ASPS Conference Proceedings 1: 321-329 (2022)

Proceedings of

12th Structural Engineering Convention - An International Event (SEC 2022)

Available at https://asps-journals.com/index.php/acp

On Structural Design of Steel Roof Truss Geometry Used in Factory Shed

Arghya Ghosh[1], Sukanta Jana[2, *]

[1]Department of Civil Engineering, Assistant Professor, Techno India University, Kolkata, 700 091, India
[2]Department of Civil Engineering, M. Tech. Student, Techno India University, Kolkata, 700 091, India
Paper ID - 040080

Abstract

Use of steel is steadily increasing all over the world in civil engineering related fields due to its superior material properties like high strength and durability, high ductility, light weight etc. Various types of steel structures become more popular because of their high aesthetic appearance. Among these steel structures, roof trusses are widely used to cover large column free open areas like shopping malls, auditoriums, car parking lots, stadiums as well as factory sheds etc. Design of steel truss members is an important aspect to the practicing civil engineers. Hence this paper aims to study the design and analysis of different types of truss geometries used in a factory shed using commercial well-established software package STAAD Pro V8i. Various types of truss geometries like Pratt truss, Howe truss, Fink truss are considered in the present investigations with different aspect ratios. Besides these truss geometries, portal frame geometry is also taken up here to examine the best suitable geometries which are to be used as roofing units in industrial purposes. The results obtained from the present numerical experimentations are studied meticulously to extract a set of meaningful conclusions regarding the design and optimum choice of steel truss geometry which is used as roofing units in industrial sheds. The practical design guidelines along with the best choice of roof trusses are highlighted in the results and discussions section of this paper.

Keywords: Steel structures, Roof truss, Optimization, Steel design

1. Introduction

Now-a-days steel structures are used in several civil engineering constructions including factory sheds, railway workshops etc. For this type of structures roof trusses are generally used to cover the structural frame. The roof truss structures have axially loaded members which are efficient to resist external loadings where the cross section is uniformly stressed.

Researchers like Vishwakarma and Tayal [1] studied the optimization of industrial building using pre-engineering building and conventional steel building by fully stressed design. A total of five cases were studied to achieve most economical design. Comparison was done between designed structures and finally most suited and economical structure was adopted for Building. Smith et al. [2] represented trusses as a set of rigid bars connected by pin joints, which may change location during optimization. By including the location of the joints as well as the strength of individual beams in their design variables, the authors simultaneously optimized the geometry and the mass of structures. The authors presented the details of their technique together with examples of illustrating its use, including comparisons with real structures. Comparative design and study of various steel sheds with various design codes for selecting a better option for construction of new shed was carried out by Yamini U. Motghare [3]. In this paper steel sheds of various sizes were analyzed by applying different codes such as IS-800. Different loading was also applied according to the code. All this analysis was done with the help of software STAAD Pro V8i. The main aim of this paper was to find the optimum option of steel shed out of PEB steel structure (Pre-engineered Building) and CSB structures (Conventional Steel Building). Mohakul et al. [4] carried their research work on design of industrial storage shed and analysis of stresses produced on failure of a joint. This Project was a study of the forces acting in the adjacent members when one of the members failed, and calculating the excess stresses and ratios induced in these connected members. This structure was proposed to design according to IS: 800 – 2007 and the dead, live and the wind load analysis was done according to IS: 875 – 1987 (Part-I, Part-II, Part-III). A major portion of the analysis was carried out in Bentley STAAD Pro V8i. Sharma et al. [5] studied the design of industrial factory steel shed and foundation and compare with reinforced concrete portal frame structure. Shahid et al. [6] also reported design optimization of steel structures from conventional steel building to pre-engineered building by varying loads. In this study, 16 different 2D Frames were selected for each pre-engineered building and conventional steel building. By varying the tributary width and wind speed, the frames were analyzed by a software of structural analysis i.e., STAAD Pro V8i. A comparison was conducted depending upon base reactions, moments at eave, horizontal defection at eave, vertical deflection at ridge and steel take off. A building with 25 m

*Corresponding author. Tel: +917797418272; E-mail address: jobsukanta1994@gmail.com

Proceedings of the 12th Structural Engineering Convention (SEC 2022), NCDMM, MNIT Jaipur, India | 19-22 December, 2022

Published online: December 19, 2022
doi:10.38208/acp.v1.516

width, 100 m length and 10 m eave height was selected. AISI-ASD (American Iron & Steel Institute-Allowable Stress Design) and MBMA-2006 (Metal Building Manufacturers Association-2006) protocols were adopted as design code and load application respectively. The results showed that PEBs gives low base reactions, horizontal deflection at eave, and steel take off as compared to the CSBs. The study proved that with increase in loading, the percentage of saving in steel increases in pre-engineered building as compared to conventional steel building. Hence, the performance and cost effectiveness of pre-Engineered building was much improved under heavy loading as compared to the conventional ones. Design of industrial steel building by limit state method was done by Gupta and Baig [7]. In this project work it was proposed to carry out the design of an industrial steel storage shed by limit state method based on IS 800-2007 (LSM) and comparing the results with the same obtained by working stress method based on IS 800- 1984, for a structure with the same dimensions & loading.

The close review of literature establishes the fact that many researchers worked on steel structures design from early years. Some of practicing engineers also carried out their research work on this topic. Most of them showed their interest on steel structures used in conventional buildings and pre-engineered buildings. Steel factory shed is designed by working stress and limit state methods of design. STAAD Pro software package was also used for this purpose. But as per the author best knowledge, comparison between portal frame and different types of trusses used as roofing structures are done very less in number. More research works are needed for this type of study. So the present author intends to fulfil this lacuna in this research work. Different types of truss geometries as well as portal frame are analyzed and designed using STAAD Pro V8i software package with varying length to width ratios. The results obtained from this investigation are interpreted from practical design and optimization point of view.

2. Mathematical Background

The present analysis is carried out in Bentley STAAD Pro V8i. Here the present authors consider only dead load and live load. For these load calculations, guidelines proposed by the IS:875 – 1987 (Part – I and Part – II) are taken up here. The total dead and live loads which are acted on truss geometries are distributed to all the nodal points of top chord members of all trusses. These nodal loads are applied on each truss geometries as well as portal frame as two different load cases in STAAD Pro V8i model for analyzing the structures. The steel design is done here according to the inputs of working stress method of design in STAAD Pro. V8i software package. STAAD results are critically discussed here to fulfil the present scope of the paper. A typical model of the present study is shown in Fig. 1.

3. Numerical Examples

The very famous and well-established software package STAAD Pro V8i is used here for analyzing and designing the steel roof trusses of different geometries. So it is not needed to validate the program – as per the best knowledge of the authors. A steel factory shed is modelled in STAAD

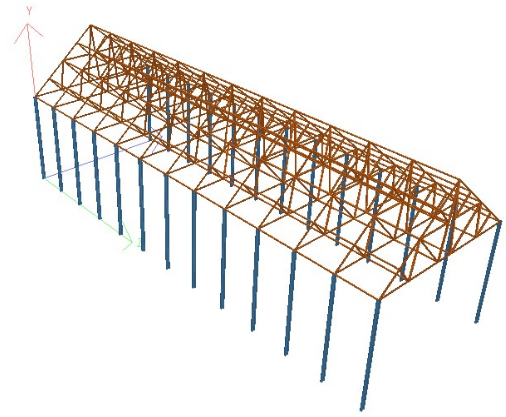

Fig. 1. Typical STAAD model of Fink truss geometry

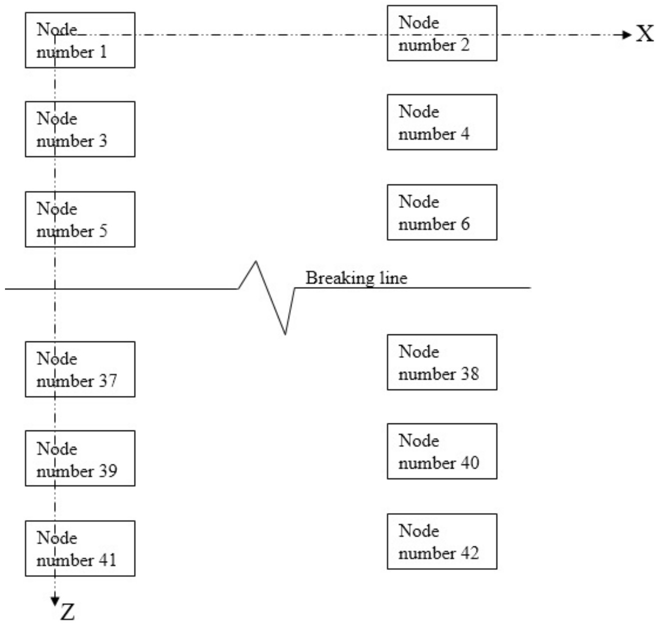

Fig.2. Typical support node numbering in plan

Pro V8i with different length to width ratios. Here, the present authors consider length to width ratios are 1, 2, 3, 4 and 5 for each model. Different types of roof trusses such as Pratt, Howe and Fink trusses are used for each cases. Along all these roof trusses portal frame is considered here for different numerical investigations. For each cases, width of the factory shed is considered as 16m. The height of shed form ground level is taken as 10m. Pitch of roofing structure is 0.4 and center to center distances of each columns are considered as 4m in the present analysis. Indian standard steel angle sections are used here for modelling of the roofing structures of factory sheds in STAAD Pro V8i. The steel columns are assumed as fixed with foundation and all truss members are assumed as axially loaded members in STAAD model. The support nodes are numbered as per the authors' convenience and these are represented in Fig.2.

4. Results and Discussions

4.1 Behavior of roofing structures based on support reactions of factory sheds

The results furnished in Tables 1 to 20 represent the support reactions of different steel factory sheds for different types of roof structures under the combination of dead and live load both. F_x, F_y and F_z represent the reaction forces in kN along X, Y and Z axes respectively while M_x, M_y and M_z signify the moments in kN – m about X, Y and Z axes respectively. Undoubtedly it is clear that the vertical support reactions (F_y) and moment (M_z) give the higher values among other four components of support reactions under transverse loading. The results of these tables establish this fact very strongly. For all length to width ratios (1 to 5), the extreme end columns such as front and rear side columns give lower values of support reactions in compare to other internal columns. This is because of higher effective areas of internal columns. This observation can be used for designing the foundations of factory sheds.

Table-1. Support reactions of portal frame with length to width ratio = 1

Node numbers	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN–m)	M_y (kN–m)	M_z (kN–m)
1	5.123	19.555	0.008	0.027	0	-31.702
2	-5.123	19.555	0.008	0.027	0	31.702
3	5.198	21.833	-0.004	-0.014	0	-32.196
4	-5.198	21.833	-0.004	-0.014	0	32.196
5	5.232	21.459	0	0	0	-32.424
6	-5.232	21.459	0	0	0	32.424
7	5.198	21.833	0.004	0.014	0	-32.196
8	-5.198	21.833	0.004	0.014	0	32.196
9	5.123	19.555	-0.008	-0.027	0	-31.702
10	-5.123	19.555	-0.008	-0.027	0	31.702

Table-2. Support reactions of Pratt truss with length to width ratio = 1

Node numbers	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN–m)	M_y (kN–m)	M_z (kN–m)
1	0.06	19.376	0.013	0.044	0	-0.39
2	-0.06	19.376	0.013	0.044	0	0.39
3	0.065	20.876	-0.001	-0.002	0	-0.424
4	-0.065	20.876	-0.001	-0.002	0	0.424
5	0.065	20.875	0	0	0	-0.424
6	-0.065	20.875	0	0	0	0.424
7	0.065	20.876	0.001	0.002	0	-0.424
8	-0.065	20.876	0.001	0.002	0	0.424
9	0.06	19.376	-0.013	-0.044	0	-0.39
10	-0.06	19.376	-0.013	-0.044	0	0.39

Table-3. Support reactions of Howe truss with length to width ratio = 1

Node numbers	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN–m)	M_y (kN–m)	M_z (kN–m)
1	0.059	19.187	0.013	0.044	0	-0.363
2	-0.059	19.236	0.013	0.044	0	0.362
3	0.064	20.699	-0.001	-0.002	0	-0.393
4	-0.064	20.753	-0.001	-0.002	0	0.395
5	0.064	20.691	0	0	0	-0.394
6	-0.064	20.745	0	0	0	0.395
7	0.064	20.699	0.001	0.002	0	-0.393
8	-0.064	20.753	0.001	0.002	0	0.395
9	0.059	19.187	-0.013	-0.044	0	-0.363
10	-0.059	19.236	-0.013	-0.044	0	0.362

Table-4. Support reactions of Fink truss with length to width ratio = 1

Node numbers	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN–m)	M_y (kN–m)	M_z (kN–m)
1	0.06	18.421	0.013	0.043	0	-0.378
2	-0.06	18.411	0.013	0.043	0	0.372
3	0.064	19.843	-0.001	-0.003	0	-0.409
4	-0.064	19.827	-0.001	-0.003	0	0.403
5	0.064	19.836	0	0	0	-0.409
6	-0.064	19.819	0	0	0	0.403
7	0.064	19.843	0.001	0.003	0	-0.409
8	-0.064	19.827	0.001	0.003	0	0.403
9	0.06	18.421	-0.013	-0.043	0	-0.378
10	-0.06	18.411	-0.013	-0.043	0	0.372

Table-5. Support reactions of portal frame with length to width ratio = 2

Node numbers	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN–m)	M_y (kN–m)	M_z (kN–m)
1	3.924	14.759	0.007	0.023	0	-28.216
2	-3.924	14.759	0.007	0.023	0	28.216
3	3.986	15.894	-0.004	-0.014	0	-28.68
4	-3.986	15.894	-0.004	-0.014	0	28.68
5	4.031	15.765	-0.001	-0.003	0	-29.018
6	-4.031	15.765	-0.001	-0.003	0	29.018
7	4.051	15.806	0	-0.002	0	-29.171
8	-4.051	15.806	0	-0.002	0	29.171
9	4.056	15.807	0	0	0	-29.213
10	-4.056	15.807	0	0	0	29.213
11	4.051	15.806	0	0.002	0	-29.171
12	-4.051	15.806	0	0.002	0	29.171
13	4.031	15.765	0.001	0.003	0	-29.018
14	-4.031	15.765	0.001	0.003	0	29.018
15	3.986	15.894	0.004	0.014	0	-28.68
16	-3.986	15.894	0.004	0.014	0	28.68
17	3.924	14.759	-0.007	-0.023	0	-28.216
18	-3.924	14.759	-0.007	-0.023	0	28.216

Table-6. Support reactions of Pratt truss with length to width ratio = 2

Node numbers	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN–m)	M_y (kN–m)	M_z (kN–m)
1	0.059	19.055	0.013	0.044	0	-0.381
2	-0.059	19.055	0.013	0.044	0	0.381
3	0.064	20.56	-0.001	-0.002	0	-0.415
4	-0.064	20.56	-0.001	-0.002	0	0.415
5	0.064	20.558	0	0	0	-0.415
6	-0.064	20.558	0	0	0	0.415
7	0.064	20.558	0	0	0	-0.415
8	-0.064	20.558	0	0	0	0.415
9	0.064	20.558	0	0	0	-0.415
10	-0.064	20.558	0	0	0	0.415
11	0.064	20.558	0	0	0	-0.415
12	-0.064	20.558	0	0	0	0.415
13	0.064	20.558	0	0	0	-0.415
14	-0.064	20.558	0	0	0	0.415
15	0.064	20.56	0.001	0.002	0	-0.415
16	-0.064	20.56	0.001	0.002	0	0.415
17	0.059	19.055	-0.013	-0.044	0	-0.381
18	-0.059	19.055	-0.013	-0.044	0	0.381

Table-7. Support reactions of Howe truss with length to width ratio = 2

Node numbers	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN–m)	M_y (kN–m)	M_z (kN–m)
1	0.062	19.937	0.013	0.045	0	-0.382
2	-0.062	19.983	0.013	0.044	0	0.381
3	0.066	21.437	-0.001	-0.002	0	-0.412
4	-0.066	21.488	-0.001	-0.002	0	0.414
5	0.066	21.436	0	0	0	-0.413
6	-0.066	21.487	0	0	0	0.414
7	0.066	21.436	0	0	0	-0.413
8	-0.066	21.487	0	0	0	0.414
9	0.066	21.436	0	0	0	-0.413
10	-0.066	21.487	0	0	0	0.414
11	0.066	21.436	0	0	0	-0.413
12	-0.066	21.487	0	0	0	0.414
13	0.066	21.436	0	0	0	-0.413
14	-0.066	21.487	0	0	0	0.414
15	0.066	21.437	0.001	0.002	0	-0.412
16	-0.066	21.488	0.001	0.002	0	0.414
17	0.062	19.937	-0.013	-0.045	0	-0.382
18	-0.062	19.983	-0.013	-0.044	0	0.381

Table-8. Support reactions of Fink truss with length to width ratio = 2

Node numbers	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN–m)	M_y (kN–m)	M_z (kN–m)
1	0.06	18.42	0.013	0.043	0	-0.379
2	-0.06	18.41	0.013	0.043	0	0.372
3	0.064	19.841	-0.001	-0.003	0	-0.409
4	-0.064	19.825	-0.001	-0.003	0	0.403

5	0.064	19.835	0	0	0	-0.409
6	-0.064	19.819	0	0	0	0.403
7	0.064	19.836	0	0	0	-0.409
8	-0.064	19.819	0	0	0	0.403
9	0.064	19.836	0	0	0	-0.409
10	-0.064	19.819	0	0	0	0.403
11	0.064	19.836	0	0	0	-0.409
12	-0.064	19.819	0	0	0	0.403
13	0.064	19.835	0	0	0	-0.409
14	-0.064	19.819	0	0	0	0.403
15	0.064	19.841	0.001	0.003	0	-0.409
16	-0.064	19.825	0.001	0.003	0	0.403
17	0.06	18.42	-0.013	-0.043	0	-0.379
18	-0.06	18.41	-0.013	-0.043	0	0.372

Table-9. Support reactions of portal frame with length to width ratio = 3

Node numbers	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN–m)	M_y (kN–m)	M_z (kN–m)
1	3.618	13.944	0.01	0.034	0	-25.899
2	-3.618	13.944	0.01	0.034	0	25.899
3	3.656	14.227	-0.004	-0.012	0	-26.188
4	-3.656	14.227	-0.004	-0.012	0	26.188
5	3.67	14.222	0	-0.001	0	-26.293
6	-3.67	14.222	0	-0.001	0	26.293
7	3.671	14.225	0	0	0	-26.3
8	-3.671	14.225	0	0	0	26.3
9	3.671	14.225	0	0	0	-26.3
10	-3.671	14.225	0	0	0	26.3
11	3.671	14.225	0	0	0	-26.3
12	-3.671	14.225	0	0	0	26.3
13	3.671	14.225	0	0	0	-26.3
14	-3.671	14.225	0	0	0	26.3
15	3.671	14.225	0	0	0	-26.3
16	-3.671	14.225	0	0	0	26.3
17	3.671	14.225	0	0	0	-26.3
18	-3.671	14.225	0	0	0	26.3
19	3.671	14.225	0	0	0	-26.3
20	-3.671	14.225	0	0	0	26.3
21	3.67	14.222	0	0.001	0	-26.293
22	-3.67	14.222	0	0.001	0	26.293
23	3.656	14.227	0.004	0.012	0	-26.188
24	-3.656	14.227	0.004	0.012	0	26.188
25	3.618	13.944	-0.01	-0.034	0	-25.899
26	-3.618	13.944	-0.01	-0.034	0	25.899

Table-10. Support reactions of Pratt truss with length to width ratio = 3

Node numbers	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN–m)	M_y (kN–m)	M_z (kN–m)
1	0.058	18.734	0.013	0.044	0	-0.372
2	-0.058	18.734	0.013	0.044	0	0.372
3	0.062	20.245	-0.001	-0.002	0	-0.406
4	-0.062	20.245	-0.001	-0.002	0	0.406
5	0.062	20.24	0	0.001	0	-0.406
6	-0.062	20.24	0	0.001	0	0.406
7	0.062	20.24	0	0	0	-0.406
8	-0.062	20.24	0	0	0	0.406
9	0.062	20.24	0	0	0	-0.406
10	-0.062	20.24	0	0	0	0.406
11	0.062	20.24	0	0	0	-0.406
12	-0.062	20.24	0	0	0	0.406
13	0.062	20.24	0	0	0	-0.406
14	-0.062	20.24	0	0	0	0.406
15	0.062	20.24	0	0	0	-0.406
16	-0.062	20.24	0	0	0	0.406
17	0.062	20.24	0	0	0	-0.406
18	-0.062	20.24	0	0	0	0.406
19	0.062	20.24	0	0	0	-0.406
20	-0.062	20.24	0	0	0	0.406
21	0.062	20.24	0	-0.001	0	-0.406
22	-0.062	20.24	0	-0.001	0	0.406
23	0.062	20.245	0.001	0.002	0	-0.406
24	-0.062	20.245	0.001	0.002	0	0.406
25	0.058	18.734	-0.013	-0.044	0	-0.372
26	-0.058	18.734	-0.013	-0.044	0	0.372

Table-11. Support reactions of Howe truss with length to width ratio = 3

Node numbers	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN–m)	M_y (kN–m)	M_z (kN–m)
1	0.059	19.092	0.013	0.045	0	-0.361
2	-0.058	19.14	0.013	0.044	0	0.359
3	0.063	20.512	-0.001	-0.002	0	-0.388
4	-0.063	20.566	-0.001	-0.002	0	0.39
5	0.063	20.504	0	0	0	-0.388
6	-0.063	20.558	0	0	0	0.39
7	0.063	20.504	0	0	0	-0.389
8	-0.063	20.558	0	0	0	0.389
9	0.063	20.504	0	0	0	-0.389
10	-0.063	20.558	0	0	0	0.389
11	0.063	20.504	0	0	0	-0.389
12	-0.063	20.558	0	0	0	0.389
13	0.063	20.504	0	0	0	-0.389
14	-0.063	20.558	0	0	0	0.389
15	0.063	20.504	0	0	0	-0.389
16	-0.063	20.558	0	0	0	0.389
17	0.063	20.504	0	0	0	-0.389
18	-0.063	20.558	0	0	0	0.389
19	0.063	20.504	0	0	0	-0.389
20	-0.063	20.558	0	0	0	0.389
21	0.063	20.504	0	0	0	-0.388
22	-0.063	20.558	0	0	0	0.39
23	0.063	20.512	0.001	0.002	0	-0.388
24	-0.063	20.566	0.001	0.002	0	0.39
25	0.059	19.092	-0.013	-0.045	0	-0.361
26	-0.058	19.14	-0.013	-0.044	0	0.359

Table-12. Support reactions of Fink truss with length to width ratio = 3

Node numbers	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN–m)	M_y (kN–m)	M_z (kN–m)
1	0.06	18.402	0.013	0.043	0	-0.378
2	-0.06	18.392	0.013	0.043	0	0.372
3	0.064	19.825	-0.001	-0.003	0	-0.409
4	-0.064	19.809	-0.001	-0.003	0	0.403
5	0.064	19.818	0	0	0	-0.409
6	-0.064	19.802	0	0	0	0.403
7	0.064	19.818	0	0	0	-0.409
8	-0.064	19.802	0	0	0	0.403
9	0.064	19.818	0	0	0	-0.409
10	-0.064	19.802	0	0	0	0.403
11	0.064	19.818	0	0	0	-0.409
12	-0.064	19.802	0	0	0	0.403
13	0.064	19.818	0	0	0	-0.409
14	-0.064	19.802	0	0	0	0.403
15	0.064	19.818	0	0	0	-0.409
16	-0.064	19.802	0	0	0	0.403
17	0.064	19.818	0	0	0	-0.409
18	-0.064	19.802	0	0	0	0.403
19	0.064	19.818	0	0	0	-0.409
20	-0.064	19.802	0	0	0	0.403
21	0.064	19.818	0	0	0	-0.409
22	-0.064	19.802	0	0	0	0.403
23	0.064	19.825	0.001	0.003	0	-0.409
24	-0.064	19.809	0.001	0.003	0	0.403
25	0.06	18.402	-0.013	-0.043	0	-0.378
26	-0.06	18.392	-0.013	-0.043	0	0.372

Table-13. Support reactions of portal frame with length to width ratio = 4

Node numbers	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN–m)	M_y (kN–m)	M_z (kN–m)
1	3.88	15.116	0.01	0.035	0	-26.151
2	-3.88	15.116	0.01	0.035	0	26.151
3	3.916	15.4	-0.003	-0.011	0	-26.416
4	-3.916	15.4	-0.003	-0.011	0	26.416
5	3.929	15.395	0	0	0	-26.509
6	-3.929	15.395	0	0	0	26.509
7	3.93	15.397	0	0	0	-26.514
8	-3.93	15.397	0	0	0	26.514
9	3.93	15.397	0	0	0	-26.514
10	-3.93	15.397	0	0	0	26.514
11	3.93	15.397	0	0	0	-26.514

12	-3.93	15.397	0	0	0	26.514
13	3.93	15.397	0	0	0	-26.514
14	-3.93	15.397	0	0	0	26.514
15	3.93	15.397	0	0	0	-26.514
16	-3.93	15.397	0	0	0	26.514
17	3.93	15.397	0	0	0	-26.514
18	-3.93	15.397	0	0	0	26.514
19	3.93	15.397	0	0	0	-26.514
20	-3.93	15.397	0	0	0	26.514
21	3.93	15.397	0	0	0	-26.514
22	-3.93	15.397	0	0	0	26.514
23	3.93	15.397	0	0	0	-26.514
24	-3.93	15.397	0	0	0	26.514
25	3.93	15.397	0	0	0	-26.514
26	-3.93	15.397	0	0	0	26.514
27	3.93	15.397	0	0	0	-26.514
28	-3.93	15.397	0	0	0	26.514
29	3.929	15.395	0	0	0	-26.509
30	-3.929	15.395	0	0	0	26.509
31	3.916	15.4	0.003	0.011	0	-26.416
32	-3.916	15.4	0.003	0.011	0	26.416
33	3.88	15.116	-0.01	-0.035	0	-26.151
34	-3.88	15.116	-0.01	-0.035	0	26.151

Table-14. Support reactions of Pratt truss with length to width ratio = 4

Node numbers	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN–m)	M_y (kN–m)	M_z (kN–m)
1	0.06	19.374	0.013	0.044	0	-0.39
2	-0.06	19.374	0.013	0.044	0	0.39
3	0.065	20.876	-0.001	-0.002	0	-0.424
4	-0.065	20.876	-0.001	-0.002	0	0.424
5	0.065	20.876	0	0.001	0	-0.424
6	-0.065	20.876	0	0.001	0	0.424
7	0.065	20.876	0	0	0	-0.424
8	-0.065	20.876	0	0	0	0.424
9	0.065	20.876	0	0	0	-0.424
10	-0.065	20.876	0	0	0	0.424
11	0.065	20.876	0	0	0	-0.424
12	-0.065	20.876	0	0	0	0.424
13	0.065	20.876	0	0	0	-0.424
14	-0.065	20.876	0	0	0	0.424
15	0.065	20.876	0	0	0	-0.424
16	-0.065	20.876	0	0	0	0.424
17	0.065	20.876	0	0	0	-0.424
18	-0.065	20.876	0	0	0	0.424
19	0.065	20.876	0	0	0	-0.424
20	-0.065	20.876	0	0	0	0.424
21	0.065	20.876	0	0	0	-0.424
22	-0.065	20.876	0	0	0	0.424
23	0.065	20.876	0	0	0	-0.424
24	-0.065	20.876	0	0	0	0.424
25	0.065	20.876	0	0	0	-0.424
26	-0.065	20.876	0	0	0	0.424
27	0.065	20.876	0	0	0	-0.424
28	-0.065	20.876	0	0	0	0.424
29	0.065	20.876	0	-0.001	0	-0.424
30	-0.065	20.876	0	-0.001	0	0.424
31	0.065	20.876	0.001	0.002	0	-0.424
32	-0.065	20.876	0.001	0.002	0	0.424
33	0.06	19.374	-0.013	-0.044	0	-0.39
34	-0.06	19.374	-0.013	-0.044	0	0.39

Table-15. Support reactions of Howe truss with length to width ratio = 4

Node numbers	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN–m)	M_y (kN–m)	M_z (kN–m)
1	0.059	19.185	0.013	0.045	0	-0.363
2	-0.059	19.234	0.013	0.045	0	0.362
3	0.064	20.699	-0.001	-0.002	0	-0.394
4	-0.064	20.753	-0.001	-0.002	0	0.395
5	0.064	20.691	0	0.001	0	-0.394
6	-0.064	20.745	0	0.001	0	0.395
7	0.064	20.692	0	0	0	-0.394
8	-0.064	20.746	0	0	0	0.395
9	0.064	20.692	0	0	0	-0.394
10	-0.064	20.746	0	0	0	0.395
11	0.064	20.692	0	0	0	-0.394
12	-0.064	20.746	0	0	0	0.395
13	0.064	20.692	0	0	0	-0.394
14	-0.064	20.746	0	0	0	0.395
15	0.064	20.692	0	0	0	-0.394
16	-0.064	20.746	0	0	0	0.395
17	0.064	20.692	0	0	0	-0.394
18	-0.064	20.746	0	0	0	0.395
19	0.064	20.692	0	0	0	-0.394
20	-0.064	20.746	0	0	0	0.395
21	0.064	20.692	0	0	0	-0.394
22	-0.064	20.746	0	0	0	0.395
23	0.064	20.692	0	0	0	-0.394
24	-0.064	20.746	0	0	0	0.395
25	0.064	20.692	0	0	0	-0.394
26	-0.064	20.746	0	0	0	0.395
27	0.064	20.692	0	0	0	-0.394
28	-0.064	20.746	0	0	0	0.395
29	0.064	20.691	0	-0.001	0	-0.394
30	-0.064	20.745	0	-0.001	0	0.395
31	0.064	20.699	0.001	0.002	0	-0.394
32	-0.064	20.753	0.001	0.002	0	0.395
33	0.059	19.185	-0.013	-0.045	0	-0.363
34	-0.059	19.234	-0.013	-0.045	0	0.362

Table-16. Support reactions of Fink truss with length to width ratio = 4

Node numbers	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN–m)	M_y (kN–m)	M_z (kN–m)
1	0.059	18.124	0.013	0.043	0	-0.371
2	-0.059	18.114	0.013	0.043	0	0.364
3	0.063	19.554	-0.001	-0.002	0	-0.402
4	-0.063	19.539	-0.001	-0.002	0	0.395
5	0.063	19.544	0	0.001	0	-0.402
6	-0.063	19.528	0	0.001	0	0.396
7	0.063	19.544	0	0	0	-0.402
8	-0.063	19.528	0	0	0	0.396
9	0.063	19.544	0	0	0	-0.402
10	-0.063	19.528	0	0	0	0.396
11	0.063	19.544	0	0	0	-0.402
12	-0.063	19.528	0	0	0	0.396
13	0.063	19.544	0	0	0	-0.402
14	-0.063	19.528	0	0	0	0.396
15	0.063	19.544	0	0	0	-0.402
16	-0.063	19.528	0	0	0	0.396
17	0.063	19.544	0	0	0	-0.402
18	-0.063	19.528	0	0	0	0.396
19	0.063	19.544	0	0	0	-0.402
20	-0.063	19.528	0	0	0	0.396
21	0.063	19.544	0	0	0	-0.402
22	-0.063	19.528	0	0	0	0.396
23	0.063	19.544	0	0	0	-0.402
24	-0.063	19.528	0	0	0	0.396
25	0.063	19.544	0	0	0	-0.402
26	-0.063	19.528	0	0	0	0.396
27	0.063	19.544	0	0	0	-0.402
28	-0.063	19.528	0	0	0	0.396
29	0.063	19.544	0	-0.001	0	-0.402
30	-0.063	19.528	0	-0.001	0	0.396
31	0.063	19.554	0.001	0.002	0	-0.402
32	-0.063	19.539	0.001	0.002	0	0.395
33	0.059	18.124	-0.013	-0.043	0	-0.371
34	-0.059	18.114	-0.013	-0.043	0	0.364

Table-17. Support reactions of portal frame with length to width ratio = 5

Node numbers	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN–m)	M_y (kN–m)	M_z (kN–m)
1	3.88	15.116	0.01	0.035	0	-26.151
2	-3.88	15.116	0.01	0.035	0	26.151
3	3.916	15.4	-0.003	-0.011	0	-26.416
4	-3.916	15.4	-0.003	-0.011	0	26.416
5	3.929	15.395	0	0	0	-26.509
6	-3.929	15.395	0	0	0	26.509
7	3.93	15.397	0	0	0	-26.514
8	-3.93	15.397	0	0	0	26.514
9	3.93	15.397	0	0	0	-26.514

10	-3.93	15.397	0	0	0	26.514
11	3.93	15.397	0	0	0	-26.514
12	-3.93	15.397	0	0	0	26.514
13	3.93	15.397	0	0	0	-26.514
14	-3.93	15.397	0	0	0	26.514
15	3.93	15.397	0	0	0	-26.514
16	-3.93	15.397	0	0	0	26.514
17	3.93	15.397	0	0	0	-26.514
18	-3.93	15.397	0	0	0	26.514
19	3.93	15.397	0	0	0	-26.514
20	-3.93	15.397	0	0	0	26.514
21	3.93	15.397	0	0	0	-26.514
22	-3.93	15.397	0	0	0	26.514
23	3.93	15.397	0	0	0	-26.514
24	-3.93	15.397	0	0	0	26.514
25	3.93	15.397	0	0	0	-26.514
26	-3.93	15.397	0	0	0	26.514
27	3.93	15.397	0	0	0	-26.514
28	-3.93	15.397	0	0	0	26.514
29	3.93	15.397	0	0	0	-26.514
30	-3.93	15.397	0	0	0	26.514
31	3.93	15.397	0	0	0	-26.514
32	-3.93	15.397	0	0	0	26.514
33	3.93	15.397	0	0	0	-26.514
34	-3.93	15.397	0	0	0	26.514
35	3.93	15.397	0	0	0	-26.514
36	-3.93	15.397	0	0	0	26.514
37	3.929	15.395	0	0	0	-26.509
38	-3.929	15.395	0	0	0	26.509
39	3.916	15.4	0.003	0.011	0	-26.416
40	-3.916	15.4	0.003	0.011	0	26.416
41	3.88	15.116	-0.01	-0.035	0	-26.151
42	-3.88	15.116	-0.01	-0.035	0	26.151

Table-18. Support reactions of Pratt truss with length to width ratio = 5

Node numbers	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN–m)	M_y (kN–m)	M_z (kN–m)
1	0.06	19.373	0.013	0.044	0	-0.39
2	-0.06	19.373	0.013	0.044	0	0.39
3	0.065	20.876	-0.001	-0.002	0	-0.424
4	-0.065	20.876	-0.001	-0.002	0	0.424
5	0.065	20.876	0	0.001	0	-0.424
6	-0.065	20.876	0	0.001	0	0.424
7	0.065	20.876	0	0	0	-0.424
8	-0.065	20.876	0	0	0	0.424
9	0.065	20.876	0	0	0	-0.424
10	-0.065	20.876	0	0	0	0.424
11	0.065	20.876	0	0	0	-0.424
12	-0.065	20.876	0	0	0	0.424
13	0.065	20.876	0	0	0	-0.424
14	-0.065	20.876	0	0	0	0.424
15	0.065	20.876	0	0	0	-0.424
16	-0.065	20.876	0	0	0	0.424
17	0.065	20.876	0	0	0	-0.424
18	-0.065	20.876	0	0	0	0.424
19	0.065	20.876	0	0	0	-0.424
20	-0.065	20.876	0	0	0	0.424
21	0.065	20.876	0	0	0	-0.424
22	-0.065	20.876	0	0	0	0.424
23	0.065	20.876	0	0	0	-0.424
24	-0.065	20.876	0	0	0	0.424
25	0.065	20.876	0	0	0	-0.424
26	-0.065	20.876	0	0	0	0.424
27	0.065	20.876	0	0	0	-0.424
28	-0.065	20.876	0	0	0	0.424
29	0.065	20.876	0	0	0	-0.424
30	-0.065	20.876	0	0	0	0.424
31	0.065	20.876	0	0	0	-0.424
32	-0.065	20.876	0	0	0	0.424
33	0.065	20.876	0	0	0	-0.424
34	-0.065	20.876	0	0	0	0.424
35	0.065	20.876	0	0	0	-0.424
36	-0.065	20.876	0	0	0	0.424
37	0.065	20.876	0	-0.001	0	-0.424
38	-0.065	20.876	0	-0.001	0	0.424
39	0.065	20.876	0.001	0.002	0	-0.424
40	-0.065	20.876	0.001	0.002	0	0.424
41	0.06	19.373	-0.013	-0.044	0	-0.39
42	-0.06	19.373	-0.013	-0.044	0	0.39

Table-19. Support reactions of Howe truss with length to width ratio = 5

Node numbers	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN–m)	M_y (kN–m)	M_z (kN–m)
1	0.06	19.373	0.013	0.045	0	-0.363
2	-0.06	19.373	0.013	0.045	0	0.362
3	0.065	20.876	-0.001	-0.002	0	-0.394
4	-0.065	20.876	-0.001	-0.002	0	0.395
5	0.065	20.876	0	0.001	0	-0.394
6	-0.065	20.876	0	0.001	0	0.395
7	0.065	20.876	0	0	0	-0.394
8	-0.065	20.876	0	0	0	0.395
9	0.065	20.876	0	0	0	-0.394
10	-0.065	20.876	0	0	0	0.395
11	0.065	20.876	0	0	0	-0.394
12	-0.065	20.876	0	0	0	0.395
13	0.065	20.876	0	0	0	-0.394
14	-0.065	20.876	0	0	0	0.395
15	0.065	20.876	0	0	0	-0.394
16	-0.065	20.876	0	0	0	0.395
17	0.065	20.876	0	0	0	-0.394
18	-0.065	20.876	0	0	0	0.395
19	0.065	20.876	0	0	0	-0.394
20	-0.065	20.876	0	0	0	0.395
21	0.065	20.876	0	0	0	-0.394
22	-0.065	20.876	0	0	0	0.395
23	0.065	20.876	0	0	0	-0.394
24	-0.065	20.876	0	0	0	0.395
25	0.065	20.876	0	0	0	-0.394
26	-0.065	20.876	0	0	0	0.395
27	0.065	20.876	0	0	0	-0.394
28	-0.065	20.876	0	0	0	0.395
29	0.065	20.876	0	0	0	-0.394
30	-0.065	20.876	0	0	0	0.395
31	0.065	20.876	0	0	0	-0.394
32	-0.065	20.876	0	0	0	0.395
33	0.065	20.876	0	0	0	-0.394
34	-0.065	20.876	0	0	0	0.395
35	0.065	20.876	0	0	0	-0.394
36	-0.065	20.876	0	0	0	0.395
37	0.065	20.876	0	-0.001	0	-0.394
38	-0.065	20.876	0	-0.001	0	0.395
39	0.065	20.876	0.001	0.002	0	-0.394
40	-0.065	20.876	0.001	0.002	0	0.395
41	0.06	19.373	-0.013	-0.045	0	-0.363
42	-0.06	19.373	-0.013	-0.045	0	0.362

Table -20. Support reactions of Fink truss with length to width ratio = 5

Node numbers	F_x (kN)	F_y (kN)	F_z (kN)	M_x (kN–m)	M_y (kN–m)	M_z (kN–m)
1	0.059	18.124	0.013	0.044	0	-0.371
2	-0.059	18.114	0.013	0.043	0	0.364
3	0.063	19.554	-0.001	-0.002	0	-0.402
4	-0.063	19.539	-0.001	-0.002	0	0.395
5	0.063	19.544	0	0.001	0	-0.402
6	-0.063	19.528	0	0.001	0	0.396
7	0.063	19.544	0	0	0	-0.402
8	-0.063	19.528	0	0	0	0.395
9	0.063	19.544	0	0	0	-0.402
10	-0.063	19.528	0	0	0	0.396
11	0.063	19.544	0	0	0	-0.402
12	-0.063	19.528	0	0	0	0.396
13	0.063	19.544	0	0	0	-0.402
14	-0.063	19.528	0	0	0	0.396
15	0.063	19.544	0	0	0	-0.402
16	-0.063	19.528	0	0	0	0.396
17	0.063	19.544	0	0	0	-0.402
18	-0.063	19.528	0	0	0	0.396
19	0.063	19.544	0	0	0	-0.402
20	-0.063	19.528	0	0	0	0.396
21	0.063	19.544	0	0	0	-0.402
22	-0.063	19.528	0	0	0	0.396
23	0.063	19.544	0	0	0	-0.402

24	-0.063	19.528	0	0	0	0.396
25	0.063	19.544	0	0	0	-0.402
26	-0.063	19.528	0	0	0	0.396
27	0.063	19.544	0	0	0	-0.402
28	-0.063	19.528	0	0	0	0.396
29	0.063	19.544	0	0	0	-0.402
30	-0.063	19.528	0	0	0	0.396
31	0.063	19.544	0	0	0	-0.402
32	-0.063	19.528	0	0	0	0.396
33	0.063	19.544	0	0	0	-0.402
34	-0.063	19.528	0	0	0	0.396
35	0.063	19.544	0	0	0	-0.402
36	-0.063	19.528	0	0	0	0.395
37	0.063	19.544	0	-0.001	0	-0.402
38	-0.063	19.528	0	-0.001	0	0.396
39	0.063	19.554	0.001	0.002	0	-0.402
40	-0.063	19.539	0.001	0.002	0	0.395
41	0.059	18.124	-0.013	-0.044	0	-0.371
42	-0.059	18.114	-0.013	-0.043	0	0.364

The values of maximum support reaction forces (F_y) and maximum support moments (M_z) are plotted with respect to different length to width ratios for various factory shed models in Figs. 3 to 5. The close observations of Figs. 3 to 5 establish that the values of support moments (M_z) for portal frame models are very much higher than the support moment values of other truss cases for all length to width ratios. The same trend is followed for the values of reaction forces (F_y) for unit length to width ratio only and it is shown in Fig.3. The base plates and foundations are designed by consideration of support reactions and moments both. So, it is definitely concluded that portal frames require much higher sections with compare to the other truss options for designing the base plates and foundations. It is preferred to the design engineers not to choose portal frame options for designing steel sheds unless otherwise mentioned. This suggestion may be a very helpful tool to the practicing engineers. Among the truss geometries taken up here, Fink truss gives the lower values of support reactions. So, in general, Fink truss is the best option to the designers to select an optimum geometry for steel factory shed.

In many practical situations, lengths and widths of factory sheds are very important for designing. Hence, the author investigates the structural behaviour of steel roof trusses for varying length to width ratios up to five. It is interestingly noticed from the results furnished in Figs. 3 to 5 that the values of support reactions are lower for length to width ratio is equal to three for most of the cases. For Fink truss case, the length to width ratio = 5 gives the lower values but the differences of values between length to width ratios 3 and 5 are very less (about 1.4%). So it may be ignored and it is safely concluded that the optimum ratio of length to width is three for the present study.

4.2 Behavior of roofing structures based on designed steel sections

To get an overall idea about the optimum design sections, the present author also studies the steel sections required for roof trusses as well as portal frame for various length to width ratios. These sections are shown in the Table 21. It is clearly visible from the Table 21 that portal frame requires much higher sections in compare to the sections required for other steel roof trusses for all cases. So the author suggests to the designer not to use portal frame as roofing structures unless depending on the availability of steel sections in market. Among all the truss geometries it is noticed that, rafter and tie members require lower steel sections compare to the sections required for sling and strut members.

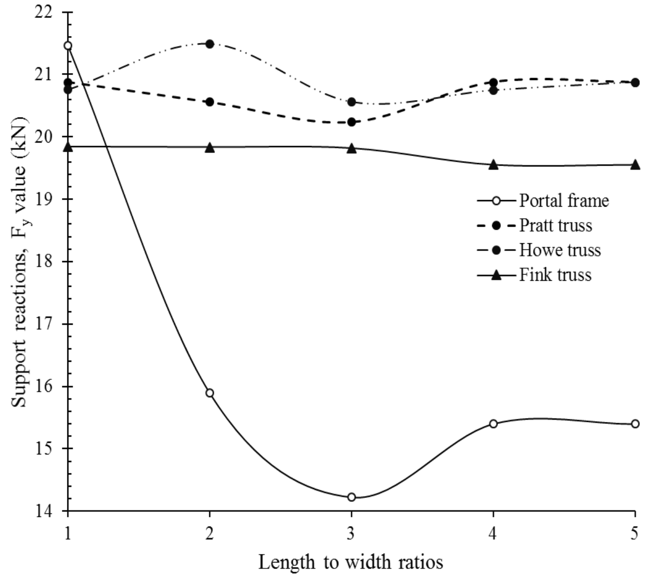

Fig.3. Support reactions (F_y) of different types of factory sheds for varying length to width ratios.

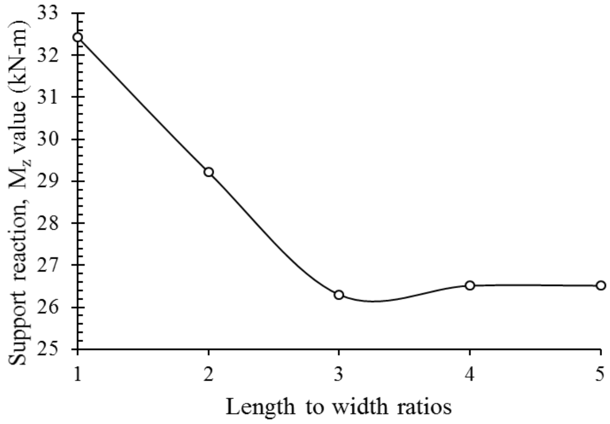

Fig.4. Support reactions (M_z) of portal frame factory shed for varying length to width ratios.

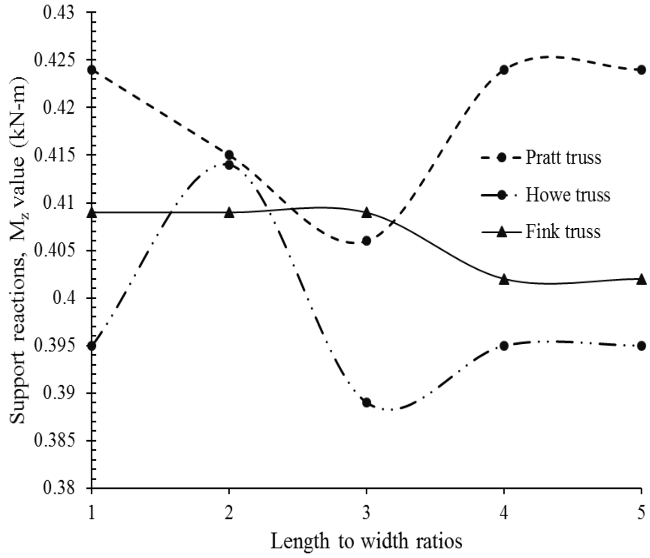

Fig.5. Support reactions (M_z) of different types of factory sheds for varying length to width ratios.

The author also studies the total weight of steel sections for different types of factory sheds considered here in Table 22. For unit length to width ratio, the gross steel weight of roofing structures of portal frame has higher value than the steel weight of other truss type roofing structures and this value may increase up to 72%. As it is well known that square plan-form is the most suitable plan-form from constructional point of interest, so it can be safely concluded that the truss option is the best option than the portal frame. Among the Pratt, Howe and Fink truss geometries, the Fink truss gives lower gross steel weight values for all length to width ratios taken up here. So it is recommended to the practicing design engineers to choose Fink truss geometry for using as a roofing structure in steel factory shed.

Table-21. Steel sections required for different types of steel factory sheds

Roofing structure type	Length to width ratio	Member type			
		Rafter member	Tie member	Sling member	Strut member
Portal frame	1	ISA 200X200 X25			
	2	ISA 200X200 X12			
	3	ISA 200X200 X12			
	4	ISA 200X200 X16			
	5	ISA 200X200 X16			
Pratt truss	1	ISA 80X80X8	ISA 75X75X8	ISA 120X120 X8	ISA 120X120 X8
	2	ISA 80X80X8	ISA 75x75x8	ISA 110X110 X8	ISA 110X110 X8
	3	ISA 80X80X8	ISA 75X75X8	ISA 100X100 X8	ISA 100X100 X8
	4	ISA 80X80X8	ISA 75X75X8	ISA 120X120 X8	ISA 120X120 X8
	5	ISA 80X80X8	ISA 75X75X8	ISA 120X120 X8	ISA 120X120 X8
Howe truss	1	ISA 80X80X8	ISA 75X75X8	ISA 100X100 X8	ISA 100X100 X8
	2	ISA 80X80X8	ISA 75X75X8	ISA 120X120 X8	ISA 120X120 X8
	3	ISA 80X80X8	ISA 75X75X8	ISA 100X100 X8	ISA 100X100 X8
	4	ISA 80X80X8	ISA 75X75X8	ISA 100X100 X8	ISA 100X100 X8
	5	ISA 80X80X8	ISA 75X75X8	ISA 100X100 X8	ISA 100X100 X8
Fink truss	1	ISA 80X80X8	ISA 75X75X8	ISA 100X100 X8	ISA 100X100 X8
	2	ISA 80X80X8	ISA 75X75X8	ISA 120X120 X8	ISA 120X120 X8
	3	ISA 80X80X8	ISA 75X75X8	ISA 100X100 X8	ISA 100X100 X8
	4	ISA 80X80X8	ISA 75X75X8	ISA 90X90X8	ISA 90X90X8
	5	ISA 80X80X8	ISA 75X75X8	ISA 90X90X8	ISA 90X90X8

Table-22. Weight of steel sections for different types of steel factory sheds

Roofing structure type	Length to width ratio	Member type				Total roofing structure weight (Ton)
		Weight of rafter member (Ton)	Weight of tie member (Ton)	Weight of sling member (Ton)	Weight of strut member (Ton)	
Portal frame	1	7.554				7.554
	2	6.77				6.77
	3	9.78				9.78
	4	16.86				16.86
	5	20.83				20.83
Pratt truss	1	0.98	0.71	1.79	1.79	5.27
	2	1.76	1.28	2.93	2.93	8.9
	3	2.54	1.85	3.81	3.81	12.01
	4	3.32	2.43	6.09	6.09	17.93
	5	4.11	3.0	7.5	7.5	22.11
Howe truss	1	0.98	0.71	1.72	1.72	5.13
	2	1.76	1.28	3.77	3.77	10.58
	3	2.54	1.85	4.46	4.46	13.31
	4	3.32	2.43	5.83	5.83	17.41
	5	4.11	3.0	7.21	7.21	21.53
Fink truss	1	0.98	0.71	1.35	1.35	4.39
	2	1.76	1.28	2.43	2.43	7.9
	3	2.54	1.82	3.5	3.5	11.36
	4	3.32	2.43	4.09	4.09	13.93
	5	4.11	3.0	5.06	5.06	17.23

5. Concluding Remarks

The following conclusions are drawn from the present study.

- The extreme end columns such as front and rear side columns give lower values of support reactions in compare to other internal columns and it may be used in design of foundations.
- In general, the Fink truss is the best suited option among all the geometries taken up here.
- It is concluded that the optimum ratio of length to width is three for the present study.
- Among all the truss geometries it is concluded that, rafter and tie members require lower steel sections compare to the sections required for sling and strut members.
- It is recommended to the practicing design engineers to choose Fink truss geometry for using as a roofing structure in steel factory shed.

Disclosures

Free Access to this article is sponsored by SARL ALPHA CRISTO INDUSTRIAL.

References

1. Viswakarma N, Tayal H. Optimization of industrial building using pre-engineering building and conventional steel building by fully stressed designed. International Journal of Applied Engineering Research, 2018; 13(20): 14573-14590.

2. Smith J, Hodgins JK, Oppenheim I, Witkin A. Creating models of truss structure with optimization. ACM Transactions on Graphics, 2002; 20(3): 295-301.

3. Yamini U. Motghare. Compartive design and study of various steel sheds with various design codes for selecting a better option for construction of new sheds. International Research Journal of Engineering and Technology, 2018; 5(6): 94-98.

4. Mohakul S, Yajdani S, Dhurde A. Design of industrial storage shed and analysis of stresses produced on failure of a joint. International Journal of Civil Engineering and Technology, 2014; 5(8): 114-127.

5. Sharma A, Sikka R, Arora B, Dewangan A. Study of design of industrial factory steel shed and foundation and compare with reinforce concrete portal frame structure. International Journal of Engineering Research and Management, 2018; 5(6): 60-63.

6. Shahid S, Ali S, Hussain F. Design optimization of steel structures from conventional steel building to pre-engineered building by varying loads. NFC-IEFR Journal of Engineering and Scientific Research, 2018; 103-109.

7. Gupta DK, Baig MA. Design of industrial steel building by limit state method. International Journal of Advance Research, Ideas and Innovations in Technology, 2017; 3(4): 414-424.