Scientific Journal of Impact Factor (SJIF): 5.71

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 5, Issue 04, April -2018

COMPARATIVE STUDY OF VARIOUS PEB FRAME TYPES

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Abstract—*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. A study of different frame types changing different parameters like width, height, bay spacing, and wind pressure have been analysed& designed by using STAAD pro. To understand the behaviour of Pre-Engineered structure & to check in which case it achieve the economy in steel quantity by varying different parameters. Design is done based on IS: 800. Load case considered in modelling are Dead load, Live load, Wind load and seismic load along with the various combinations as specified in IS. Analysis results are observed for base reaction, column moment, rafter moment, displacement at ridge, displacement at mid span.*

Buildings & houses are one of the oldest construction activities of human beings. The construction technology has advanced since the beginning from primitive construction technology to the present concept of modern house buildings. The present construction methodology for buildings calls for the best aesthetic look, high quality & fast construction, cost effective & innovative touch. Pre Engineered Steel Buildings are manufactured or Produced in the plant itself. The manufacturing of structural members is done on customer requirements. The detailed structural members are designed for their respective location and are numbered, which cannot be altered; because members are manufactured with respect to design features. These components are made in modular or completely knocked condition for transportation. These materials are transported to the customer site and are erected. Pre-engineered buildings can be adapted to suit a wide variety of structural applications; the greatest economy will be realized when utilizing standard details. An efficiently designed pre-engineered building can be lighter than the conventional steel buildings by up to 30%. Lighter weight equates to less steel and a potential price savings in structural framework.

Keywords- Pre-engineered building (PEB), STAAD.pro software, IS:800

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. Through its origin can be traced back to 1960's its potential has been felt only during the recent years. This was mainly due to the development in technology, which helped in computerizing the design.In this case, you can use the production system of products available in a configurable environment and can use technologies and solutions that allow the use of technologies and durability modules. A collection of testimonials of metal building associations (MBMA) was built in 60% of the buildings without residential high-rise buildings in Luxembourg's Prefabricated Building Units.Although PEB systems are extensively used in industrial and many other non-residential constructions worldwide, it is relatively a new concept in India.

These concepts were introduced to the Indian markets lately in the late 1990's with the opening up of the economy and a number of multi nationals setting up their projects. The market potential of PEB's is 1.2 million tonnes per the current pre-engineered steel building manufacturing capacity is 0.35 million tonnes per annum.

The industry is growing at the compound rate of 25 to 30 %.With respect to design of the structure and aesthetic appearance India is way behind. Indian manufacturers are trying to catch up; comparatively PEB's is a new concept in India. Beside, in fabrication and other areas of PEB India is very good. As compared to other countries Indian codes for building design are stringent but safer. IS standards are upgraded continuously. In India, American codes are also followed. Pre-engineered steel buildings can be fitted with different structural accessories including mezzanine floors, canopies, 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 up to 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.The roof of low rise buildings may be flat or sloped. Intermediate floors of low rise buildings are made of mezzanine systems. Single storied houses for living take minimum time for construction and can be built in any type of geographical location like extreme cold hilly areas, high rain prone areas, plain land obviously and extreme hot climatic zones as well.

"Pre-engineered steel buildings" are those that are totally invented within the industrial plant once planning, shipped to site} in CKD (completely knocked down) condition; and all parts are assembled and erected at a site with nut-bolts, thereby reducing the time of completion. Pre–engineered means that, typically speaking, is any a part of a structure that's factory-made first off to its arrival on the building site. The styles were ready-made however the building parts were either ready-made or factory-made against specific orders. These buildings were pre-designed or 'pre-engineered' into normal sizes, spans, bays and heights, and use normal details for fixing protection, roofing, gutters, flashing, windows, doors taking advantage of commercial practices of production of parts economically. Though PEB systems are extensively utilized in industrial and plenty of different non-residential constructions worldwide, it's comparatively a brand-new construct in Asian country.

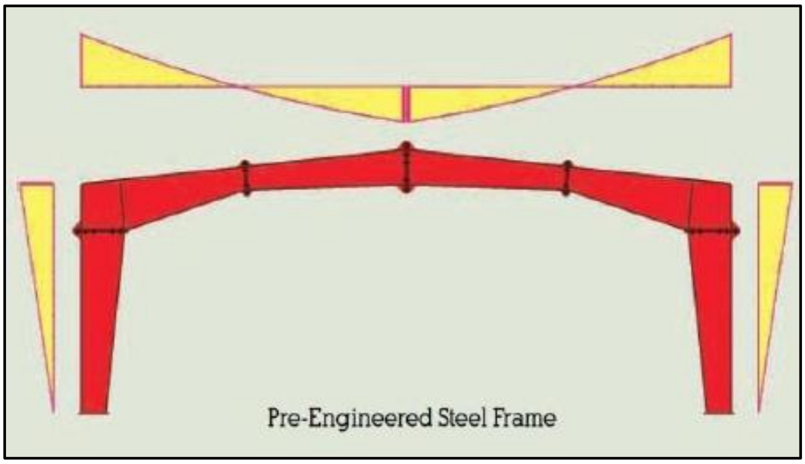

Fig 1 PEB Steel Frame with BM Diagram

Pre-built Steel Buildings are factory-made or made within the plant itself. The producing of structural members is finished on client needs. The careful structural members are designed for their several locations and are numbered, that cannot be altered; as a result of members is factory-made with regard to style options. These parts are created in standard or fully knocked condition for transportation. These materials are transported to the client website and are erected. Fastening and cutting method aren't performed at the client site.

A frame is a combination of Columns and inclined beams (rafters). There are various type of frames.

Clear Span (Cs): It's the span length between two columns without any obstruction. It has split Beams with ridge line at the peak or centre of the building. The maximum practical width or span is up to 90 meters, but it can also be extended up to 150 meters in case of Aircraft Hangars.

Arched Clear Span: The column is an RF column while the Rafter is curved. It has no ridge line and peak. The curved roof rafter is used in for aesthetic look. The maximum practical is up to 90meters, but can be extended to 120 meters.
Multi Span (MS1): The Multi spans (MS1) are those which have more than 1 span. The intermediate column is used for the clear span in which width of each span is called width module.

Arched Multi Span (AMS1): Arched multi span has RF column and a curved Rafter with one intermediate column. It has width module for the entire span. The multi spans can be extended up to AMS1, AMS2 and AMS3 etc.
Multi Span 2 (MS2): The Multi Span (MS2) has more than one intermediate span. It has three width modules with one ridge line.

Single Slope: It has two columns with different heights having Roof sloping on both the column.

Multi Gable: Multi gable has two or more spans where no intermediate columns are used. The columns are added to the extended width and columns are not placed at the ridge lines.

Roof Systems: It has straight columns with Roof having supports are not by TPCA.

Lean To: Lean to slopes is used extremely for an extending to a building on either side with short span. The rafters rest on column designed for lean to on one side and rests on the main column of the building.

Canopy: Canopies are used in case of open ends where there is an easy access. There are columns in straight path having roof extended to a large length.

II. OBJECTIVE OF THE STUDY

The objective of the study is carrying out to check the governing load by varying different parameters. To design industrial pre-fabricated steel structure by Staad Pro. 2007. To design industrial frame by varying width, clear height & different types of frame. To check the suitability and economy and practical viability of different frame types by changing the parameters like height and width of frame.

III. PARAMETERS AND STRUCTURE CONFIGURAION

A. Overview of different PEB Frame Type Study
1) Single slope frame
2) Clear span frame
3) Multi span frame
4) Multi gable frame

B. Different parameters
1) Height = 7m, 12m, 17m
2) Width = 15m, 25m, 50m
3) Length of building = 75m

C. Codal Provision
As per IS 800 2007 and taking deflection limit as per code

Table -1 Deflection Limit

Sr. No.	Description	IS 800-1984		IS 800-2007	
		Vertical	Lateral	Vertical	Lateral
1	Main Frame Main Frame With Crane (Pendent) Main Frame With Crane (Cab Operated)	L/325 L/325 L/325	H/325(D.L) H/325 H/325	L/180 L/180 L/180	H/150 H/200 H/400
2	Crane Beam Electric<50t Electric>50t	 L/750 L/1000		 L/750 L/1000	
3	Wind Column	H/325		H/150	
4	Mezzanine Beam	L/3250		L/240	
5	Under Slug Crane	L/750		L/750	
6	Purlin	L/180		L/150	
7	Girt	L/180		L/150	
8	Minimum Thickness Primary Secondary	 6 mm 2 mm		 4 mm 1.6 mm	

Slenderness ratio = compression 250
= tension 350

IV. METHODOLOGY AND LOADS ON MODELS

The Primary Load or force the design most of the on structures are wind, and earthquake. Structural analysis of a particular depends upon its location. Situation, environment condition, architectural layout, height, width, usage, client requirement etc.

A. Dead Load

Weight of purlin	: 6.78 kg/m
	: 0.048 kN =0.05 kN/m2
Weight of sheeting	: 4.33 kg/m2
	: 0.044 kN = 0.05 kN/m2
Total uniformly distributed load	0.1*7 =0.7 kN/m
Total Dead Load	0.15 kN/m2

B. Live Load

Live load	=0.75 kN/m2 (Angle less than 10 0)

C. Collateral Load

Collateral load = 0.2* 6 =1.2 kN/m (Assumed)

D. Wind Load

Pz = 0.6 Vz2

Vz= K1*K2*K3*Vb

L-Length of building (Greater horizontal dim.Of bldg.) = 75m

Width of building lesser horizontal dim. Of bldg. = 15m

Roof Slope = 1:10

Vb-Basic wind speed =39 m/s

N-Design life of structure; mean probable = 50 year

Terrain Category = 3

Class of Building = C

K1-Risk Coefficient = 1

HT Max Height of building from FGL = 7m

K2-Terrain, Str-height &size factor = 0.87

K3-Topography Factor = 1

Vz-Design wind speed = 33 m/sec

Pz-Design wind pressure = 0.69 kN/m2

Because;

Category1- Exposed open terrain with few or no obstructions having heights less than 1.5m.

Category2- Open terrain with well scattered obstructions having heights between 1.5m.& 10m.

Category3- Terrain with numerous closely spaced obstructions having heights around 10m.

Category4- Terrain with numerous closely spaced high obstructions.

Class-A - Structure & or compo like cladding, roofing etc. having greatest Hoz. Or Vert. dim < 20m.

Class-B - Structure & or compo like cladding, roofing etc. having greatest Hoz or Vert dim bet 20-50.

Class-C - Structure & or compo like cladding, roofing etc. having greatest Hoz or Vert dim > 50m.

Cpe-External Pressure Coefficient for wall

From Table no. 4 IS 875 (part 3) 1987

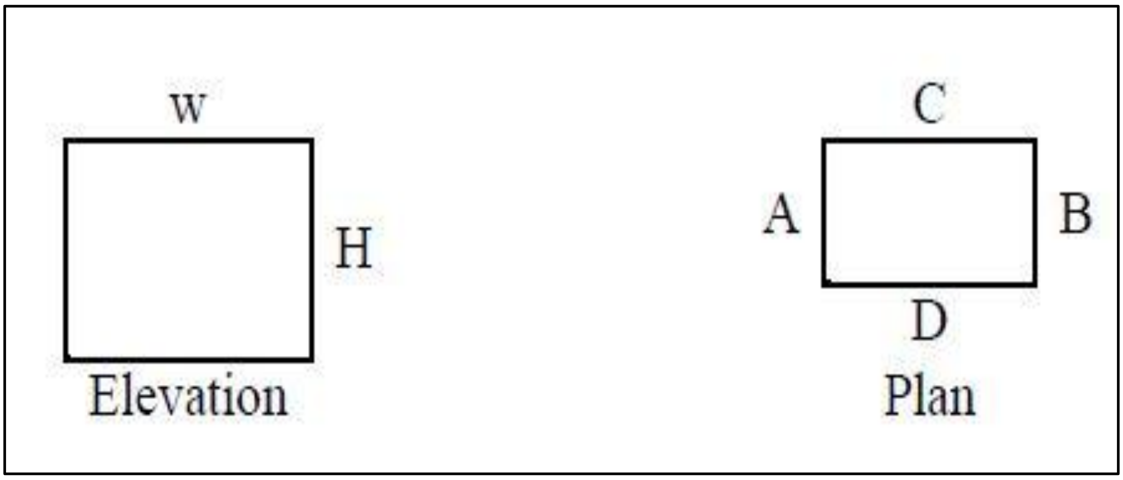

Fig 2 Plan and Elevation for Eternal Pressure Coefficient

h/w = 0.467
L/w = 4.000

Cpe-External Pressure Coefficient for Pitched Roof of Single Span Bldg

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Table -2 External Pressure Coefficient (Cpe) For Pitched Roofs of Rectangular Clad Buildings

Roof Angle	Wind Angle = 0o		Wind Angle = 90o	
	EF	GH	EG	FH
5	-0.90	-0.40	-0.80	-0.40
10	-1.20	-0.40	-0.80	-0.60
5.71	-0.94	-0.40	-0.80	-0.43

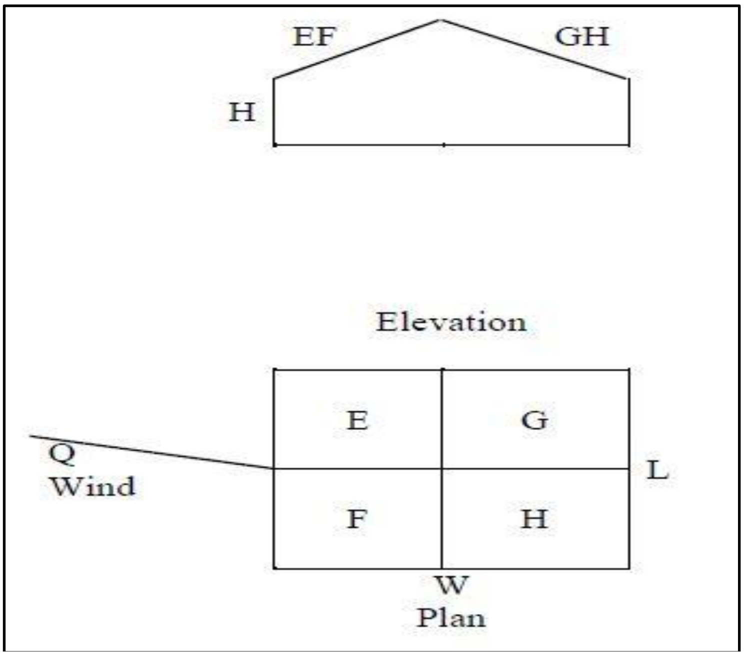


Fig 3 Roof Angle

Table No.5 IS 875 (Part3) -1987
Roof Angle in degrees =5.71
Local coefficient = -2.0
Rigid Frame Coefficient

Table 3 Wind Coefficients

Sr. no.	**Wind 1**		**Wind 2**		**Long Wind**		**Surface**
	Left	**Right**	**Left**	**Right**	**1**	**2**	**Friction**
1	0.2	-0.75	1.2	0.25	-1	0	0
2	-1.44	-0.90	-0.44	0.10	-1.30	-0.30	0
3	-0.90	-1.44	0.10	-0.44	-1.30	-0.30	0
4	-0.75	0.2	0.25	1.2	-1	0	0

Front/ Back Side Wall

Table 4 Wind Pressure/ Suction front side

Wind Pressure	Wind Suction	
1.073	-0.894	Column
1.073	-0.894	Grit/Header
1.073	-0.894	Jamb
1.073	-0.894	Panel
1.073	-0.894	Parapet Grit

Edge/ Corner Zone (Mm) = 3750
Local Coefficient = -1.5
Ratio Local to Average = 1.5
Left/Right End Wall

Table 5 Wind pressure / suction left or right side

Wind Pressure	Wind Suction	
1.073	-0.984	Column
1.073	-0.984	Grit/Header
1.073	-0.984	Jamb
1.073	-0.984	Panel
1.073	-0.984	Parapet Grit

Wind Drag
Cpi-internal pressure coefficient =0.5
Because: openings not more than 5% of wall area =0.2
Openings between 5% to 20% of wall area = 0.5
Openings larger than 20% of wall area = 0.7
Sample wind load calculation for 7m height 20m width 7.5 bay spacing.

V. WIND PRESSURE AND LOAD COMBINATION

A. Design Wind Pressure

Table 7 design wind pressure

eight	Pz (Wind Pressure) kN/m2
7 m	0.64
12 m	0.69
17 m	0.76

B. Load combination

Table 6 load combinations

1) DL+LL	6)DL+LL+WEG2
2) DL+LL+CL	7)DL+LL+WEG3
3) DL+WL/EL	8)DL+LL+WEG4
1)DL+WEPR	9)DL+LL+EQ+X
2)DL+WESL	10)DL+LL+EQ-X
3)DL+WESR	11)DL+LL+EQ+Z
4)DL+WEG1	12)DL+LL+EQ-Z
5)DL+WEG2	6) DL+LL+CL+WE/EL
6)DL+WEG3	1)DL+LL+CL+WEPL
7)DL+WEG4	2)DL+LL+CL+WEPR
4) DL+EL	3)DL+LL+CL+WESL
1)DL+EQX+	4)DL+LL+CL+WESR
2)DL+EX-	5)DL+LL+CL+WEG1
3)DL+EQZ+	6)DL+LL+CL+WEG2
4)DL+EQZ-	7)DL+LL+CL+WEG3
5) DL+LL+W/E	8)DL+LL+CL+WEG3
1)DL+LL+WEPE	9)DL+LL+CL+WEG4
2)DL+LL+WEPR	10)DL+LL+CL+EQ+X
3)DL+LL+WESL	11)DL+LL+CL+EQ-X
4)DL+LL+WESR	12)DL+LL+CL+EQ+Z
5)DL+LL+WEG1	13)DL+LL+CL+EQ-Z

VI. DESIGN SUMMARY

a) Clear Span Frame
b) Structure Configuration Details
c) Location:Himmatnagar, India.
d) Length : 75 m
e) Width : 15 m
f) Eave height : 7m (clear)
g) Seismic zone : 3
h) Wind speed : 39 m/sec
i) Wind terrain category : 3
j) Wind Class : C
k) Life Span : 50 years
l) Slope of roof : 1:10
m) Soil type : Medium
n) Importance factor : 1
o) Response reduction factor : 4
p) Purlin spacing : 1.5m
q) Girt spacing : 1.5 m

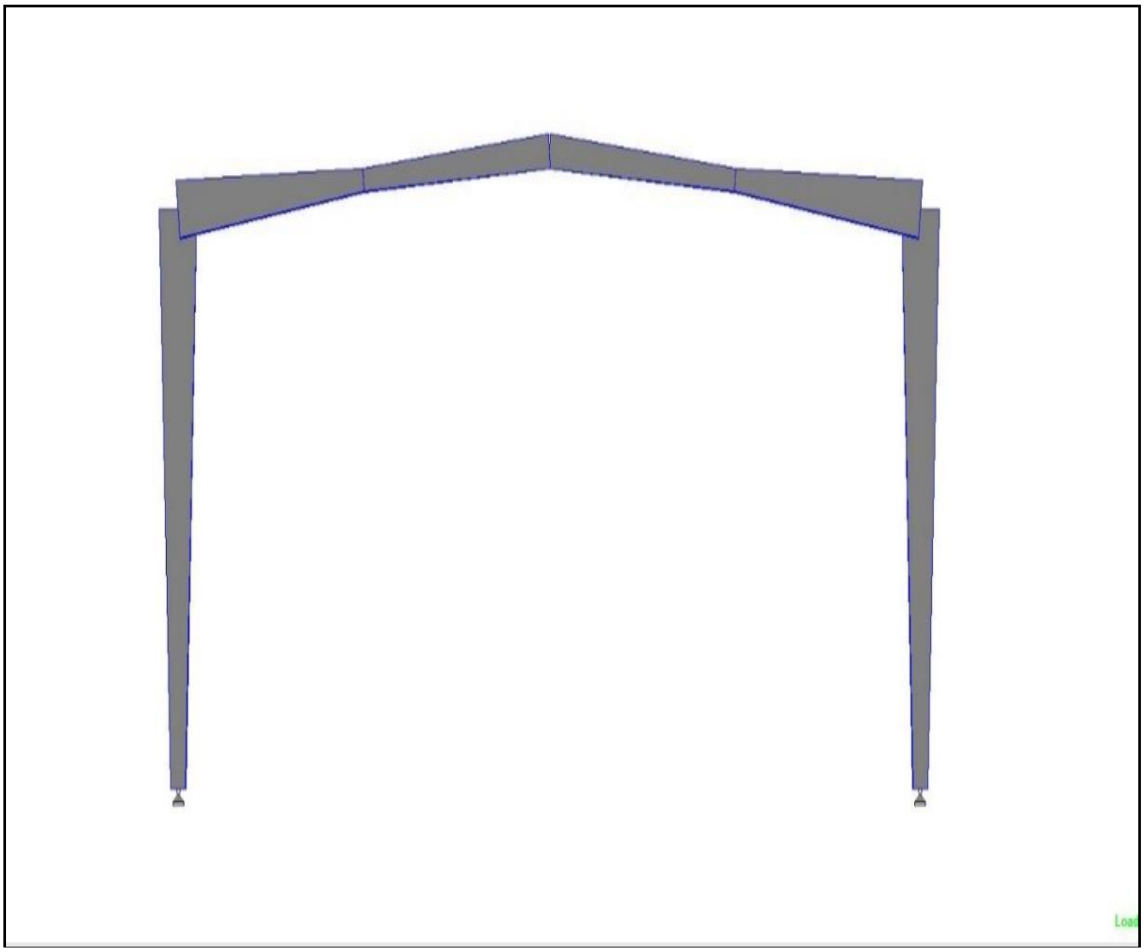


Fig 4Model of Clear Span Gable Frame

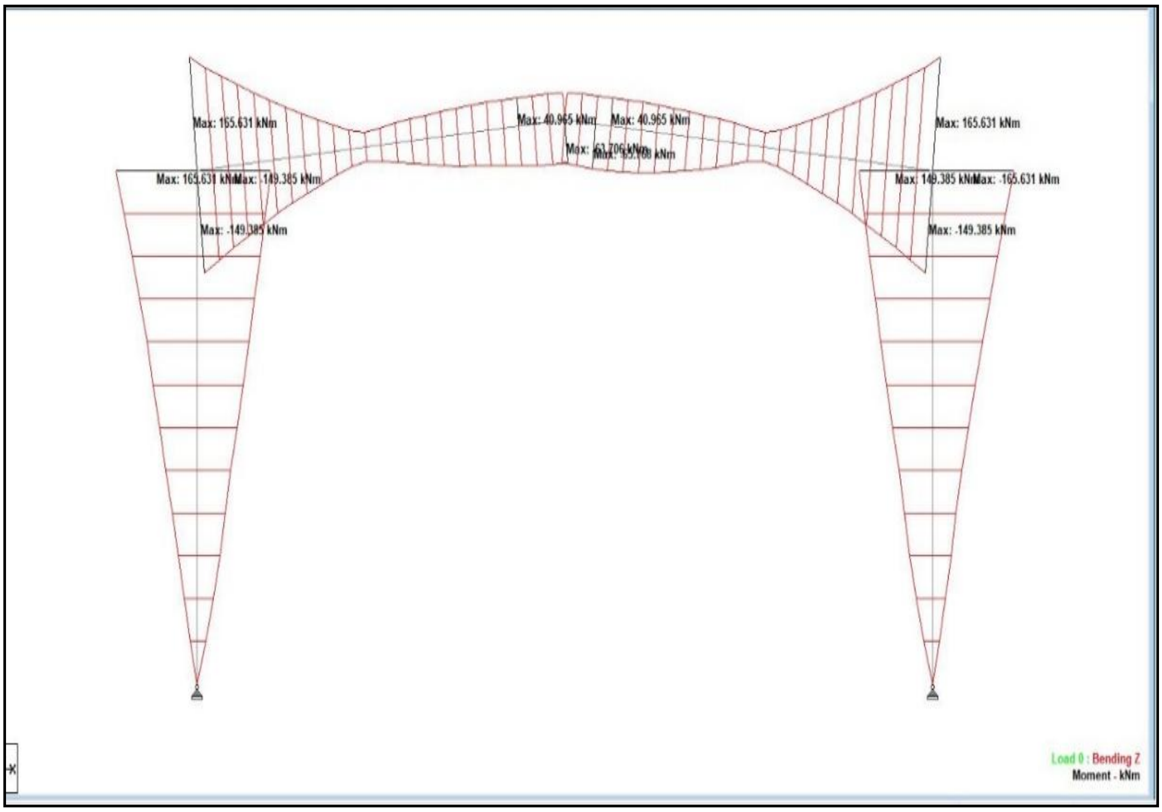


Fig 5 Bending Moment Diagram of Clear Span Gable Frame

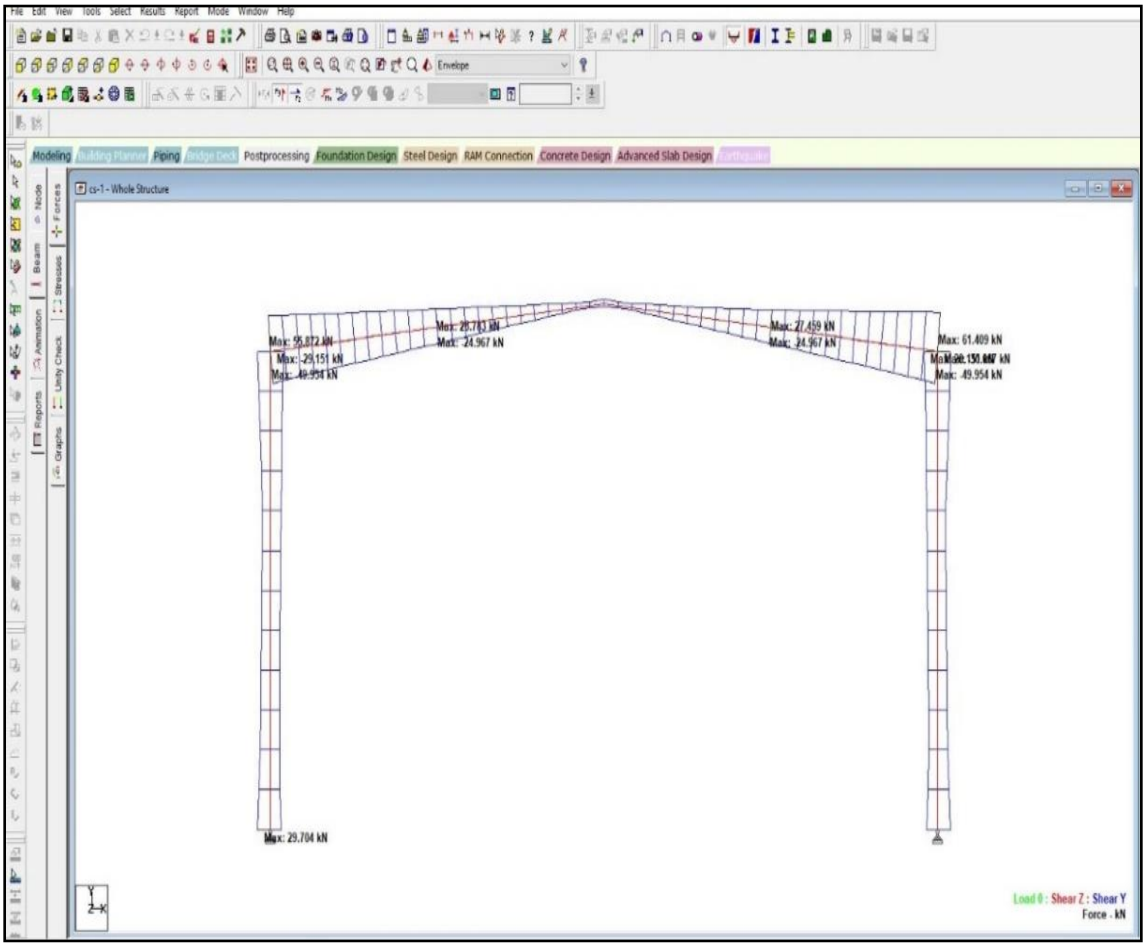
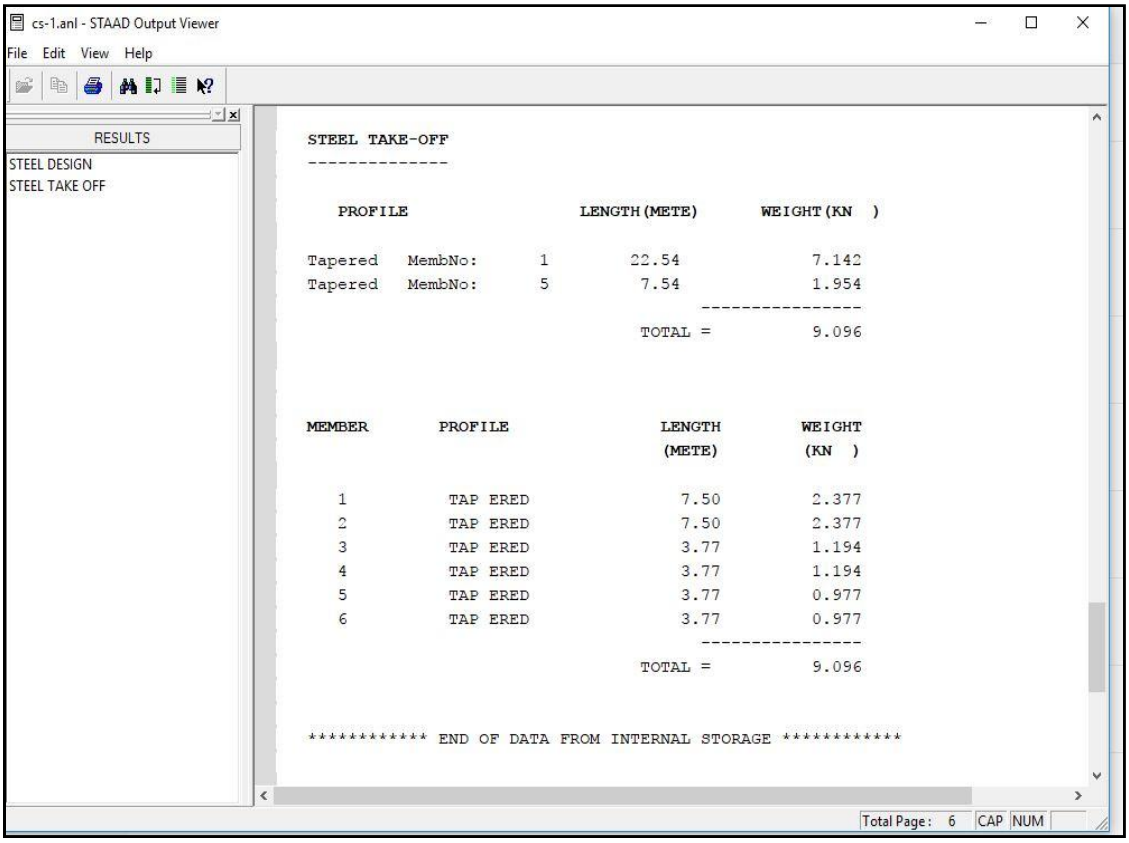


Fig 6S.F diagram clear span gable frame



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RESULTS

STEEL DESIGN

STEEL TAKE OFF

STEEL TAKE-OFF

PROFILE			LENGTH (METE)	WEIGHT (KN)
Tapered	MembNo:	1	22.54	7.142
Tapered	MembNo:	5	7.54	1.954
			TOTAL =	9.096

MEMBER	PROFILE	LENGTH (METE)	WEIGHT (KN)
1	TAP ERED	7.50	2.377
2	TAP ERED	7.50	2.377
3	TAP ERED	3.77	1.194
4	TAP ERED	3.77	1.194
5	TAP ERED	3.77	0.977
6	TAP ERED	3.77	0.977
		TOTAL =	9.096

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Fig 7weight of clear span gable frame

I did all the frames according this method.

VII. RESULTS

Table 7 results of frames

Sr.No	Types of Frames	Parameters	Weight in (kN)	Weight in (kg)
1	clear span	7m H & 15m W	9.096	927.792
2	clear span	7m H & 25m W	22.423	2287.146
3	clear span	7m H & 50m W	83.917	8559.534
4	clear span	12m H & 15m W	17.01	1735.02
5	clear span	12m H & 25m W	28.051	2861.202
6	clear span	12m H & 50m W	92.136	9397.872
7	clear span	17m H & 15m W	27.823	2837.946
8	clear span	17m H & 25m W	38.661	3943.422
9	clear span	17m H & 50m W	112.417	11466.53
10	Mono Slope	7m H & 15m W	12.489	1273.878
11	Mono Slope	7m H & 25m W	22.047	2248.794
12	Mono Slope	7m H & 50m W	95.936	9785.472
13	Mono Slope	12m H & 15m W	20.623	2103.546
14	Mono Slope	12m H & 25m W	38.434	3920.268
15	Mono Slope	12m H & 50m W	111.753	11398.81
16	Mono Slope	17m H & 15m W	34.059	3474.018
17	Mono Slope	17m H & 25m W	38.436	3920.472
18	Mono Slope	17m H & 50m W	138.528	14129.86

VIII. CONCLUSION

From the above analysis conclude that

a) In the case of 7m height and 15m width we compared both clear span and mono slope frame and we find that most economically frame is clear span frame.

b) In the case of 7m height and 25m width we compared both clear span and mono slope frame and we find that most economically frame is mono slope frame.

c) In the case of 7m height and 50m width we compared both clear span and mono slope frame and we find that most economically frame is clear span frame.

d) In the case of 12 m height and 15m width we compared both clear span and mono slope frame and we find that most economically frame is clear span frame.

e) In the case of 12 m height and 25m width we compared both clear span and mono slope frame and we find that most economically frame is clear span frame.

f) In the case of 12 m height and 50m width we compared both clear span and mono slope frame and we find that most economically frame is clear span frame.

g) In the case of 17m height and 15m width we compared both clear span and mono slope frame and we find that most economically frame is clear span frame.

h) In the case of 17m height and 25m width we compared both clear span and mono slope frame and we find that most economically frame is mono slope frame.

i) In the case of 17m height and 50m width we compared both clear span and mono slope frame and we find that most economically frame is clear span frame.

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