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Wind Analysis of Pre Engineered Building

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***Abstract:** With the development of science and technology in the field of structural engineering, it is possible to adopt pre-engineered buildings in both industrial and residential construction sectors. For important buildings it is more suitable to use pre engineered building as these are more safe and take less time in construction in comparison of RCC structures. The main objective of this paper is pre-engineered steel structure will be design and analyzed for wind loads, dead loads, live loads and different load combinations on structure. The pre-engineered construction concept involves pre-engineering and quality construction systems which will help to minimize the cost and time.*
***Keyword:** Pre engineered buildings, StaadPro software, RCC structures.*

I. INTRODUCTION

Steel Industry is growing rapidly all around the world. To meet the increasing demand of construction, alternative ways of construction are developing. 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, 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. 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.

II. PRE ENGINNERED BUILDING

In structural engineering, a pre-engineered building (PEB) is designed by a manufacturer to 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. Pre-engineering building primary frame 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. Tapered sections are also used to achieve varying depth. 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. 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). 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. 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. 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 meter wide are possible.

III. LOAD CALCULATION

Pre Engineered Building mainly design for dead load, live load, wind load. The load calculation for all three major loads is as follows:

A. Dead Load Calculation

According to IS 875 (part 1) dead load comprises of self weight of the structure, weights of roofing, bracings and other accessories.

BAY SPACING		7.75	M		
UNIT WT OF PURLIN		4.5	KG/M		
ACCESSORIES		1	KG/SQ M		
SHEET UNIT WT		4.3	KG / SQM		
PURLIN SPACING		1.55	M		
DEAD LOAD ON RAFTER (PURLIN+SHEET) =				63.575	KG/M
			OR	0.63575	KN/M

B. Live Load Calculation

According to IS 875 (part 2) for roof which does not provide access, the live load can be taken as 0.75KN/m^2 with a reduction of 0.02 KN/m^2 for every one degree above 10 degrees of roof slope.

LIVE LOAD					
BAY SPACING		7.75			
IMPOSED LOAD		0.57	KN/SQM		
	LIVE LOAD ON RAFTER =			4.4175	KN/M

C. Wind Load Calculation on Single Slope Pitched Roof

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. Wind analysis calculation given below according to IS code 875 part 3:1987 ;

Design wind speed $V_z = V_b\, k_1\, k_2\, k_3$

Where,

V_z =Design wind speed at any height z in m/s,

V_b =Basic wind speed calculated from wind speed map of India,

k_1=Probability factor (risk coefficient clause 5.3.1),

k_2=Terrain, height and structure size factor (clause 5.3.2) and

k_3=Topography factor(clause 5.3.3)

Design wind pressure $P_z=0.6\, Vz^2$

Where,

P_z=Design wind pressure in N/m^2 at height z and

V_z =Design wind speed at any height z in m/s

Wind load on individual structural member such as roofs, walls and cladding given as:

$F=(C_{pe} – C_{pi})\, A\, P_z$

Where,

C_{pe}=External pressure coefficient,

C_{pi}=Internal pressure coefficient,

A=Surface area of structural member or cladding unit and

P_z=Design wind pressure in N/m^2 at height z

HEIGHT OF STRUCTURE	7.5	M				H/W =	0.5119454	
WIDTH OF STRUCTURE	14.65	M				L/W=	4.1610922	
LENGTH OF STRUCTURE	60.96	M						
BASIC WIND SPEED	39	M/S						
K1	1	IS 875 part3-1987 table 1 clause 5.3.1(assume design life-50 year)						
K2	0.98	IS-875 part3-1987 table 2 clause 5.3.2 (Terrain category 2, Class B)						
K3	1	IS 875 part3-1987 clause 5.3.3						
BAY SPACING (LENGTH WISE)	7.11	6.1						
BAY SPACING (WIDTH WISE)	7.325							
ROOF ANGLE	5.71	DEGREE						
INTERNAL WIND PRESSURE	0.2							
BAY SPACING	7.11	M						
design wind speed (vz)	vz=vbxk1xk2xk3							
	38.22	m/s						
wind pressure at height z (Pz)=	0.6*(Vz)^2							
	876.46104	N/SQ.M	or					
	0.876461	KN/SQ.M						

EXTERNAL WIND PRESSURE FOR WALLS OF RECTANGULAR CLAD BUILDING				
IS 875 PART 3-1987 TABLE 4				
1/2 < H/W <3/2	0.5119454	= H / W		
3/2 < L/W < 4	4.1610922	= L / W		
1.WIND ANGLE FOR WALL	A	B	C	D
0	0.7	-0.3	-0.7	-0.7
90	-0.5	-0.5	0.7	-0.1
EXTERNAL WIND PRESSURE FOR MONOSLOPE ROOF (H/W<2)				
IS 875 PART3-1987 TABLE 6				
2.WIND ANGLE FOR ROOF	5.71			
0	H	L		
	-1	-0.5		
45	H	L		
	-1	-0.88		
90	HL	LL		
	-1	-0.5		
135	H	L		
	-0.88	-1		
180	H	L		
	-0.48	-1		
F = (Cpe - Cpi) A Pz				
A X Pz =	6.231638	(LENGTH WISE)		
A X PZ =	6.4200771	(WIDTH WISE)		

D. Wind Load Calculation on Rectangular Clad Pitched Roof Building

This calculation gives value of wind load for Rectangular clad pitched roof that is load on wind column according to IS 875: (part 3):1987 given below.

End wall col bay spacing	6.4				
take	6.4	m			
	area	Factor, Ka	Pd =Kd*Ka *Kc*Pz	0.7Pz [clause 7.2]	final design wind pressure Pd
Tributary area for END COL.	7.75*6.4 =49.6	0.8583	0.6094	0.6135	0.6646

Kc	0.9	clause
Kd	0.9	clause 7.2.1

wind 0 deg. (on gable end frame)			AXIS 1-1
A) ip = +0.2			
force on end col.= (-0.6-(+0.2))*0.92*6.4	-3.82826	KN/M	(IP)
B)ip =-0.2			
force on end col.= (-0.6-(0.2))*0.92*6.4	-2.12681	KN/M	(IS)

wind 90 deg. (on gable end frame)-ALONG WIND DIRECTION				AXIS 1-1
A) ip = +0.2				
force on end col.= (+0.7-(+0.2))*6.4*0.92	2.12681	KN/M	(IP)	
B)ip =-0.2				
force on end col.= (+0.7-(-0.2))*6.4*0.92	3.828257	KN/M	(IS)	

wind 90 deg. (on gable end frame)-OPPOSITE WIND DIRECTION				AXIS 13-13
A) ip = +0.2				
force on end col.= (-0.1-(+0.2))*6.4*0.92	-1.27609	KN/M	(IP)	
B)ip =-0.2				
force on end col.= (-0.1-(-0.2))*6.4*0.92	0.425362	KN/M	(IS)	

IV. MODELING

In present study, single pitched roof industrial structure of portal frame type modeled. The steel structure of portal frame type analyzed using staadProV8i software. IS codes we used for wind load calculation IS 875 (part 3) : 1987.

Table 1: Structural properties of model

Geometric Details	
Structure	Industrial Structure
Types of Buildings	Portal Frame Single Pitched Roof Structure
Plan Area	1050 m^2
Height of structure	7.5 m
Area (LxW)	70mx15m
Bay Spacing(Length wise)	7.11 m
Bay Spacing(Width wise)	7.325 m
No. of Story	Ground floor only
Roof Angle	5.71 degree
Length of canopy	2.5m

Brick wall height	Upto 3m	
Purlin spacing	1.55 m	
Location of structure	Indore	
Member Properties (Main frame and Gable end)		
Size of Rafter	Starting	(350/600mm x 5mm W)/(200mm x 10mm F)
	Middle	(350mm x 4mm W)/(165mm x 6mm F)
	End	(350/550mm x 5mm W)/(150mm x 6mm F)
Size of Column	Higher end column	(300/600mm x 5mm W)/(215mm x 10mm F)
	Lower end column	(300/550mm x 5mm W)/(180mm x 8mm F)
	Middle column	(350mm x 5mm W)/(165mm x 6mm F)
Size of Canopy	(300/500mm x 5mm W)/(165mm x 6mm F)	
Analysis Software : StaadProV8i		

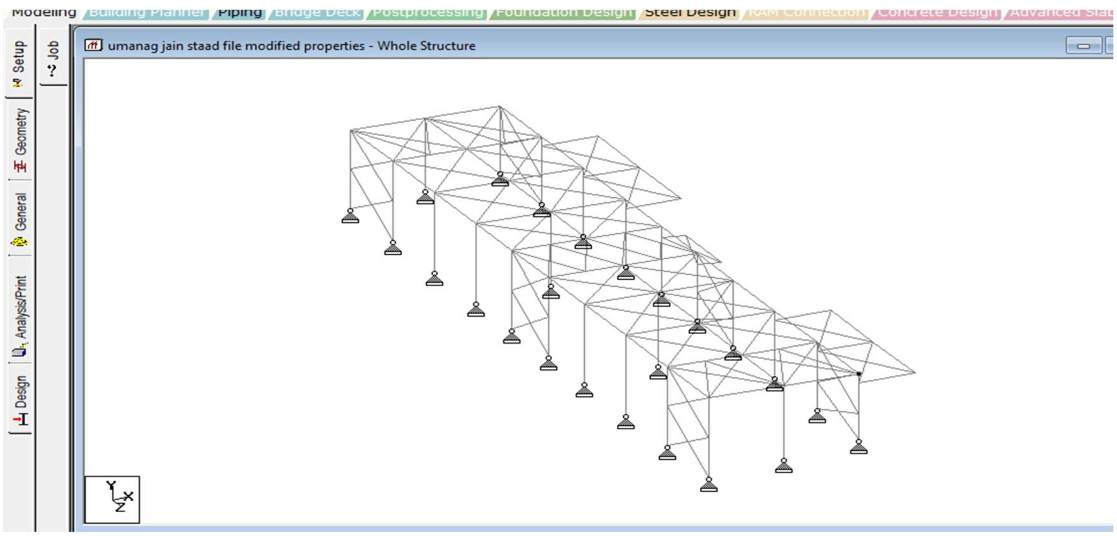

Figure 1 – Isometric view

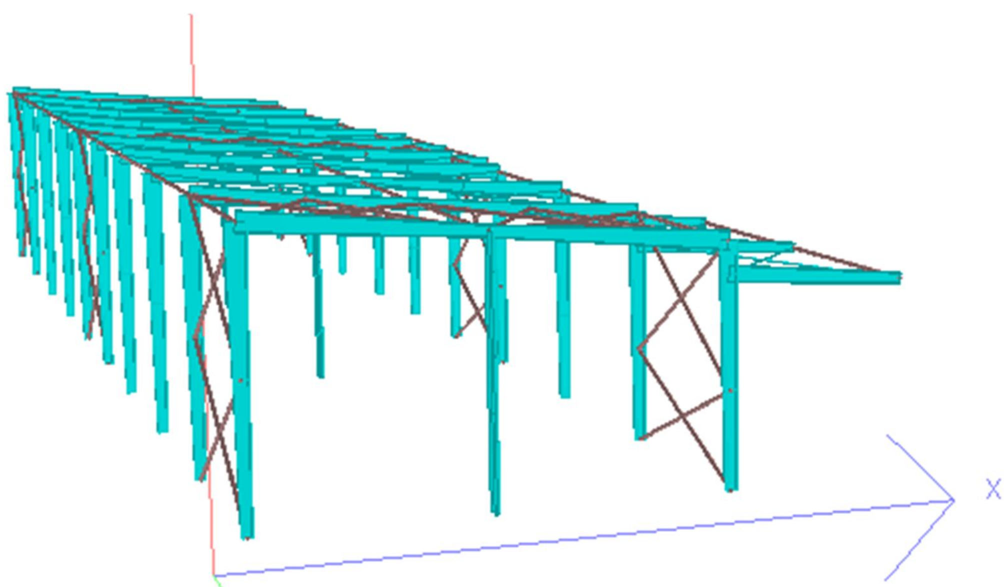

Figure 2 – 3D view

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V. RESULT AND DISCUSSION

Wind Analysis carried out for pre engineered building structure according to IS codes. With the help of this analysis following results has been drawn which are shown in form of sketch representation as below:

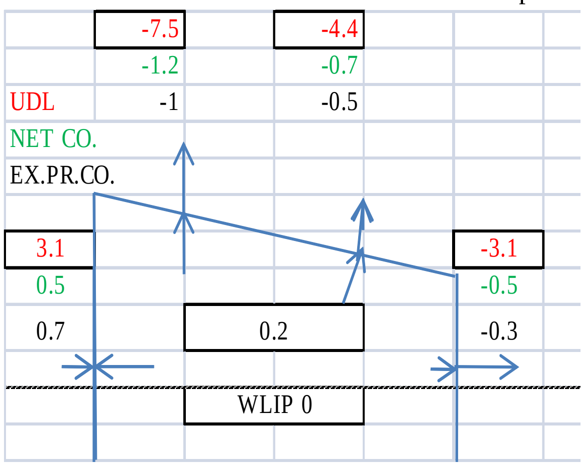

Figure 3 – WLIP 0

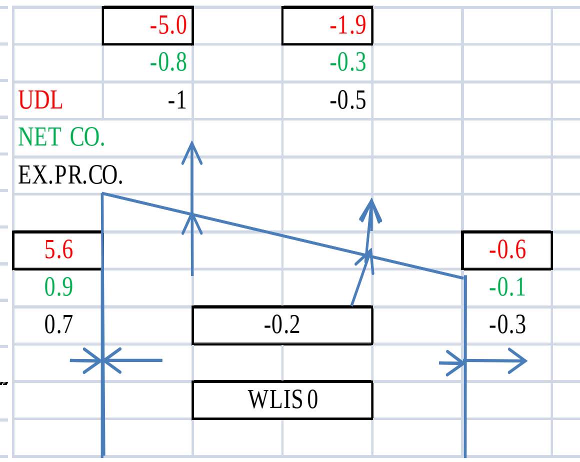

Figure 4 – WLIS 0

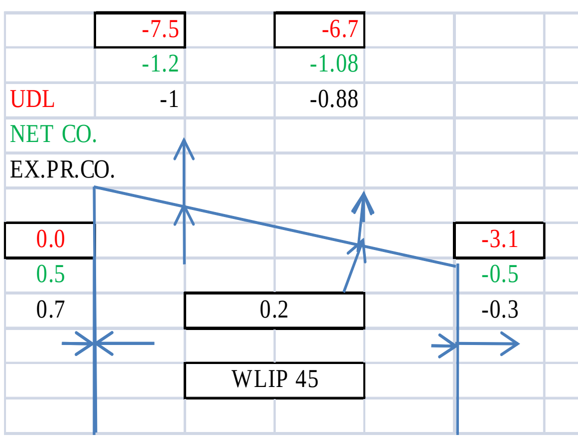

Figure 5 – WLIP 45

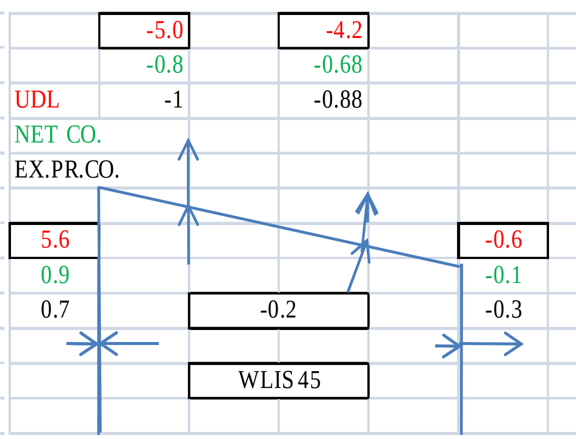

Figure 6 – WLIS 45

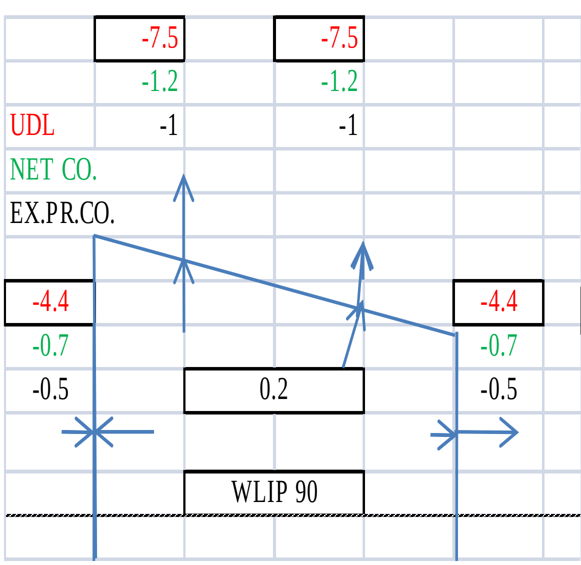

Figure 7 – WLIP 90

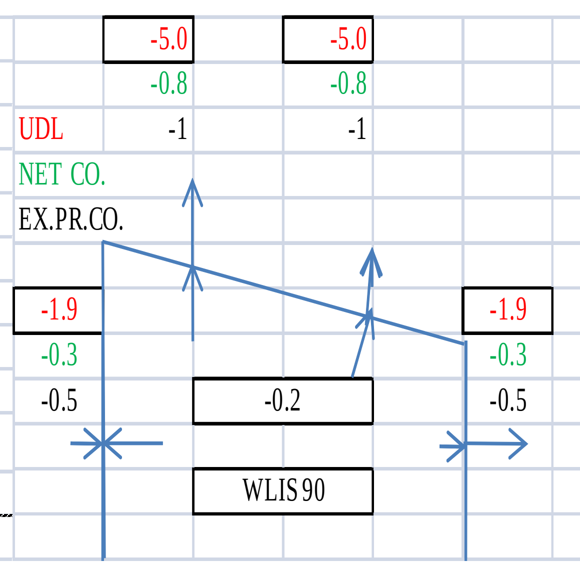

Figure 8 – WLIS 90

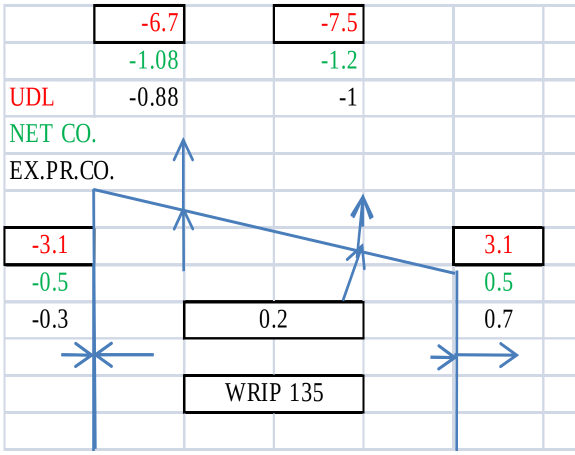

Figure 9 – WLIP 135

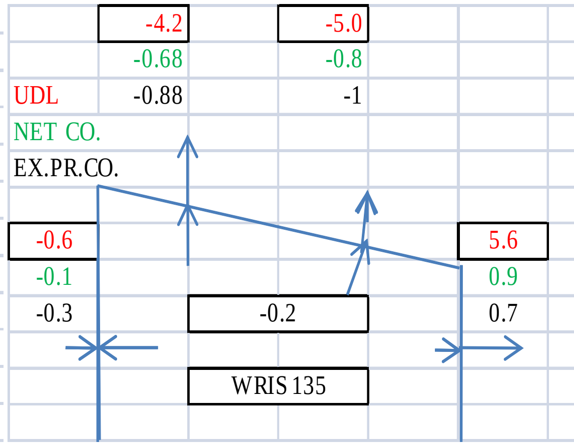

Figure 10 – WLIS 135

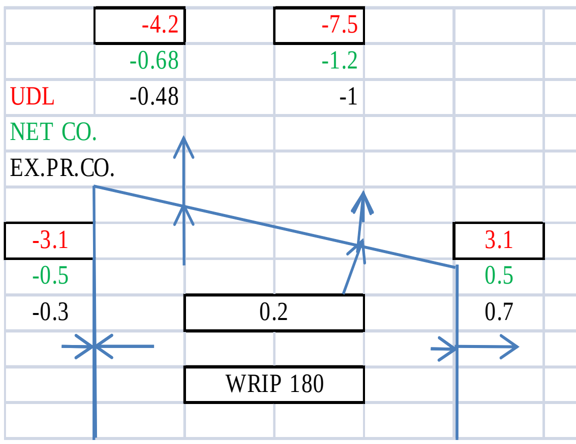

Figure 11 – WLIP 180

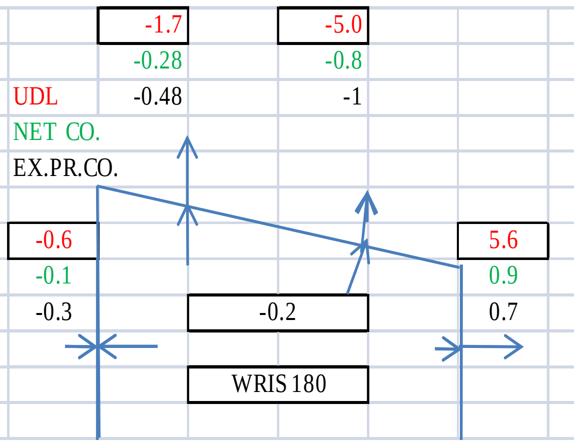

Figure 12 – WLIS 180

VI. CONCLUSION

This study explains the behavior of modeled pre engineered building when subjected to dead load, live load and wind load, How wind acts on different members of building. There are two types of wind pressure act on the building internal pressure and external pressure, they are subdivided as WLIP (wind load internal pressure) and WLIS (wind load suction pressure) these two pressure act at different wind angle 0^0, 45^0, 90^0, 135^0 and 180^0. There is one more most important load factor that is seismic load which can be considered as future scope of this work.

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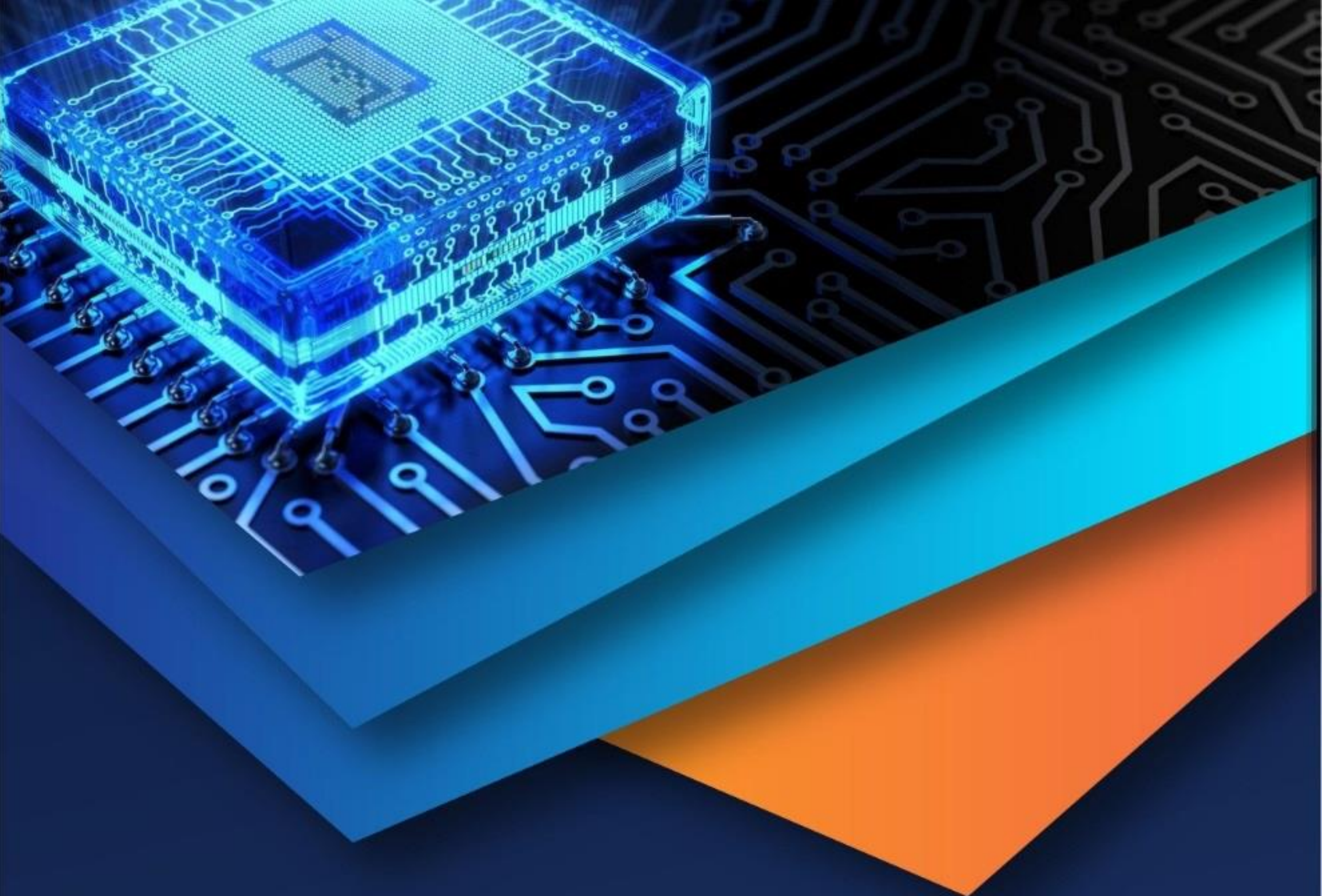

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