IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 1 Ver. IV (Jan- Feb. 2015), PP 01-07
www.iosrjournals.org

Large Span Lattice Frame Industrial Roof Structure

[1]Milan Masani, [2]Dr. Y. D. Patil
[1]Chartered Civil Engineer & Structural Consultant,M.Tech-R (Structure) Student
Department of Applied Mechanics Sardar Vallabhbhai National Institute of Technology Surat-395007, India
2Professor, Phd, M.Tech-(Structure), Department of Applied Mechanics Sardar Vallabhbhai National Institute of Technology Surat-395007, India

Abstract**:** *Recent growth in India for construction of large span roof steel structure using shop fabricated steel sheet built-up members are facing challenges in transportation and erection from shop to site. Lattice frame construction using rolled section for larger span can be batter solution if feasible to construct on site with restricted dimensions and lighter weight. Using systematic analysis of various alternatives of large span roof a solution to adopt most economical profile is presented in this paper work using software based analysis results.*
Keywords: *Pre Engineering Building(PEB), Lattice Portal frame(LPF),Wind Load(WL), Dead Load(DL), Live Load(LL),Reinforced Cement Concrete(RCC), Beuraw of Indian Standard(BIS)*

I. Introduction

Construction industries in India, in terms of usages of construction equipments, technology and materials are on growing phase. It has increases the perception of achieving quick completion targets schedule. Increased cost of resources has put the structural engineer on sharp edges of safety requirements. Engineers are inevitably be innovative though economical for building structures.

Single storey Large Floor Area Sheds are now part of almost every industry. These buildings are typically used for storage , engineering workshops, and distribution warehouses. Referred to colloquially as ‘sheds’, span vary from small workshops of just a few meters up to 100 meters for warehouses and industrial sheds.

Most single-storey buildings are relatively simpler in design with sloped roof structure supported on columns. In recent years, construction of such buildings has led to huge improvements in terms of quality, cost and delivery performance. These improvements have been achieved by design-and-build steelwork contractors, improved project planning, and active supply chain management. As steel can be recycled any number of times without loss of quality or strength, it is gaining popularity in Indian market. Steel building components are fabricated under factory-controlled conditions with minimal waste. As the site activity is mainly assembly, there is rarely any waste on site. Also steel structures are relatively simple structures in single storey buildings, can be easily assembled or dissembled.

Sophisticated computer software is widely available to design portal frames to the optimum efficiency. These programs use plastic or elasto-plastic design techniques, and can handle multi-span frames with varying geometries and multiple load cases. Design is still normally carried out to BS 5950-1, with loads taken from BS 6399, as plastic design of portal frames is not included in the Euro codes. However, Interim guidance in the form of SCI P400 is available and full guidance is due to be published in mid-2014.

The main alternative to portal frames is lattice construction. Lattice trusses supported on steel or RCC columns are generally more expensive than Steel portal frames for smaller spans. However, they will offer the best framing solution for very large spans (greater than 30m), for service facilities needing space / machineries suspended from the roof area, or where deflection criteria are particularly critical (in case of using corrugated cement roofing sheet)

Lattice Portal is a fusion of both types of structures. Trusses are being replaced by Lattice Rafter having members usually either rolled or structural hollow sections. The internal members can be angles, beams or hollow sections, depending on the design loads, configuration and fabrication costs. Two basic configurations are used in single storey buildings – pitched roof shed.

II. The Case Study

A design of a coal Storage Shed of an industrial building at coastal Zone of Gujarat, in India has been done by author in year 2012 using above concept. The shed has 60 mtr span and 100 mtr length. Fig.1 presents the general outline with three dimensional view of basic concept of Lattice Portal fame Roof.

Figure: 1 Lattice Frame Assembly for Large Span

Analysis and Design of a large span structural system using software STAAD-PRO has been done and worked out different alternatives. A comparative study of various systems analysed is made and the most economical system is concluded.

III. The Design Data

A. Basic data for Member Force Calculations:-

1) Building size – 100 mtr x 60 mtr
2) Span of building - 60 mtr
3) Height of column at eaves –to decide,
4) Slope of roof- to decide by designer
5) Location of building – coastal zone of Gujarat
6) Use of shed – to store coal
7) Roof covering – non asbestos cement sheets
8) Cladding – same as roof
9) Spacing of truss – to decide by designer
10) Seismic zone – zone –IV

B. Wind load calculation for Zone-IV

Design wind speed V2= (Vb)K1K2K3

Where,

K1= risk coefficient = 1.0

K2=Terrain coefficient = category-3 class-C, 0.82 H=10mtr²

K3 = topography coefficient Flat terrain, K3=1

Design Speed = 1.0x0.82x1.0x44
= 36.08 m/sec
= 130Kmph

Pressure P2 = 0.6 V2²
= 0.6x (36)²
= 781.06 N/m²
= 0.781 KN/m²

For Design purpose we have consider Pz= 1 KN/m². Assume Normal permeability, since slope is less than 10°, Live load= 75 Kg/m²= 750 N/m² & External wind base side pressure= (-) 0.7p. Internal wind pressure for normal permeability = ±0.2p. Wind Load calculations are as below. WL1 & WL2 = Wind Normal to ridge with internal suction & Wl3= wind parallel to ridge with internal pressure.

C. Design Loads and Load Combination for Zone-IV

Dead load

Nodal Point Load = Load due end reaction of Purlin
= Load due to sheet + purlin + self Weight
Sheeting Load = 21Kg/m²x Truss spacing X purlin Spacing.
= 25 X 6 X 1.2
= 180 Kg / mtr
Weight Of Purlin = Self Wt X Length of purlin supported by truss.
= 25.0 kg/ m X6mtr
= 150 Kg / Node
Self Weight Of truss =Self Wt of Truss/mtr x Node Spacing
= 100 Kg / mtr x 1.20 mtr
= 120 Kg / Node
Total Nodal Load = 180 Kg + 150 Kg + 120 Kg
= 450 Kg
= 4500N or 4.5 KN

Live load

Live Load = 750 N/m²x6mtr spacing
Nodal Point Load = Load due end reaction of Purlin
= 750 N/m²x Truss spacing X purlin Spacing.
= 5400N/ Node
or 5.4 KN
Total Nodal Load = DL+LL
= 4500+5400
= 9900 N
Say 10 KN

Load Combinations

Load Combination for STAAD Analysis (Nodal point load is considered for analysis with appropriate value and direction for load combination)

D.L.+L.L.
--------------------------------Load Combination (1)

D.L. =4.5 KN.
Imposed Load =5.50 KN.

D.L.+L.L. =10.0 KN.

D.L.+W.L.1
--------------------------------Load Combination (2)

D.L.1 = 4.5 KN - 0.3 KN
= 4.1 KN. On Rafter
W.L.1 = 0.7P
= 0.7 X 1.2
= 0.84 KN.
On Wind ward.
W.L.L.1 = 0.3P
= 0.3 X 1.2
= 0.36 KN.
On Lee Ward.

D.L.+W.L.2
--------------------------------Load Combination (3)

D.L.2 = 4.5 KN - 0.84 KN = 3.66 KN On Rafter.
W.L.2 = 0.3P = 0.36 KN
On Wind ward.
W.L.L.2 = 0.7P = 0.84 KN

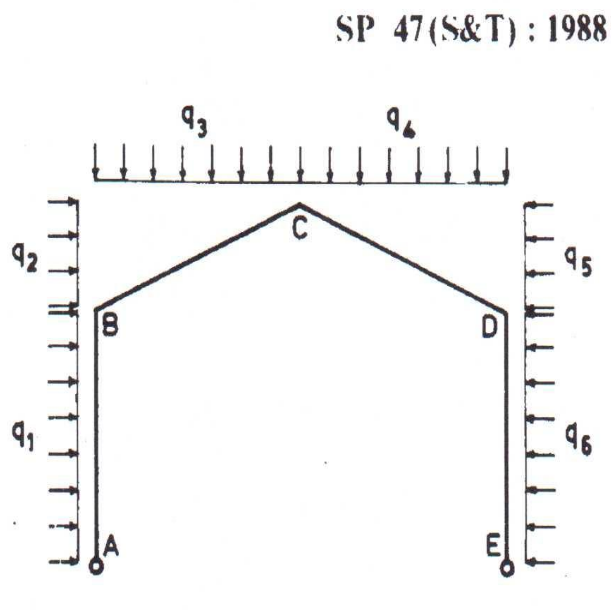
On Lee ward.

<u>D.L.+W.L.3</u>
-------------------------------Load Combination (4)

D.L.3	= 4.5 KN.-0.96 KN	= 3.4 KN On Rafter
W.L.3	= 0.2P	= 0.24 KN On Wind ward.
W.L.L.3	= 0.2P	= 0.24 KN On Lee ward.

Governing Load Combination is DL + LL =10 KN
This is accurate to consider as a preliminary design of member forces and worked out Initial members sizes.

Geometry of portal frame can also be optimised with preliminary design using unit loading method. A basic calculation sheet, prepared on the basis of polynomial equations for different geometry can be worked out as a guide to select geometry of the frame.



⇒ For different span, portal rise at centre is worked out as below

RISE IN DEGREE/ SPAN IN MTR	**30mtr**	**40mtr**	**50mtr**	**60mtr**
6^0	1.576	2.102	2.628	3.153
7^0	1.842	2.455	3.07	3.684
8^0	2.108	2.811	3.514	4.216
9^0	2.376	3.168	3.96	4.751
10^0	2.645	3.527	4.408	5.29

IV. Results

Using spread sheets prepared on the basis of polynomial equations, member forces are worked out for unit loading on rafter for different geometry of slopes and eaves height for Three Different Span is as below.

Span	=	40 mtr		Base	Fix Base
UDL	=	10 kN	(D.L. +L.L)		
Column Height=5mtr					
RISE	Moment-KnMtr			Shear in Kn	
In Deg.	BASE	EAVES	CENTRE	REACTION	THRUST
6^0	96.67	95.15	28.11	20	
7^0	95.89	80.85	20.43	20	1.4
8^0	94.41	84.33	15.17	20	2.01
9^0	92.41	80.16	10.47	20	2.45
10^0	90.07	76.33	6.28	20	2.74
Column Height=6mtr					
RISE	Moment-KnMtr			Shear in Kn	
In Deg.	BASE	EAVES	CENTRE	REACTION	THRUST
6^0	90.54	100.12	36.31	20	
7^0	91.09	94.76	29.19	20	-0.61
8^0	90.73	90.79	24.15	20	-0.01
9^0	89.88	87.04	19.53	20	0.47
10^0	86.63	83.49	15.31	20	0.85
Column Height=7mtr					
RISE	Moment-KnMtr			Shear in Kn	
In Deg.	BASE	EAVES	CENTRE	REACTION	THRUST
6^0	85.42	103.26	42.81	20	
7^0	86.62	98.72	36.26	20	-1.72
8^0	86.91	95.29	31.53	20	-1.19
9^0	86.75	91.98	27.12	20	-0.74
10^0	86.23	88.79	23.01	20	-0.36
Column Height=8mtr					
RISE	Moment-KnMtr			Shear in Kn	
In Deg.	BASE	EAVES	CENTRE	REACTION	THRUST
6^0	81.21	105.24	48.14	20	
7^0	82.71	101.38	42.12	20	-2.33
8^0	83.36	98.41	37.71	20	-1.88
9^0	83.62	95.51	33.54	20	-1.48
10^0	83.57	92.68	29.6	20	-1.13
Column Height=9mtr					
RISE	Moment-KnMtr			Shear in Kn	
In Deg.	BASE	EAVES	CENTRE	REACTION	THRUST
6^0	77.74	106.44	52.62	20	
7^0	79.36	103.13	47.08	20	-2.64
8^0	80.2	100.56	42.97	20	-2.26
9^0	80.72	98.02	39.05	20	-1.92
10^0	80.96	95.52	35.31	20	-1.61

Span	=	50 mtr		Base	Fix Base
UDL	=	10 kN	(D.L. +L.L)		
Column Height=5mtr					
RISE	Moment-KnMtr			Shear in Kn	
In Deg.	BASE	EAVES	CENTRE	REACTION	THRUST
6^0	160.56	133.74	24.24	25	5.36
7^0	157.01	126.36	16.11	25	6.12
8^0	151.11	117.6	6.79	25	6.7
9^0	144.52	109.95	-1.04	25	6.91
10^0	139.07	104.54	6.42	25	6.9
Column Height=6mtr					
RISE	Moment-KnMtr			Shear in Kn	
In Deg.	BASE	EAVES	CENTRE	REACTION	THRUST
6^0	152.93	144.24	37.99	25	1.44
7^0	151.64	137.69	30.17	25	2.32
8^0	148.59	129.49	20.78	25	3.18
9^0	144.56	122.1	12.61	25	3.74
10^0	140.9	116.72	6.84	25	4.03
Column Height=7mtr					
RISE	Moment-KnMtr			Shear in Kn	
In Deg.	BASE	EAVES	CENTRE	REACTION	THRUST
6^0	145.36	151.36	49.24	25	-0.89
7^0	145.4	145.85	41.81	25	-0.06
8^0	144.22	138.46	32.69	25	0.82
9^0	142.01	131.59	24.55	25	1.48
10^0	139.72	126.49	18.67	25	1.89
Column Height=8mtr					
RISE	Moment-KnMtr			Shear in Kn	
In Deg.	BASE	EAVES	CENTRE	REACTION	THRUST
6^0	138.56	156.86	58.71	25	-2.28
7^0	139.36	151.77	51.54		-1.55
8^0	139.37	145.17	42.84	25	-0.72
9^0	138.41	138.91	34.91	25	-0.06
10^0	137.12	134.18	29.09	25	0.36
Column Height=9mtr					
RISE	Moment-KnMtr			Shear in Kn	
In Deg.	BASE	EAVES	CENTRE	REACTION	THRUST
6^0	132.64	160.51	66.32	25	-3.09
7^0	133.88	156.04	59.8	25	-2.46
8^0	134.63	150.18	51.55	25	-1.72
9^0	134.52	144.53	43.93	25	-1.11
10^0	133.93	140.2	38.26	25	-0.69

Span	=	60 mtr		Base	Fix Base
UDL	=	10 kN	(D.L. + L.L)		

Column Height=5mtr

RISE	Moment-KnMtr			Shear in Kn	
In Deg.	BASE	EAVES	CENTRE	REACTION	THRUST
6^0	238.05	175.08	14.64	30	12.59
7^0	226.66	161.68	0.93	30	12.99
8^0	214.46	150.27	-10.31	30	12.83
9^0	203.32	141.36	-18.83	30	12.39
10^0	191.42	132.9	-26.69	30	11.7

Column Height=8mtr

RISE	Moment-KnMtr			Shear in Kn	
In Deg.	BASE	EAVES	CENTRE	REACTION	THRUST
6^0	212.68	218.4	69.92	30	-0.71
7^0	212.1	204.62	52.64	30	0.93
8^0	210.93	199.06	45.92	30	1.48
9^0	206.34	186.14	30.81	30	2.52
10^0	204.41	182.13	26.27	30	2.78

Column Height=6mtr

RISE	Moment-KnMtr			Shear in Kn	
In Deg.	BASE	EAVES	CENTRE	REACTION	THRUST
6^0	232.55	196.36	39.16	30	6.3
7^0	224.78	170.74	20.79	30	7.5
8^0	220.58	173.36	14	30	7.87
9^0	208.93	159.19	-0.63	30	8.29
10^0	204.86	154.98	-4.85	30	8.31

Column Height=9mtr

RISE	Moment-KnMtr			Shear in Kn	
In Deg.	BASE	EAVES	CENTRE	REACTION	THRUST
6^0	203.73	225.28	81.71	30	-2.39
7^0	204.95	212.91	65.29	30	-0.88
8^0	204.64	207.85	58.81	30	-0.35
9^0	202.24	195.88	43.99	30	0.7
10^0	201.03	192.11	39.47	30	0.99

Column Height=7mtr

RISE	Moment-KnMtr			Shear in Kn	
In Deg.	BASE	EAVES	CENTRE	REACTION	THRUST
6^0	222.52	209.07	55.95	30	1.92
7^0	219.1	193.8	37.94	30	3.61
8^0	216.69	187.78	31.09	30	4.13
9^0	209.07	174.04	15.97	30	5
10^0	206.19	169.87	11.5	30	5.18

Member forces results of different configuration, worked out as above for unit loading, shows that uniform results at eaves junction in trusses and column follows one particular pattern. For calculation of above results ratio of Izz for column and Izz for Truss is considered to be unity. This assumption gives heavier design for column but at the same time will reduce considerable moment in truss members near eaves. Since truss length is more than column length, overall economy can be achieved. Base is considered as rigid, gives less load in truss members.

V. Conclusion

Observing above results and its uniformity pattern, It is possible to narrate that forces becomes uniform in one particular patter which has following approximate relation between span and eaves height,

$$H = m \times (ø/\pi) \times L,$$

WHERE
H= Eaves Height
ø = Pitch of Roof
L = Span of Rafter
m= co-efficient varies between 3.00 to 4.00, depending upon the pitch.

In many cases height of column is to be decided by an architect as client has having limitation on minimum height in storage type of sheds. This relation is helpful in finalising Geometry of the portal to be design for uniform member forces at critical locations, which in turn gives balance design, giving overall economy in weight.

Hand calculations are advised to proceed further for deciding preliminary member sizes based on SP 47: 2003. A STAAD model is than prepared and run for detail analysis and working out final member sizes.

References

[1]. Is 800:2007:, "Design of steel structures"
[2]. Is 875-part-III :, " Wind load on roof"
[3]. SP38: 1978:, " Design of roof trusses"
[4]. SP 40 : 1987 :, " Design of steel portal frames"
[5]. SP 47 : 1987 (reaffirmed on 2003):, " Design of steel lattice portal frames"
[6]. INS/PUB/010, "Steel Work Design Guide to BS 5950 Vol-4"
[7]. INS/PUB/013, "Introduction to steelwork design to BS 5950"
[8]. INS/PUB/024, "Design of Structural Steel Work C-Southcombe"
[9]. INS/PUB/045, " Connection Design and Detailing"
[10]. INS/PUB/046:, " Structural Design to BS 5950-5:1998 Section Properties and Load Tables"
[11]. Bungale S Tarnath, "Wind and Earthquake resisting Buildings"
[12]. Subramaian.N, "Design of Steel Structure"
[13]. K. Suresh Kumar , C. Cinib, Valerie Sifton:, "Assessment of design wind speeds for metro cities of India"
[14]. K. Suresh Kumar :,"Wind Engineering for Design of Structures -Fundamentals"