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Analysis and Design of Pre-Engineered Building with Different Parameters

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Abstract: With the development of science and technology in the field of structural engineering and also in civil engineering, it is possible to observe the adaptation of pre-engineered buildings in both industrial and residential construction sectors. In this paper, pre-engineered steel building will be design with different parameter using software Staadprov8i and analyzed with different loads on building i.e. dead load, live load, collateral load, wind load and load combinations on building .The main objective of this work is to understand the concepts of PEB and find the least possible weight of structure and various displacement or significance of forces in each direction which will help the structure to be safe and stable. The pre-engineered construction concept involves pre-engineered structure and quality construction systems which will help to minimize the use of cost and time.
Keywords: Pre-engineering steel building, industrial building and staadprov8i software etc.

I. INTRODUCTION

Steel Industry is growing rapidly in all the parts of the world .To meet the rising demand of construction, alternative way construction is to be incorporated. In structural engineering, a pre-engineered building (PEB) is designed by a manufacturer to be fabricated using a pre-determined inventory of raw materials and manufacturing methods that can efficiently satisfy a wide range of structural and aesthetic design requirements. The primary framing structure of a pre-engineered building is an assembly of I-shaped members, often referred as I beam. Also the sections used are Tapered sections. In PEB, I section beams used are usually formed by welding together steel plates to form of I section. I section beams are then field-assembled (e.g. bolted connections) to form the entire frame of the pre-engineered building. Advances in technology have greatly improved over the years, contributing tremendously to improving living standards through various new products and services. A pre-engineered building (PEB) is one such revolution. They use a defined stock of raw materials that have been time tested to meet a wide range of structural and architectural design specifications. The majority of steel structures being built are only low-rise buildings, which are generally of one storey only. Industrial buildings, a subset of low-rise buildings are normally used for steel plants, automobile industries, light, utility and process industries, thermal power stations, warehouses, assembly plants, storage, garages, small scale industries etc[10]. They use a defined stock of raw materials that have been time tested to meet a wide range of structural and architectural design specifications. PEB systems are extensively used in industrial and much other non-residential construction world-wide. These buildings were pre-designed or 'pre-engineered' into standard sizes, spans, bays and heights, and use standard details for fixing cladding, roofing, gutters, flashing, windows, doors etc. taking advantage of industrial practices of mass production of components economically. The concept of PEB is the frame geometry which matches the shape of the internal stress (bending moment) diagram thus optimizing material usage and reducing the total weight of the structure[12]. The use of steel structures is not only economical but also eco-friendly at the time when there is a threat of global warming. Here, “economical” word is stated considering time and cost. Time being the most important aspect, steel structures (Pre- fabricated) is built in very short period and one such example is Pre Engineered Buildings (PEB)[7]. Pre-engineered building are steel building wherein the framing members and other components are fully fabricated in the factory after designing and brought to the site for assembly, mainly by nut-bolts, thereby resulting into a steel structure of high quality and precision[13]. Steel is an expensive material as compared to the rest but when it comes to the cost-savings during the life span of the structure, steel proves to be a very affordable material . Steel can also be made rust proof by the application of special coated paints [8]. Apart from that, steel is an insect and termite resistant material and the maintenance cost is lower during its life span as compared to other materials. PEB are generally low rise buildings however the maximum eave height can go up to 30 metres, Clear span upto 90 metre wide are possible.

The application of low rise buildings are ideal for showrooms, offices etc. The application of pre-engineered building concepts to low rise buildings is very economical due to its light weight and economical construction. Pre-engineering primary framing structure is an assembly of I-shaped structural members. The I-shaped beams are usually formed in the factory by welding steel plates together to form the I-sections. The I-section beams are then assembled on site with bolted connections to form the entire frame of the pre-engineered building[7].

A. Aim Of Study

The aim of design is the achievement of an acceptable probability that structures being designed will perform satisfactorily during their intended life.

B. Objective Of The Study

1) To identify and design the structure as per the various loads and load combinations acting on the structure.
2) To design the industrial warehouse as per IS codes.
3) To determine the least possible weight of the structure so that the cost will reduce.
4) To check the structure as per IS code in the staadprov8i software is safe or not.
5) To arrange the section at the identified location only as per the requirement of that spot.
6) As per bending moment diagram, the sections will vary along the length.
7) As there is smallest section, steel is saved as well as cost is reduced significantly.

II. LITERATURE REVIEW

1) Syed Firoz, et. al (2012) observed that the pre-engineered steel construction system presents great advantages for single-story buildings, a practical and efficient alternative to conventional constructions, representing the system a central model within several disciplines. Pre-engineered construction creates and maintains support in real-time is currently being implemented by Staad Pro Choosing steel to design a pre-engineered steel frame building is choosing a material that offers low cost, strength, durability, design flexibility , adaptability and recyclability. Steel is the basic material used in the materials used for pre-engineered steel construction. It also means choosing reliable industrial products that come in a huge variety of shapes and colors; means quick on-site installation and lower energy consumption. It means choosing to commit to the principles of sustainability. Infinitely recyclable, steel is the material that reflects the imperatives of sustainable development. A tall steel building is no longer in the total number of tall steel structures that are built all over the world. The large steel structures that are built are just one-story buildings for industrial purposes.
2) J.D. Thakar, P. Patel (2013),Pre-engineered building are steel building wherein the framing members and other components are fully fabricated in the factory after designing and brought to the site for assembly, mainly by nut-bolts, thereby resulting into a steel structure of high quality and precision. In conventional steel construction, we have site welding involved, which is not the case in P.E.B using nut-bolt mechanism. These structures use hot rolled tapered sections for primary framing and cold rolled sections (generally “Z”and “C”sections) for secondary framing as per the internal stress requirements, thus reducing wastage of steel and the selfweight of the structure and hence lighter foundations.
3) Naidu & et. al. (2014) In this work Long Span, Column free structures are the most essential in any type of industrial structures and Pre Engineered Buildings (PEB) fulfills this requirement along with reduced time and cost as compared to conventional structures. The present work involves the comparative study and design of Pre Engineered Buildings (PEB) and Conventional steel frames. Design of the structure is being done in Staad Pro software and the same is then compared with conventional type, in terms of weight which in turn reduces the cost. Three examples have been taken for the study. Comparison of Pre Engineered Buildings (PEB) and Conventional steel frames is done in two examples and in the third example, Pre Engineered Building structure with increased bay space is taken for the study. In the present work, Pre Engineered Buildings (PEB) and Conventional steel frames structure is designed for wind forces. Wind analysis has been done manually as per IS 875 (Part III) – 1987.
4) Sagar Wankhede et.al (2014) presented a review article on comparisons of conventional steel buildings and pre-engineered buildings. The article begins with a discussion of various elements of industrial construction such as purlins, rafters, main beams, roof trusses, gantry beams, brackets, column and column base, beam rods, bracing. In addition, transported by study load and load combination as per IS 875-1987. Then, he gave an overview of the concepts of Pre-engineering of Construction, informing their advantages, effective use and about their structure.

5) Meena & et. al. (2015) In this work effectively conveys that Pre-Engineered steel Buildings can be easily designed by simple design procedures in accordance Low weight flexible frames of PreEngineered steel Building offer higher resistance to earthquake loads. After analysing, the following are the conclusions of Pre-Engineered steel Building when compared with Conventional Steel Buildings.
6) Bhagatkar & et. al. (2015) In this work From the past advancement, the use of PEB is implemented and continuously increasing, but its usage is not throughout the construction industry. It is reviewed that PEB structures can be easily designed by simple design procedures in accordance with country standards, it is energy efficient, speedy in construction, saves cost, sustainable and most important its reliable as compared to conventional buildings. Thus PEB methodology must be implemented and researched for more outputs.
7) Shrunkhal V. Bhagatkar et. al (2015), presented a study on Pre-Construction with a review of several authors of articles on Pre-Construction. The work aimed to evaluate from the past advance, if the use of PEB is implemented and in constant increase, its use is not in the entire construction industry.
8) Chavanke & Tolani (2017) In this work Long span, Column free structures are the most essential in any type of industrial structures and Pre Engineered Buildings (PEB) fulfill this requirement along with reduced time and cost as compared to conventional structures. The present investigation aims at comparison of conventional steel building and pre-engineered building. In this investigation analysis of and design of pre-engineered building and conventional steel building will be carried out for spans like 15m, 20m, 25m, and 36 m using computer software STAAD Pro v8i.
9) Katkar & Phadtare (2018) In this work recent years, the introduction of Pre-Engineered Building (PEB) concept in the design of structures has helped in optimizing design. Long span, Column free structures are the most essential in any type of industrial structures and Pre Engineered Buildings (PEB) fulfil this requirement along with reduced time and cost as compared to conventional structures. This methodology is versatile not only due to its quality predesigning and prefabrication, but also due to its light weight and economical construction. The present work presents the comparative study and design of conventional steel frames with concrete columns and steel columns and Pre Engineered Buildings (PEB). In this work, an industrial building of length 44m and width 20m with roofing system as conventional steel truss and pre-engineered steel truss is analyzed and designed by using STAAD Pro V8i.

III. METHODOLOGY

A. *History of PEB*

Since then, the use of pre-engineered buildings has spread across Asia and Africa, where the PEB architecture concept has been widely accepted and praised. The principle of pre-engineered steel buildings is known as the most flexible and economical building. In civil construction, the economy and speed of delivery and installation of these buildings are incomparable. No other building system can match the pre-engineered building system in terms of speed and cost from excavation to occupation.

B. *Components Of PEB*

1) *Primary Members:* The primary members in a PEB are the primary load-bearing membranes and usually consist of the rigid main structure. Vertical members are called columns and horizontal members are called columns. These are generally members constructed from hot rolled plate.
2) *Secondary Members:* Cold formed members such as roof purlins, wall beams, eaves struts, etc. are the secondary members in the PEB process. These are called cold formed members as there is no involvement of processes such as cutting, welding and grinding.

C. *Load Application.*

1) *Dead Load:* According to IS: 875 (part 1) - Dead load comprises of self-weight of the structure, weights of roofing, bracings and other accessories.
2) *Live Load:* According to IS: 875 (Part 2) - for roof with no access provided, the live load can be taken as 0.75 kN/m2 with a reduction of 0.02 kN/m2 for every one degree above 10 degrees of roof slope.
3) *Wind Load:* According to IS: 875 (part 3) - The force exerted by the horizontal component of wind is to be considered in the design of buildings, towers etc. The wind force depends upon the velocity of wind, shape, size & location of buildings. Brief idea is given below;

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Volume 10 Issue III Mar 2022- Available at www.ijraset.com

a) Using colour code, the basic wind velocity 'Vb' is shown in a map of India. Designer can pick up the value of Vb depending upon the location of the structure.
b) To get the design wind velocity Vz , the following expression shall be used;

$$V_z = k_1 \, k_2 \, k_3 \, k_4 \, V_b \qquad \text{Eq.(1)}$$

Where,
k_1 = Risk coefficient
k_2 = Coefficient based on terrain, height and structure size
k_3 = Topography factor
k_4 = Importance factor for cyclonic regions
The design wind pressure is given by,

$$p_d = k_d \, k_a \, k_c \, p_z \qquad \text{Eq.(2)}$$

Where, $p_z = 0.6\, V_z^2$ Eq.(3)

p_d = design wind pressure
p_z = wind pressure at height z
k_d = wind directionality factor
k_a = area averaging factor
k_c = combination factor
Wind loading on individual structural members such as roofs, walls, and individual cladding units and their fittings as per IS875 (part 3):2015,

$$F = (Cpe - Cpi)*Apd \qquad \text{Eq.(4)}$$

Where,
C_{pe} = external pressure coefficient,
C_{pi} = internal pressure coefficient,
A = surface area of structural element or cladding unit

IV. ANALYSIS USING STAAD PRO V8I

StaadProV8i software was used to analyze and design pre-engineered building structures and conventional structures in this project. For the first structure, a pre-designed 3D construction model of a WAREHOUSE building was designed and compared to the conventional structure using conventional steel. In the second example, an 88m wide 2D flat structure was designed with conical sections for PEB, this structure cannot be built by the conventional method as it is not feasible and also not economical for the project. Different spacings between stalls were considered to verify the most adequate.(6)

A. *Pre-engineered building by STAAD PRO*

StaadproV8i comes with several tools and modes to benefit from a user-friendly interface. Design and analysis can be done side by side to check designs for errors. For PEB design, different dimensions of Conical I sections can be verified for a stable and optimized structure and the same is for conventional steel design, where pre-rolled sections with commercially available dimensions are accessible for design and analysis purposes. STAAD Pro software can be used to analyze and design pre-engineered buildings. It can analyze the bending moment, axial forces, shear forces, torsion, beam stresses of a steel structure so that the design can be done using conical sections and check safety. For the current design, the common stiffness matrix method was used for the structure analysis. Used pre-engineered building members are funneled using the Software's built-in option. The software offers a choice of support options for

our requirements. Here in this project, fixed supports are assigned. For the loads, we manually calculated and assigned them to our structure using the correct steps.

V. DESIGN AND ANALYSIS

A. Building Parameters

Table 5.1: Building Parameters for the structure

Length	45 meter
width	21 meter
Clear height	7.0 mater
Brick wall	3.0 meter
Location	Jabalpur , MP
Basic wind speed	39 m/s
Roof Slop	1:10
Solar Panel Load	25 kg/m2 on roof
Bay Spacing	7.5 meter

B. Load Calculation

1) Dead load

Weight of sheeting = 5 kg/m^2
Weight of purlin = 4.12 kg/m^2
Weight of sag rod, bracing, clips etc = 5.75 kg/m^2
Total = 15 kg/m2
So, dead load = 0.15 KN/m^2

2) Collateral Load

Solar panel load = 25 kg/m^2
Collateral load on frame = 0.25 * 7.5 = 1.875 KN/m^2

3) Live Load

Live load for non-accessible roof = 0.75KN/m^2
Live load on frame = 0.75 * 7.5 = 5.625KN/m^2
Bay spacing = 7.5
Dead load on frame = 0.15 * 7.5 = 1.125 KN/m^2

4) Wind Load

$Vz = k_1\ k_2\ k_3\ k_4\ V_b$
K1 = 1.0, K2= 1.0, K3 = 1.0, K4 = 1.0
Vz= 39.0 m/s^2
$Pz = 0.6\ V_z^2$
$P_z = 0.912\ KN/m^2$

Design pressure, $Pd=k_d\ k_a\ k_c\ p_z$
$K_d = 0.9$
$K_a = 0.9$
$K_c = 0.9$
$P_d = 0.67\ KN/m^2$

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Volume 10 Issue III Mar 2022- Available at www.ijraset.com

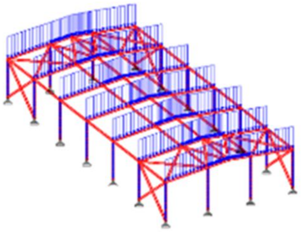
Fig. 6.2.1 Dead Load on Structure


Figure 6.2.2 Live Load on Structure

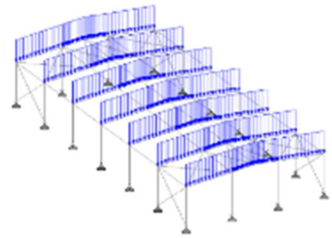
Figure 6.2.3 Collateral Load on Structure

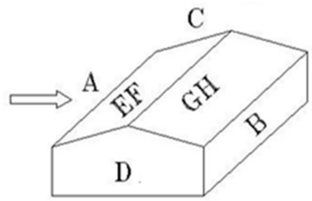

Fig 6.2.4 Wind load direction on structure

CASE-1- WIND ACROSS THE RIDGE(ZERO DEGREE) Positive Cpi					
SURFACE	Cpe	Cpi	Cp=(Cpe-Cpi)	Wind load on frame	
A	0.70	0.2	0.50	0.5x0.67x7.5=	2.51
EF	-0.94	0.2	-1.14	-1.14x0.67x7.5=	-5.73
GH	-0.40	0.2	-0.60	-0.6x0.67x7.5=	-3.02
B	-0.25	0.2	-0.45	-0.45x0.67x7.5=	-2.26
C	-0.60	0.2	-0.80	-0.8x0.67x6=	-3.22
D	-0.60	0.2	-0.80	-0.8x0.67x6=	-3.22
CASE-2- WIND ACROSS THE RIDGE(ZERO DEGREE) Negative Cpi					
SURFACE	Cpe	Cpi	Cpe-Cpi	Wind load on frame	
A	0.70	-0.2	0.9	0.9x0.67x7.5=	4.52
EF	-0.94	-0.2	-0.74	-0.74x0.67x7.5=	-3.72
GH	-0.40	-0.2	-0.2	-0.2x0.67x7.5=	-1.01
B	-0.25	-0.2	-0.05	-0.05x0.67x7.5=	-0.25
C	-0.60	-0.2	-0.4	-0.4x0.67x6=	-1.61
D	-0.60	-0.2	-0.4	-0.4x0.67x6=	-1.61
CASE-3- WIND PARALLEL TO RIDGE(90 DEGREE) WITH Posative Cpi					
SURFACE	Cpe	Cpi	Cpe-Cpi	Wind load on frame	
A	-0.50	0.2	-0.7	-0.7x0.67x7.5=	-3.52
EG	-0.80	0.2	-1	-1x0.67x7.5=	-5.03
EG	-0.80	0.2	-1	-1x0.67x7.5=	-5.03
B	-0.50	0.2	-0.7	-0.7x0.67x7.5=	-3.52
C	0.70	0.2	0.5	0.5x0.67x6=	2.01
D	-0.10	0.2	-0.3	-0.3x0.67x6=	-1.21
CASE-4- WIND PARALLEL TO RIDGE(90 DEGREE) WITH Negative Cpi					
SURFACE	Cpe	Cpi	Cpe-Cpi	Wind load on frame	
A	-0.50	-0.2	-0.3	-0.3x0.67x7.5=	-1.51
EG	-0.80	-0.2	-0.6	-0.6x0.67x7.5=	-3.02
EG	-0.80	-0.2	-0.6	-0.6x0.67x7.5=	-3.02
B	-0.50	-0.2	-0.3	-0.3x0.67x7.5=	-1.51
C	0.70	-0.2	0.9	0.9x0.67x6=	3.62
D	-0.10	-0.2	0.1	0.1x0.67x6=	0.40

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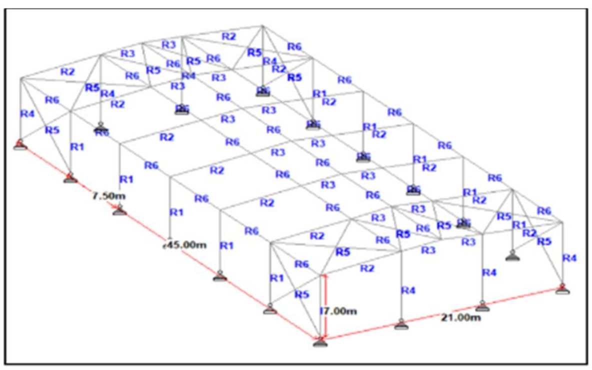
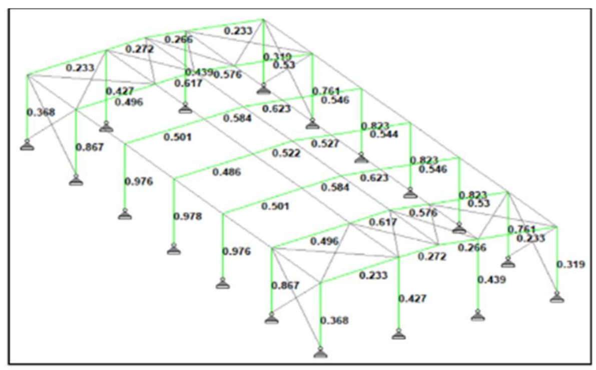
VI. RESULT AND DISCUSSION

STEEL TAKE-OFF

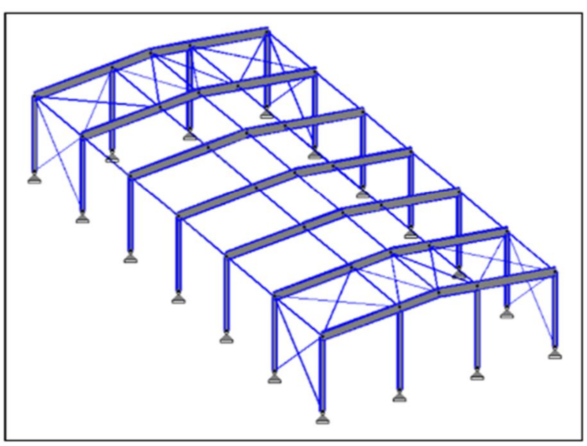
PROFILE			LENGTH(METE)	WEIGHT(KN)
Tapered	MembNo:	1	58.80	31.799
Tapered	MembNo:	3	98.49	95.027
Tapered	MembNo:	6	49.24	54.519
Tapered	MembNo:	10	70.00	50.891
ST	PIP889M		225.00	18.494
ST	ISA30X30X3		230.61	3.065
			TOTAL =	253.796



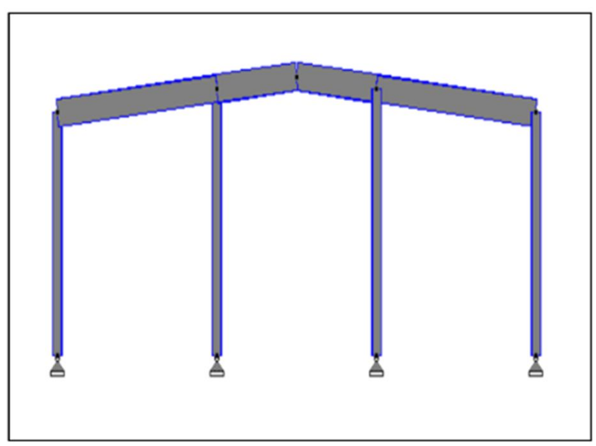
SECTION DIAGRAM FOR INDUSTRIAL WAREHOUSE



DESIGN RATIO OF FRAMES USING PEB



FRONT VIEW OF PEB



ISOMERIC VIEW OF PEB

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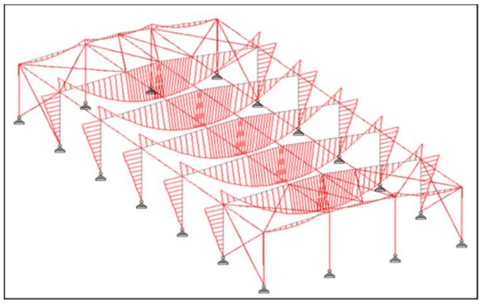
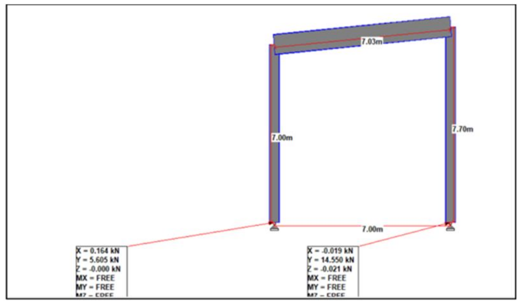
Volume 10 Issue III Mar 2022- Available at www.ijraset.com



BMD DIAGRAM OF PEB



REACTIONS ON A PARTICULAR FRAME

MAX SHEAR FORCE AND MAX BM ON A PARTICULAR FRAME IN X-Y-Z DIRECTION

BEAM	NODE	ENVELOPE	FX KN	FY KN	FZ KN	MX KN-M	MY KN-M	MZ KN-M
40.	45	+Ve	76.631	30.969	.001	0.00	0.00	0.00
		-Ve	-27.952	-31.518	-0.078	0.00	0.00	0.00
42.	46	+Ve	23.749	60.610	0.047	0.008	0.191	91.107
		-Ve	-21.415	-33.285	-0.016	-0.003	-0.091	-81.372
76.	52	+Ve	137.901	13.155	0.053	0.00	0.00	0.00
		-Ve	-41.017	-13.126	-0.228	0.00	0.00	0.00

VII. CONCLUSIONS

A. In the present days, money is gaining their importance in every sector including the construction industry. Sustainability is what the world is running behind. In all these aspects PEB stands in the top position when compared with other technologies.

B. The material used here is not only eco-friendly but also reusable. Steel is the basic material that is used in pre-engineered steel building materials. Infinitely recyclable, steel is the material that reflects the sustainability imperatives.

C. A well optimized industrial warehouse will be designed with least possible weight i.e 253.796 KN and analysed by loads and loads combinations parameters.

D. The maximum SF and maximum BM for a particular frame will come out for positive and negative envelope 173.901KN (+ve), 41.017 KN (-ve) for beam 76 and 91.107KN-m(+ve), 81.372KN-m (-ve) for beam 42 respectively are given above.

E. The most appealing economy of civil construction can be achieved through the efficient use of high-grade steel and composite building form with advanced materials. The model building cost study showed that PEB structure is economical.

VIII. FUTURE SCOPE OF THE STUDY

The future scope of Pre-Engineered Building (PEB) has emerged tremendously after the initiation of various government schemes such as Make In India, Smart City Initiative and with increased approval from the FDI's demand for infrastructures. This paper represents a well optimized warehouse with least possible weight and different loads values acting on it. The study states that these kinds of buildings provide the required section as per the optimum requirement based on the bending moment. This method has pre-fabricated steel components that are assembled on the site and is lightweight and economical. Times being the controlling factor, the pre-fabricated steel structures are erected in less time and with ease construction on site.

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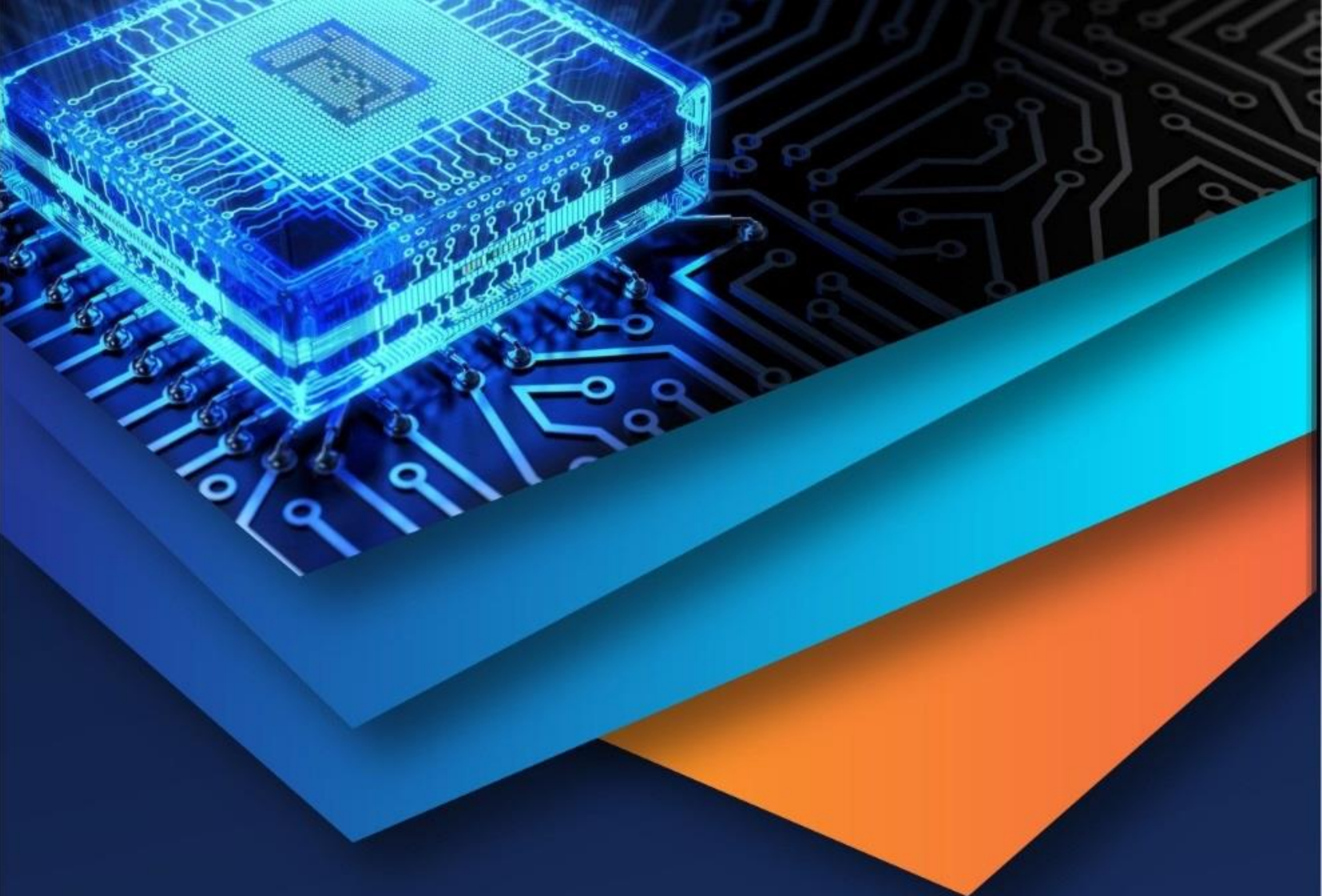

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