iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** VI **Month of publication:** June 2020

DOI: http://doi.org/10.22214/ijraset.2020.6248

Wind Analysis of Pre-Engineering and Conventional Steel Structure using Pratt Truss

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Abstract: ***The paper presents a simple computer based wind analysis on PEB and conventional steel structure using different span having a constant pitch ratio to understand the behavior of two different structure. In this study industrial shed using Pratt truss with different structural configuration like PEB and conventional steel structure having vary span 30m,27m and 24m using Etab2017 version software. From output of analysis different parameters like total dead load, story displacement and overturning moment is analyzing. the introduction of Pre-Engineered Building (PEB) design of structures has helped in optimizing design. The construction of PEB in the place of Conventional Steel Building (CSB) design concept resulted in many advantages as the members are design as per bending moment diagram and thus reducing the steel requirement.***
Keywords: ***Pratt truss, conventional, analysis, story displacement, bending moment.***

I. INTRODUCTION

An industrial building is any structure that is used to store raw materials, house a manufacturing process, or store the furnished goods from a manufacturing process. Industrial buildings can range from the simplest warehouse type structure to highly sophisticated structures integrated with a manufacturing system. These buildings are low rise steel structures characterised by low height, lack of interior floor, walls, and partitions. The roofing system for such a building is a truss with roof covering. Design of basic elements of the structure (Roof deck, Purlins, Girders, Columns and Girts) is not difficult, but combining them into functional and cost-effective system is a complex task.

In Industrial building structures, the walls can be formed of steel columns with cladding which may be of profiled or plain sheets, GI sheets, precast concrete, or masonry. The wall must be adequately strong to resist the lateral force due to wind or earthquake.

A. Component of an Industrial Building

The elements of industrial buildings are listed below.

1) Principal Rafters
2) Roof Truss
3) Purlins
4) Sag rods
5) Gantry Girders
6) Bracket
7) Column and Column base
8) Girt Rods
9) Bracings

B. Wind load

The most critical load on an industrial building is the wind load. For the roof and walls of an industrial building, consideration must be made for pressure difference between the opposite faces of such elements to accounts for external and internal air pressures exerted by wind blowing against the building. When the negative air pressure is less than the atmospheric pressure is known as suction. IS 875 (part 3) 1987 specifies the following wind load coefficients to be assumed in the analysis of an industrial building.

The wind force F is obtained by an equation

$F = (C_{pe} - C_{pi})\, A P_z$

II. OBJECTIVE

Following are the main objective of the present study.

1) To understand the behavior of Pre engineering material building and conventional building.
2) To understand the linear Analysis or wind analysis.
3) To find out the maximum and minimum axial forces in column from different load combination.

4) To understand the formation of lateral displacement under the action of wind analysis from is 875(part3):2015.
5) To find out factored load on base column under the action of different load combination according to IS code.

III. PROBLEM FORMULATION

Industrial building with 3-dimensional frame, Pre-engineered steel building with 30m span using Pratt truss terms as model1, conventional steel building with 30m span using Pratt truss terms as model2, Pre-engineered steel building with 27m span using Pratt truss terms as model3, conventional steel building with 27m span using Pratt truss terms as model4, Pre-engineered steel building with 24m span using Pratt truss terms as model5, conventional steel building with 24m span using Pratt truss terms as model6 were taken or study. Six different industrial building models with six bays in horizontal and one bays in lateral direction is analyzed by Equivalent Static Method and Wind Method.
The geometrical parameters of the building are as follows:

A. Height of each industrial building = 6.4 m
B. Fixed type support at the bottom.

The loads on the building are as follows:
1) *Dead Load:* Self-weight of the frame
2) *Dead Load of Industrial Truss:* Dead floor load of all the intermediate industrial AC sheet = 171 N/m2
3) *Dead load of walls:* On outer beams = 18.85 KN/m2
4) *Live Load:* Live load on roof depend upon rise to span ratio of each industrial shed

Wind load in X-direction & Y-direction as specified in IS 875(Part3): 2015.

IV. ANALAYTICAL MODELING

The study in thesis is based on Wind analysis of industrial steel structural models using **ETAB 2000 vs. 19**. Accurate modeling of all models consist various elements is very important in wind and static linear analysis. In present study, frame element is modeled with plastic and elastic flexural hinge using elastic model as area element providing Steel property.

A. Industrial Building Geometry

Industrial Steel Frame Structure were taken or the study. Six different Industrial building models with constant width of 36m in X-direction (6 bay@ 6m), variation in Y-direction having 24m (6 bay@ 4m), 27m (6 bay@ 4.5m) and 30m (6 bay@ 5m) using pratt truss with constant pitch (span/rise ratio) that is 1/6 and industrial building height equal to 6.4m were considered for this study. The structures are modeled by using computer software ETAB 2000vs19. The column section defined for the frame satisfies both the requirement for strength and stiffness. All the selected models were designed with Fe-250, grade of steel as per Indian standards.
Detail of structure and Finite element modeling, the basic geometries of pre-engineered and conventional structure with eight different models with same plans are as following;
Computer modelling the basic assumption on geometry of steel frame structure with six different models with different plan area are as follows

1) Plan area (36*30 m^2) which is similar for model1 and model2 shown in (fig 1) with their detail.

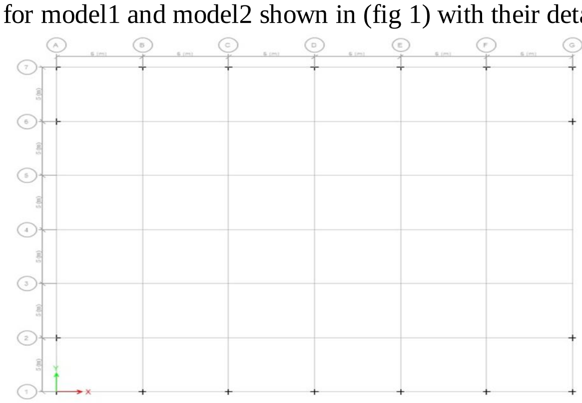

Figure1: Representation of plan area of model1 and model2 building models

2) Plan area (36*27 m^2) which is similar for model3 and model4 shown in (fig 2) with their detail.

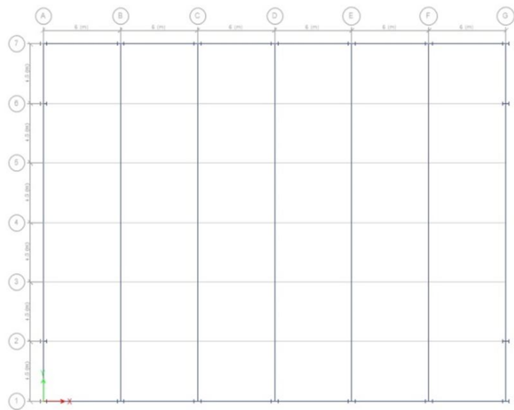

Figure2: Representation of plan area of model3 and model4 building models

3) Plan area (36*24 m^2) which is similar for mode5 and model6 shown in (fig 3) with their detail.

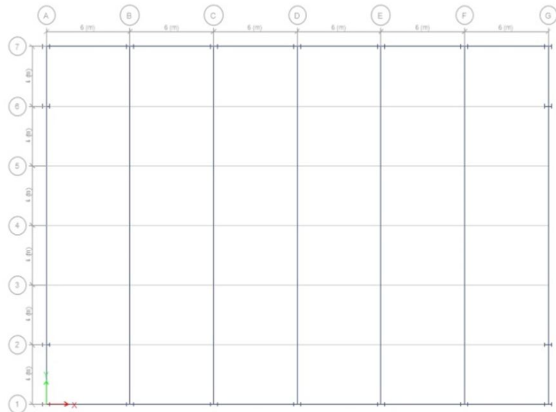

Figure3: Representation of plan area of model5 and model6 building models

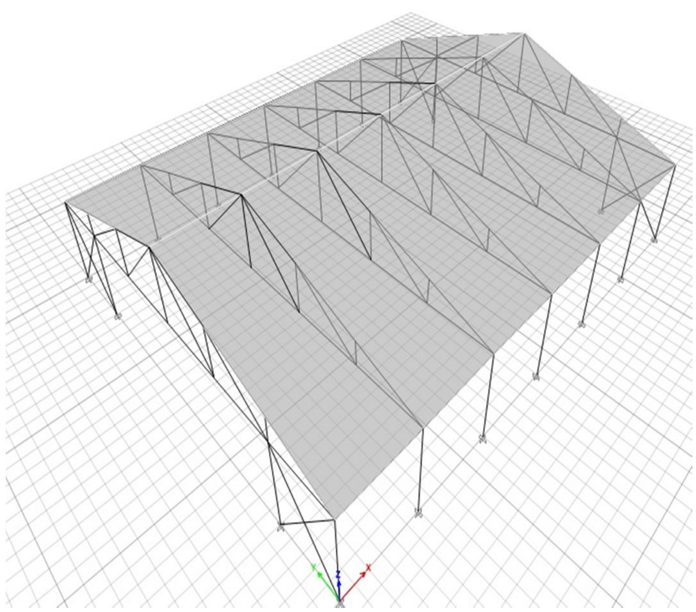

Figure4:3-Dimensional model of Pre-Engineered Building having 30m span Pratt truss

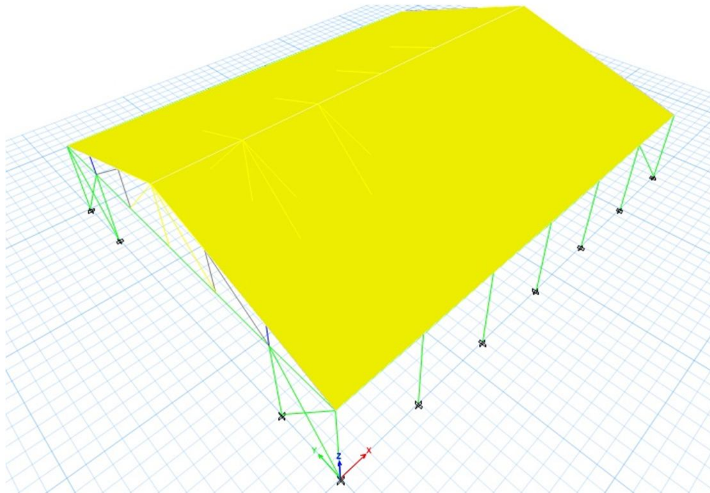

Figure5:3-Dimensional model of Conventional Steel Building having 30m span Pratt truss

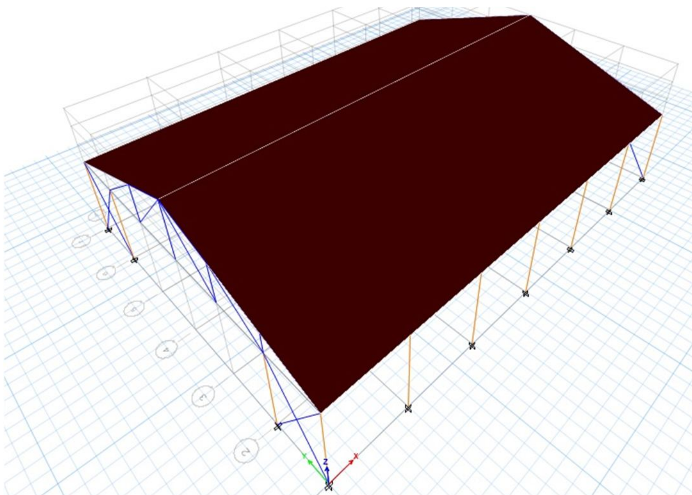

Figure6:3-Dimensional model of Pre-Engineered Building having 27m span Pratt truss

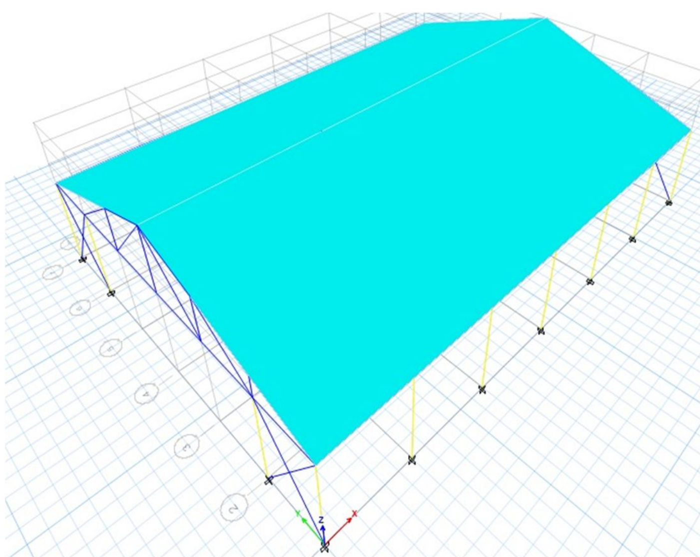

Figure7:3-Dimensional model of Conventional Steel Building having 27m span Pratt truss

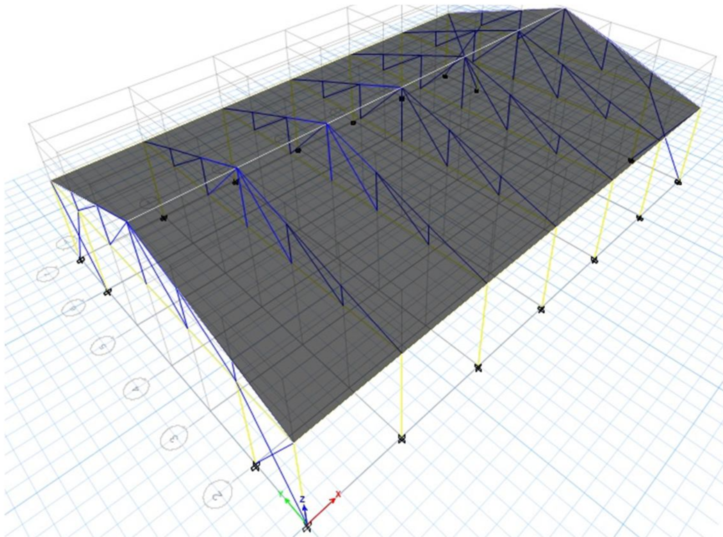

Figure8:3-Dimensional model of Pre-Engineered Building having 24m span Pratt truss

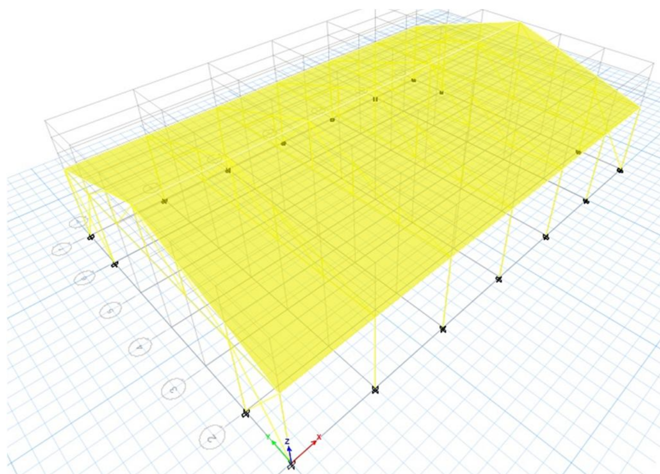

Figure9:3-Dimensional model of Conventional Steel Building having 24m span Pratt truss

B. Load Distribution

1) Load Calculation For 30m Span Pratt Truss

For 30m span
Pitch (Rise/span) =1/6
Rise of truss=1/6*30=5m

Let **Θ** be the inclination of the roof truss with the horizontal

$$\tan\theta = \frac{1}{3}$$
$$\theta = 18.43°$$

Length of rafter =$\sqrt{15^2 + 5^2}$=15.81m
Distance between panel joint=15.81/3=5.27m

a) Dead load calculation

Weight of AC sheets=171 N/m^2
Assume Weight of purlins=318 N/m
Weight of bracing =12 N/m^2
Self-weight of roof truss =(span/3+5) *10= (30/3+5) *10
= 150.0 N/m^2

Total dead load=171+12+150=333 N/m^2
Dead load of purlin=318*6=1908 N
6m are c/c spacing of roof truss.
The panel length=L_0U_1=U_1U_2=U_2U_3=5.27m
The panel length in plan =5.27$\cos 18.43°$=5m
Spacing of truss= 6m
Load on each intermediate panel due to dead load= 333*6*5+1908=11.898kN
Load on end panel=11.898/2=5.949kN

b) Live load calculation (for $\theta = 18.43$)

Let us assume that no access is provided to the roof truss. The live load is reduced by 20 N/m^2 for each one degree above 10° slope.
∴ Live load= (750-20*(18.43-10)) =581.4 N/m^2
The load on each intermediate panel=581.4*6*5=17.442 kN
The load on each end panel =17.442/2 = 8.721 kN

2) Load Calculation For 27m Span Pratt Truss

For 27m span
Pitch (Rise/span) =1/6
Rise of truss=1/6*27=4.5m
Let **Θ** be the inclination of the roof truss with the horizontal

$$\tan\theta = \frac{1}{3}$$
$$\theta = 18.43°$$

Length of rafter =$\sqrt{13.5^2 + 4.5^2}$=14.23m
Distance between panel joint=14.23/3=4.74m

a) Dead load calculation

Weight of AC sheets=171 N/m^2
Assume Weight of purlins=318 N/m
Weight of bracing =12 N/m^2
Self-weight of roof truss =(span/3+5) *10= (27/3+5) *10
= 140.0 N/m^2
Total dead load=171+12+140=323 N/m^2
Dead load of purlin=318*6=1908 N
6m are c/c spacing of roof truss.
The panel length=L_0U_1=U_1U_2=U_2U_3=4.74m
The panel length in plan =5.27$\cos 18.43°$=4.5m
Spacing of truss= 6m
Load on each intermediate panel due to dead load= 323*6*4.5+1908=10.629kN
Load on end panel=10.629/2=5.314kN

b) Live load calculation (for $\theta = 18.43$)

Let us assume that no access is provided to the roof truss. The live load is reduced by 20 N/m^2 for each one degree above 10° slope.
∴ Live load= (750-20*(18.43-10)) =581.4 N/m^2
The load on each intermediate panel=581.4*6*4.5=15.698 kN
The load on each end panel =15.698/2 = 7.849 kN

3) Load Calculation For 24m Span Pratt Truss

For 24m span
Pitch (Rise/span) =1/6
Rise of truss=1/6*24=4m
Let **Θ** be the inclination of the roof truss with the horizontal

$$\tan\theta = \frac{1}{3}$$
$$\theta = 18.43°$$

Length of rafter $=\sqrt{12^2+4^2}$=12.65m
Distance between panel joint=12.65/3=4.216m

a) Dead load calculation

Weight of AC sheets=171 N/m^2
Assume Weight of purlins=318 N/m
Weight of bracing =12 N/m^2
Self-weight of roof truss =(span/3+5) *10= (24/3+5) *10
= 130.0 N/m^2
Total dead load=171+12+130=313 N/m^2
Dead load of purlin=318*6=1908 N
6m are c/c spacing of roof truss.
The panel length=L_0U_1=U_1U_2=U_2U_3=4.216m
The panel length in plan =5.27cos 18.43°=4m
Spacing of truss= 6m
Load on each intermediate panel due to dead load= 313*6*4+1908=9.42kN
Load on end panel=9.42/2=4.71kN

b) Live load calculation (for $\theta = 18.43$)

Let us assume that no access is provided to the roof truss. The live load is reduced by 20 N/m^2 for each one degree above 10° slope.
∴ Live load= (750-20*(18.43-10)) =581.4 N/m^2
The load on each intermediate panel=581.4*6*4=13.953 kN

V. RESULT

Wind and linear static analysis conducted over pre-engineered structure with different industrial plan configuration having constant pitch ratio over different span of truss using Pratt truss. The various results obtained after the analysis presented and discussed in this paper.

A. Force Distribution

Table 1 Wind Base force of all models in Z-directions (Total dead load)

Models	Base force kN
	Z-direction
Model 1	946.65
Model 2	970.1
Model 3	843.63
Model 4	866.11
Model 5	805.89
Model 6	827.25

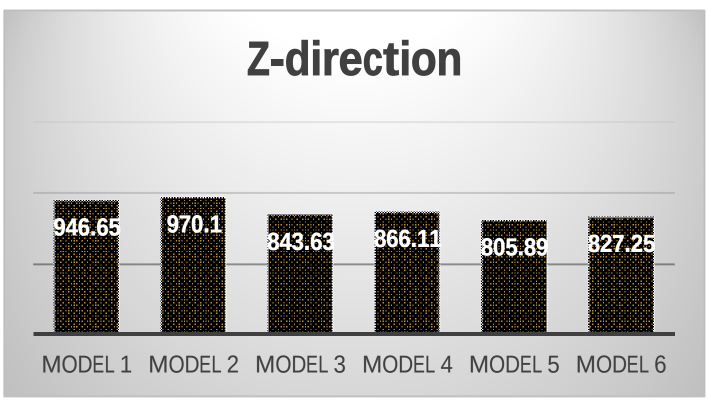

Figure 10: Base force of all models in Z directions

The value of Base force in Z-direction on comparing between different models is analysis. It is found that minimum force value of model5 (pre-engineered building having span 24m) because of larger shorter span and tapered steel section are used as compare to other models.

On comparing between model1 (PEB 30m span) and model2 (conventional 30m span) in table 4.1 and figure 4.1. It is observed that total dead load of model1is 946.65kN and model2 is 970.1kN having same span but show reduced value in dead load which provide economical or cheaper section for same loading and span condition.

B. *Load Combination*

When Wind forces are considered on a structure, these shall be combined as per IS 875(part3) 2015 where the terms DL, LL, WL_x and WL_y stands for the response quantities due to dead load, live load, wind load in X direction and wind load in Y direction respectively. In the limit state design of steel structures according to IS Code 800, following load combinations shall be accounted for analysis.

Table 2: Load combination in Z-direction

	model1	model2	model3	model4	model5	model6
	kN	kN	kN	kN	kN	kN
Comb1	2408.9473	2444.3118	2163.3494	2197.06	2129.40	2161.445
Comb2	1927.1578	1955.4495	1730.6795	1757.65	1703.53	1729.1558
Comb3	744.3139	772.6056	671.4292	698.41	1235.09	1260.72
Comb4	1419.9733	1455.2118	1265.4494	1299.16	1208.83	1240.87
Comb5	-58.581	-23.343	-58.613	-24.89	623.302	655.34

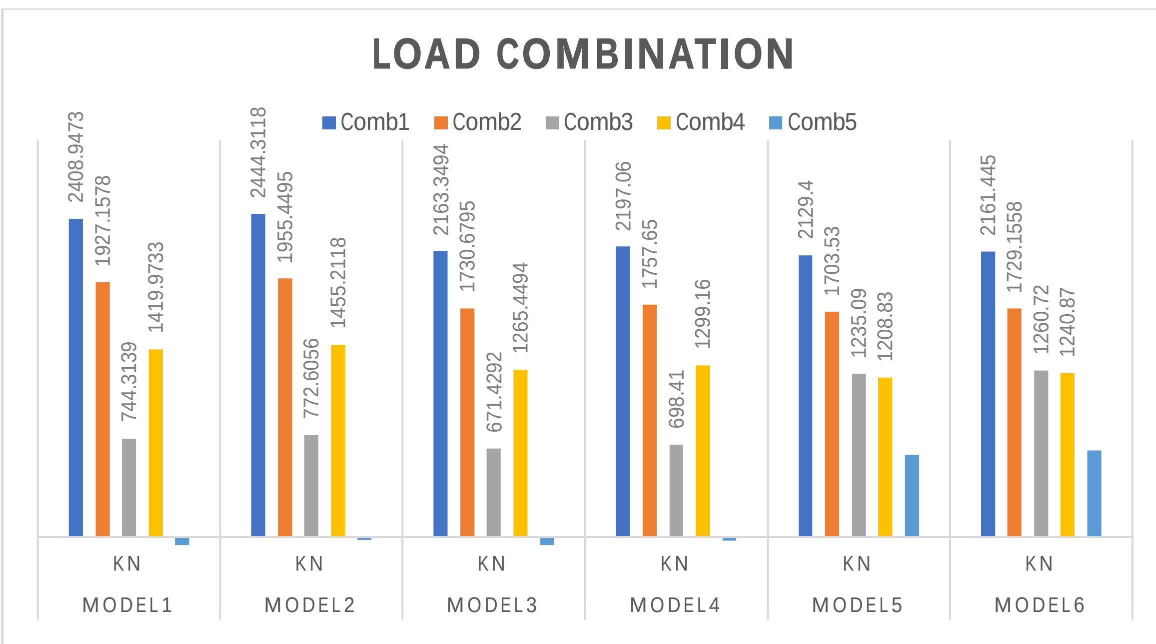

Figure 11: Load combination in Z-direction

Analysis done on all models for load combinations gives following results

1) The value of force in model1 (PEB 30m span) and model2 (conventional 30m span) for maximum load combination 3 ($DL+LL+WL_y$) due to wind load show lesser value because of generating outward wind pressure at roof truss which balancing dead load of structure.
2) The maximum value of load combination obtained in model 2 (conventional steel structure having 30m span) due to larger span and conventional steel is used in structure.

VI. CONCLUSION

Following are the important conclusion made from the present study.

A. The performed wind analysis for the present work clearly shows that there is an important difference in the dead load of the PEB and conventional steel structure with different configuration of span.
B. Maximum dead load at performance level is obtained in model 2 (conventional steel structure having span 30m) which is 2.477% higher than model1 (PEB having span 30m).
C. On comparing between model 1 (PEB having span 30m) and model 4 (conventional steel structure having span 27m) with respect to plan area ratio 1.33 to dead load ratio 1.09 about 24% steel consumption is seen.
D. Comparison between load combination wind load in y direction reduced the overall load so in this analysis dead load and live load is important consideration in design analysis

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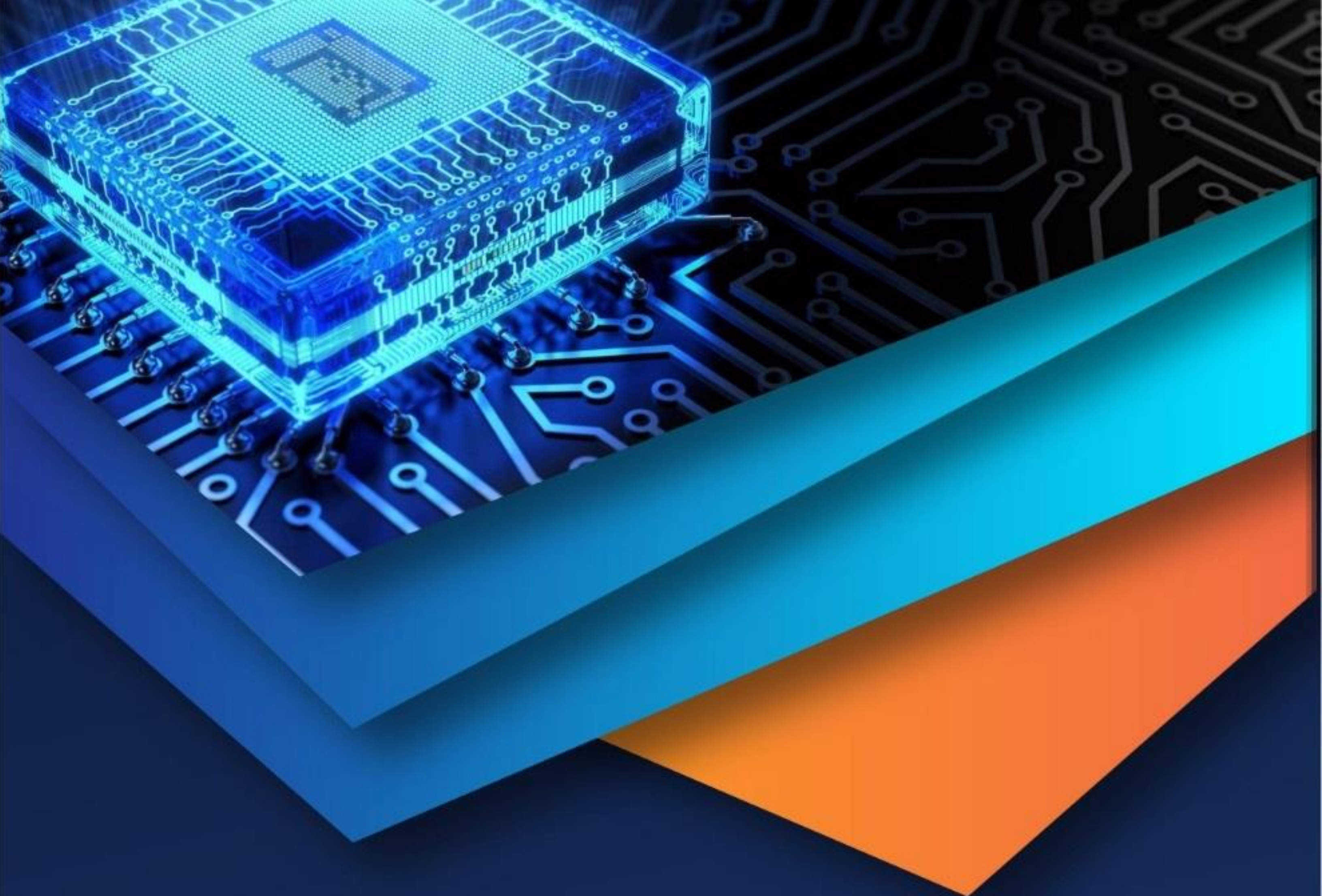

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