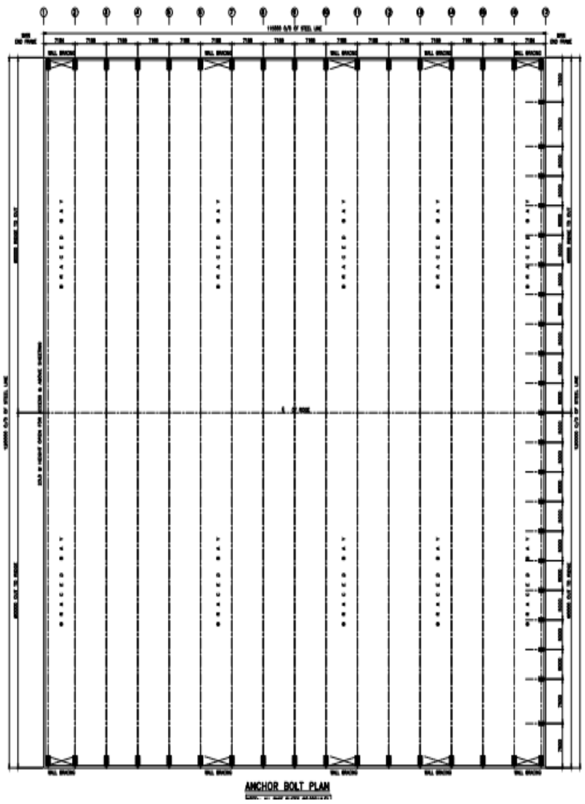

Figure 10. Plan

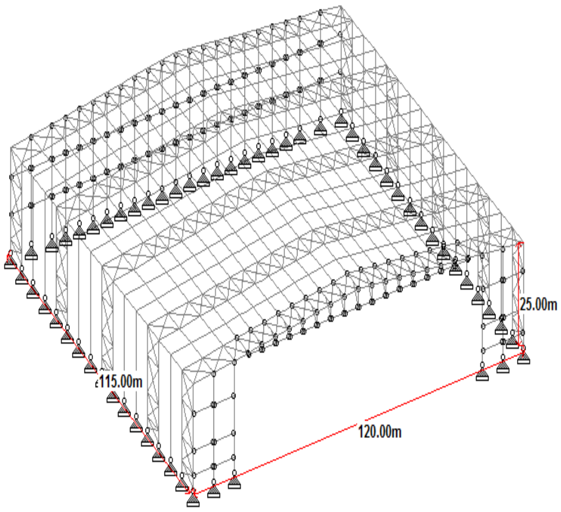

Figure 11. Staad model In 3-dimensions

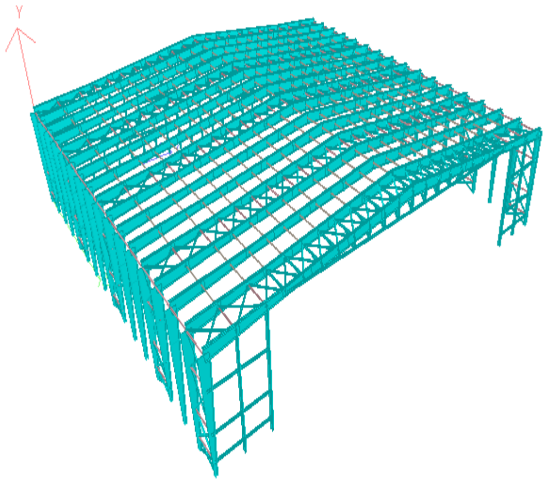

Figure 12. 3D-rendered staad- model

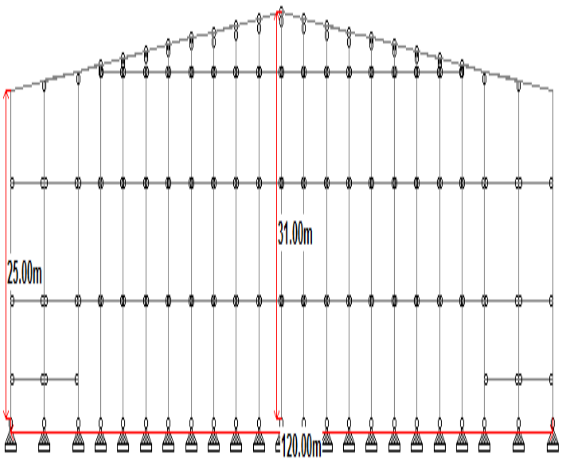

Figure 13. Front elevation of staad- model

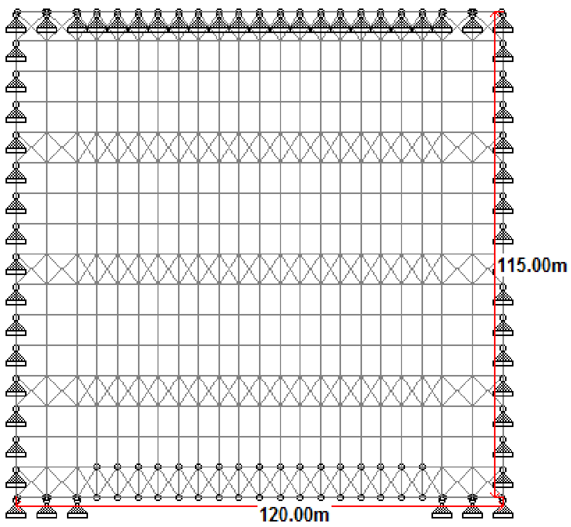

Figure 14. Top view (plan) of staad- model

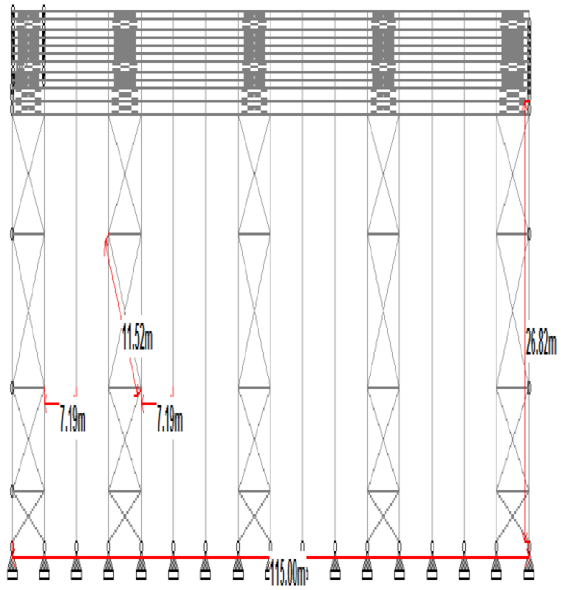

Figure 15. Side elevation of staad- model

16. RESULTS AND DISCUSSIONS

The structural analysis and design has been done for airbus A-380 hangar as pre-engineered steel framed building by considering the maximum dimensions as 120M x 115M x 26m eave height and 31M clear height as from floor finish level to the top of the frame. For designing the steel frame pre-engineered building hangar stadd-pro software has been used. In this design 3d analysis has been done and in the above all the structural details and drawings have been mentioned. The following results have been obtained from this design.

Table 4. Software analysis results and summary.

Maximum Displacements in mm				**Rotational Displacements in radians**		
S. No	X-axis	Y- axis	Z- axis	X- axis (Rx)	Y- axis (Ry)	Z- axis (Rz)
1.	109.838 mm	-0.832mm	-1.437mm	-0.000 radians	0.002 radians	0.001 radians
Max. S.F in KN				**Max. B.M in KN-M**		
S. No	X- axis	Y- axis	Z- axis	X- axis (Mx)	Y- axis (My)	Z- axis (Mz)
2.	3566.697 KN	287.432 KN	-3.530 KN	-0.672 KN-M	28.839 KN-M	846.388 KN-M
Estimated Quantity of Steel in Metric Tonne						
S. No	Primary Members	Flange Bracings, Sag Rods And CHS/SHS	Secondary Members	Roof sheeting And Wall sheeting	Anchor Bolts and High Strength Bolts	Total Quantity of Steel Obtained
3.	2861.87MT	313.51MT	133.50MT	145.81MT	47.74MT	3502.43MT

17. CONCLUSIONS

Analysis and design in this study yielded the following conclusions:

- The structure designed in this research for a maximum dimension of 120MX115M X 30M as pre-engineered building as an hangar for the maintenance of an air bus A-380 has consumed the total quantity of steel as 3502.43MT.
- The above design concludes that the obtained amount of steel mainly depends on primary members and type of purlins of the structure.
- While designing the pre-engineered building structure it is seen that when bay spacing is provided between two frames quantity of steel will get decreased but there is an increment in steel for secondary members due to increase in secondary members length.
- To resist the wind load effect less weight flexible members for pre-engineered building can be provided because light weight structural members offer better resistance against the wind forces.
- If self-weight of structural members i.e. Primary and secondary members are reduced then it may lead to economical sizes for footings and foundations.
- The aircraft hangar for air bus A-380 designed in this research is a unique design with pre-engineered building design concept in accordance with Indian standard codes is consuming more the quantity of steel compare to other countries codes.

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Moiz Mohammed
Career Point University,
Rajasthan Kota,
India.
moizmohammed93@gmail.com
ORCID 0000-0003-1687-9913

Mohammed Ahmed Hussain
Career Point University,
Rajasthan Kota,
India.
ahmediiithyd@gmail.com
ORCID 0000-0003-3431-6663