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Comparative Analysis of Mono-Slope and Dual-Slope Pre-Engineered Building Industrial Sheds Under Different Wind Speed

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Abstract: ***Pre-Engineered Buildings (PEBs) have emerged as an economical and structurally efficient alternative to conventional steel structures for industrial applications. Roof configuration significantly influences the structural performance, stability, and material consumption of PEB industrial sheds. The present study investigates the comparative behaviour of Mono-Slope and Dual-Slope PEB industrial sheds subjected to varying wind speeds of 33 m/s, 47 m/s, and 55 m/s.***
Six STAAD.Pro models were developed using identical geometric dimensions, material properties, loading conditions, and design parameters. Dead load, live load, and wind load were applied according to IS 875 (Part-3), while structural design was carried out in accordance with IS 800 provisions. Structural responses including maximum bending moment, axial force, shear force, deflection, and steel consumption were evaluated.
Results indicate that Dual-Slope structures perform significantly better than Mono-Slope structures under all wind conditions. At 55 m/s wind speed, Mono-Slope sheds exhibited approximately 31% higher bending moments, 22% higher axial forces, 18% higher shear forces, and 34% higher steel consumption compared to Dual-Slope sheds. The symmetrical geometry of Dual-Slope roofs provides balanced load distribution, improved stiffness, and reduced internal force concentration.
The study concludes that Dual-Slope PEB industrial sheds offer superior structural efficiency, improved stability, and enhanced economy, particularly in medium and high wind zones.
Keywords: Pre-Engineered Building, Mono-Slope Roof, Dual-Slope Roof, Wind Load, STAAD.Pro, Steel Consumption, Structural Analysis.

I. INTRODUCTION

Industrial buildings require large unobstructed spaces, high clear heights, and efficient structural systems capable of resisting gravity and lateral loads. Traditionally, such buildings were constructed using conventional steel structures; however, recent developments in design software and fabrication technology have promoted the widespread adoption of Pre-Engineered Buildings (PEBs).
PEB structures utilize optimized built-up steel sections designed according to the actual force distribution along structural members. This optimization results in reduced steel consumption, lower construction cost, and faster erection time.
Among the various factors affecting PEB performance, roof configuration plays a critical role. Mono-Slope and Dual-Slope roofs are commonly adopted for industrial sheds. While Mono-Slope roofs provide simplicity and ease of construction, Dual-Slope roofs offer symmetrical geometry and improved load distribution.
The present research investigates the structural behaviour of Mono-Slope and Dual-Slope PEB industrial sheds under varying wind conditions to identify the most efficient and economical configuration.

II. LITERATURE REVIEW

Syed Firoz et al. (2012) reported that PEB structures achieve considerable savings in steel consumption through optimized tapered sections.
Kavya Rao (2012) concluded that PEB systems exhibit superior material efficiency and structural economy compared to conventional steel buildings.
Pradeep and Papa Rao (2014) observed that tapered built-up members significantly reduce structural weight while maintaining safety requirements.

Arpita Bhadoria and Siddhartha Pathak (2017) reported steel savings of nearly 30% in PEB systems for large-span industrial structures.

Naik and Mahure (2021) observed approximately 15% reduction in steel weight in warehouse structures utilizing PEB concepts.

Most existing studies compare PEB systems with conventional steel buildings. Limited literature is available regarding the comparative behaviour of Mono-Slope and Dual-Slope roof configurations under varying wind speeds, which forms the basis of the present research.

III. OBJECTIVES OF STUDY

The objectives of the present investigation are:

1) To analyse Mono-Slope and Dual-Slope PEB industrial sheds under wind speeds of 33 m/s, 47 m/s, and 55 m/s.
2) To evaluate bending moment, axial force, shear force, and deflection behaviour.
3) To compare steel consumption of both roof configurations.
4) To study the effect of increasing wind speed on structural response.
5) To identify the most economical and structurally efficient roof configuration.

IV. METHODOLOGY

The research methodology consists of the following steps:

1) Selection of roof configurations.
2) Development of structural models in STAAD.Pro.
3) Assignment of material properties.
4) Application of loading conditions.
5) Structural analysis and design.
6) Comparative evaluation of results.

A. Structural Parameters

Parameter	Value
Length	98 m
Width	25 m
Clear Height	8 m
Main Frame Spacing	7 m
Gable Frame Spacing	5 m
Seismic Zone	III
Wind Speed	33, 47, 55 m/s

B. Loads Considered

Dead Load

DL = 0.15 kN/m² (15 kg for sheeting, purlin, sag rod and other accessories)

Live Load

LL = 0.75 kN/m²

Wind Load

Wind loads were calculated as per IS 875 (Part-3).

The design wind pressure is:

$Vz = Vb \times K1 \times K2 \times K3 \times K4$

$Pz = 0.6\ Vz^2$

Where:

Pz = Design Wind Pressure

Vz = Design Wind Velocity

Pd = Pz x Ka x Kc x Kd

F = Pd x (Cpe – Cpi) x A

V. MODELLING AND ANALYSIS

Six structural models were developed:

Dual-Slope Models

- Dual Slope – 33 m/s
- Dual Slope – 47 m/s
- Dual Slope – 55 m/s

Mono-Slope Models

- Mono Slope – 33 m/s
- Mono Slope – 47 m/s
- Mono Slope – 55 m/s

All models were analysed using STAAD.Pro under identical loading and design conditions.

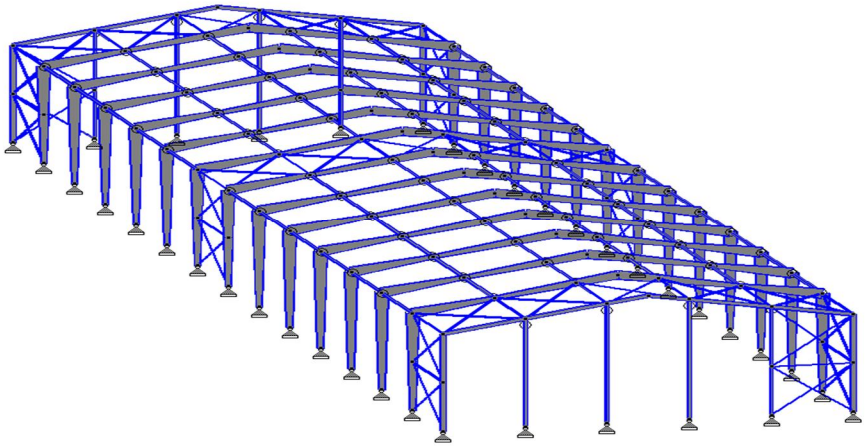

Fig 1. Dual slope staad image

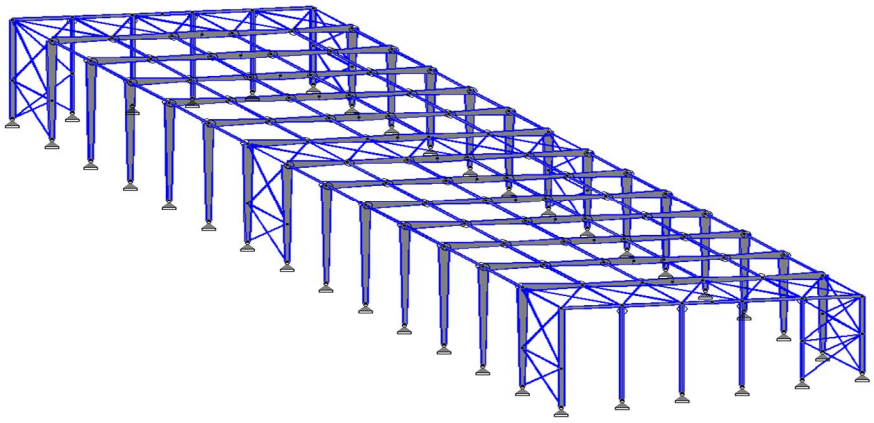

Fig 2. Mono slope staad image

VI. RESULTS AND DISCUSSION

A. Shear Force Comparison

Wind Speed	Dual Slope (kN)	Mono Slope (kN)
33 m/s	83.20	89.02
47 m/s	83.21	87.68
55 m/s	102.00	120.60

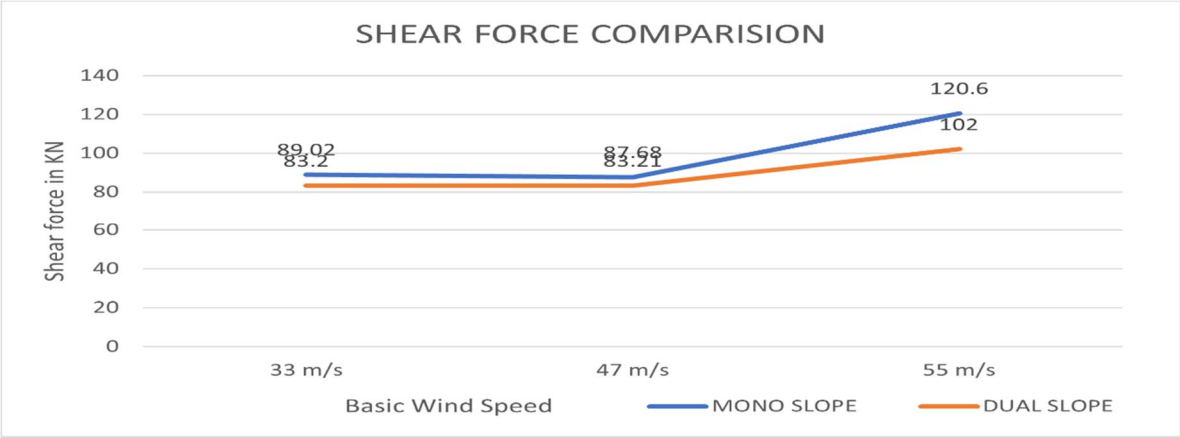

Fig 3. Shear force comparision graph

Mono-Slope structures consistently develop higher shear forces due to asymmetrical roof geometry and uneven lateral load transfer. At 55 m/s wind speed, shear force increases by approximately 18% compared to Dual-Slope structures.

B. Axial Force Comparison

Wind Speed	Dual Slope (kN)	Mono Slope (kN)
33 m/s	77.00	61.00
47 m/s	78.24	75.68
55 m/s	86.00	105.16

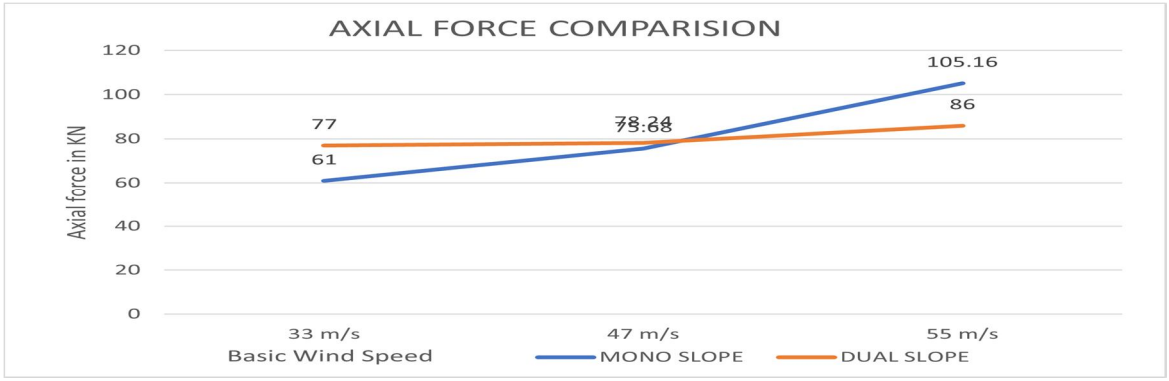

Fig 4. Axial force comparision graph

Dual-Slope structures primarily develop balanced compressive axial forces. Mono-Slope structures exhibit significantly higher axial forces at elevated wind speeds due to unequal column heights and unsymmetrical force distribution.

C. Maximum Bending Moment Comparison

Wind Speed	Dual Slope (kN-m)	Mono Slope (kN-m)
33 m/s	324.8	369
47 m/s	329.7	372
55 m/s	418	549

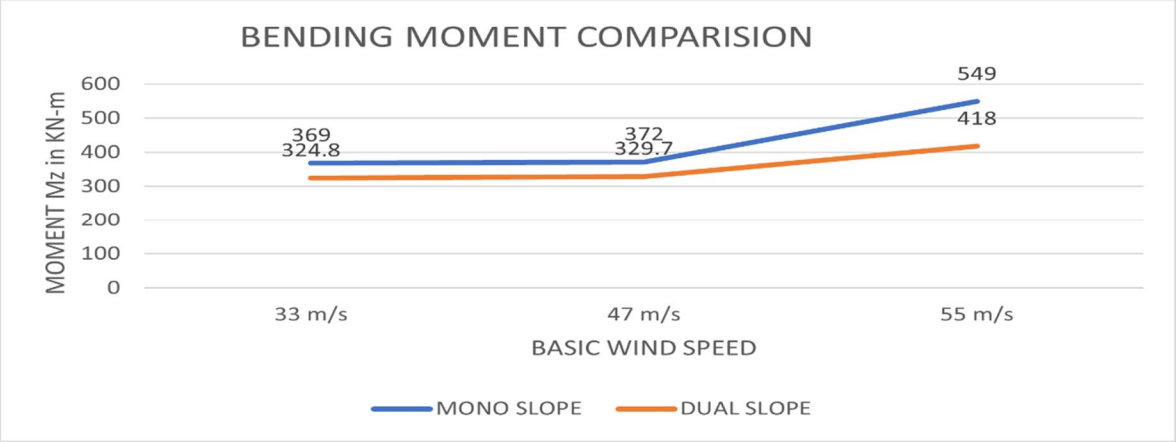

Fig 5. Shear force comparision graph

The Mono-Slope shed experiences substantially higher bending moments under all wind speeds. At 55 m/s wind speed, bending moment increases by nearly 31%, indicating higher structural demand and steel requirement.

D. Deflection Comparison

Wind Speed	Dual Slope (mm)	Mono Slope (mm)
33 m/s	134.0	128.9
47 m/s	126.2	111.0
55 m/s	131.28	132.1

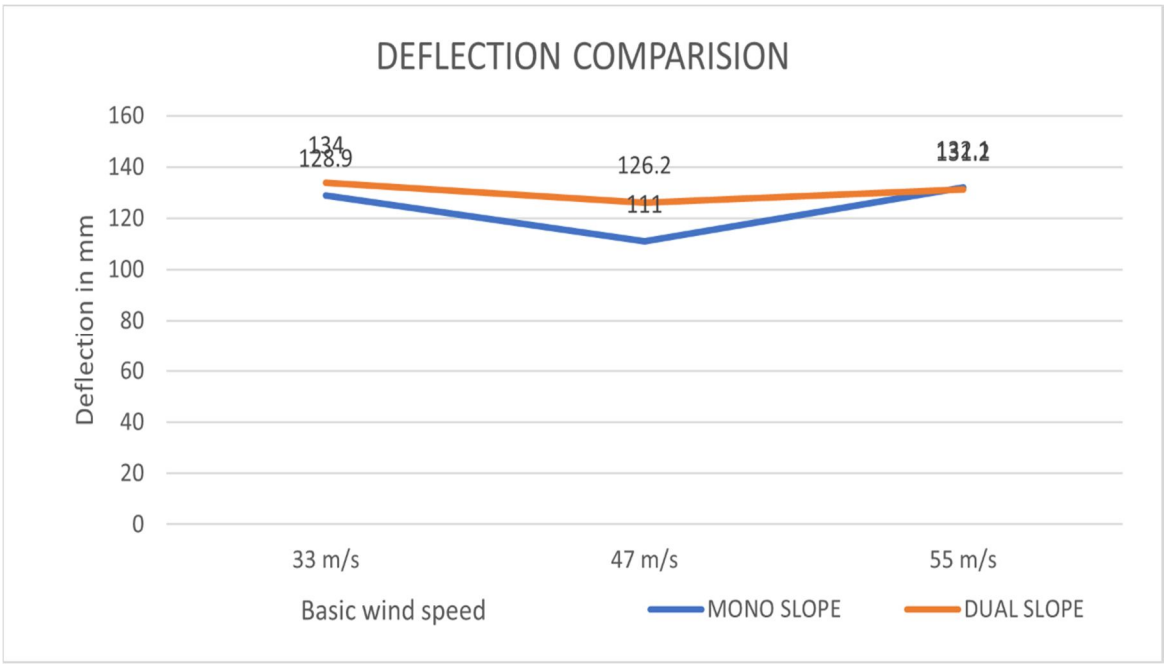

Fig 6. Deflection force comparision graph

Both structures exhibit comparable deflection values. However, Mono-Slope sheds require fixed-base support conditions to maintain serviceability, whereas Dual-Slope sheds perform efficiently under standard support conditions.

E. Steel Consumption Comparison

Wind Speed	Dual Slope (Tonnes)	Mono Slope (Tonnes)
33 m/s	30.24	37.80
47 m/s	32.00	41.26
55 m/s	35.00	46.88

Fig 7. Steel consumption Weight comparision graph

Steel consumption increases with increasing wind speed in both structures. However, Mono-Slope sheds require considerably more steel. At 55 m/s wind speed, steel consumption is approximately 34% higher than Dual-Slope sheds.

VII. CONCLUSIONS

The following conclusions are drawn from the study:

1) Dual-Slope PEB sheds consistently demonstrate superior structural performance compared to Mono-Slope sheds.

2) Steel consumption in Mono-Slope sheds is approximately:
- 25% higher at 33 m/s
- 29% higher at 47 m/s
- 34% higher at 55 m/s

3) Bending moments in Mono-Slope sheds are:
- 13–14% higher at 33 m/s
- 12–13% higher at 47 m/s
- Approximately 31% higher at 55 m/s

4) Axial forces in Mono-Slope structures increase significantly under higher wind speeds and become approximately 22% greater at 55 m/s.

5) Shear force values remain consistently higher in Mono-Slope sheds, reaching nearly 18% higher values under severe wind conditions.

6) Dual-Slope structures provide improved load distribution, lower internal force concentration, enhanced stiffness, and reduced steel requirement.

7) The Dual-Slope PEB industrial shed is the most economical, stable, and structurally efficient configuration for medium and high wind regions.

VIII. FUTURE SCOPE

1) Inclusion of EOT crane loading in industrial shed analysis.
2) Investigation of different roof slopes and bay spacings.
3) Dynamic analysis under earthquake loading.
4) Comparative study using alternative bracing systems.
5) Cost optimization using advanced structural optimization techniques.
6) Investigation of hybrid steel-concrete industrial structures.

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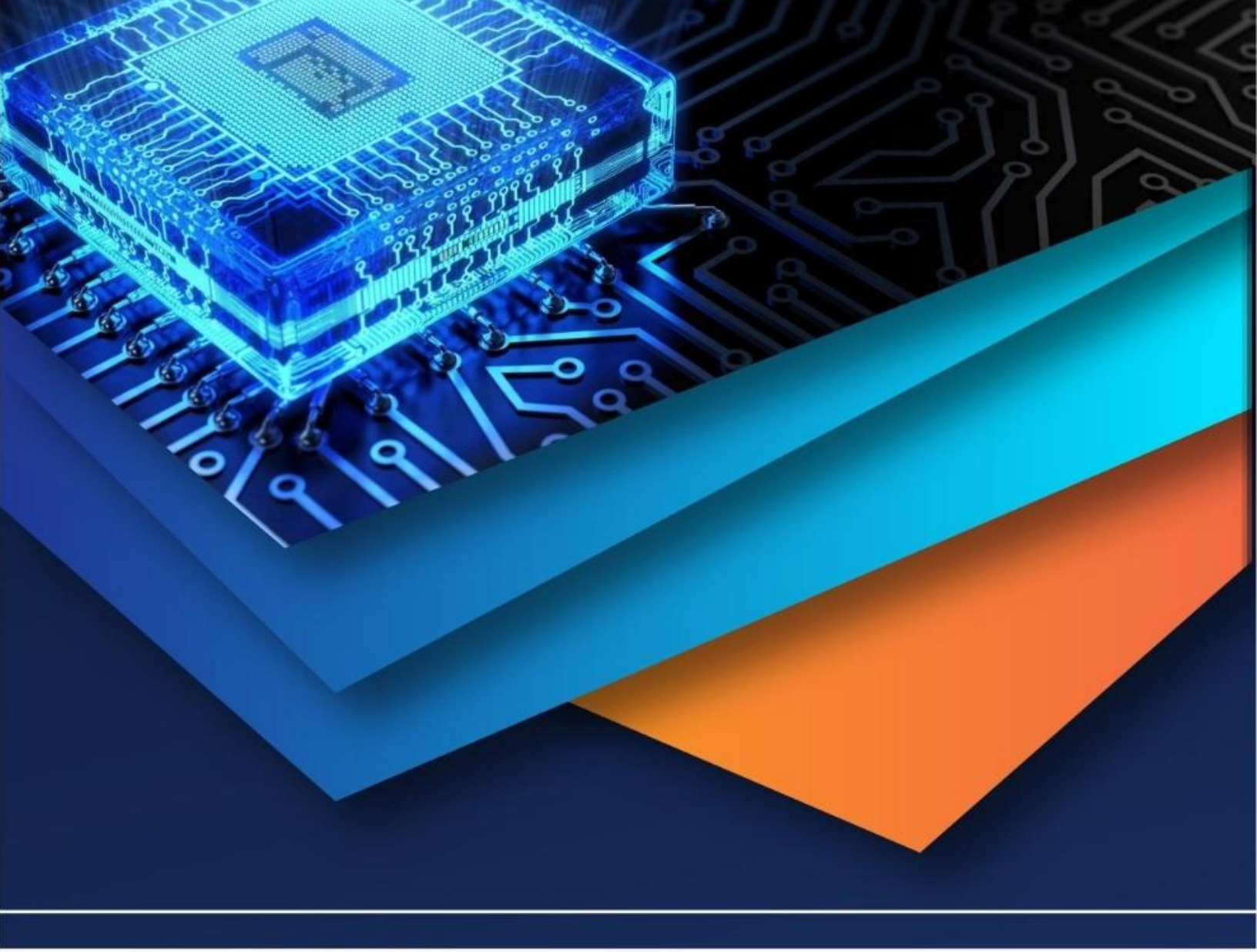

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