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Factors Influencing the Planning and Design of Metro Rail Elevated Corridor

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Abstract: As the cities are already developed. The alignment option are narrow hence optimum structure is to be planned and components are to be designed efficiently . Soil conditions may not be suitable for heavy loads, hence foundation is to be selected accordingly. Heavy traffic on roads cannot be diverted off the road for construction. The construction technology to reduce this effect is to be adopted.

Adjacent construction and traffic load may lead to differential settlement of foundation. A study is required to guide the planner and designer so that the optimization in cost, time and performance of structure can be made in said conditions. The study done under the project is to find out the effect of variation of structural general arrangement and the factors which are to be considered while planning and designing Metro-rail Corridor will be discussed in the review and justified using Analysis in SAP2000.
Keywords: Metro-rail corridor Configuration, Performance, Critical.

I. INTRODUCTION

It includes introduction of the topic, defines research problem and relevant required parameters, states objectives and future scope of the study.

A. Modes of Transportation

1) Waterways
2) Railways
3) Roadways
4) Airways.

Modes of Transportation above are arranged in cheapest to costliest modes as well as slowest to fastest mode.

Metro-rail can efficiently manage the transportation demand if proper planning and design are prepared.

To handle the traffic which cannot be handled by local trains the Metro-rail came in scope which will not require large area on ground but on Elevation or Underground, creating minimum disturbance and maximum utilization of land.

B. What is Metro-Rail

Factors that play important role in the modelling and design of the corridors are as follows. Appropriate structural modelling of continuity connections among the structural members for estimating rigidity. Estimating the seismic force and wind force acting on corridor. Estimation of effect of seasonal temperature variation on the structure. Redistribution determination of time dependent deformation of creep and shrinkage. Pre-stress applied to the member. Loading train cars and cases.

C. What is Metro Rail Configuration

Selection of General arrangement of structure is said to be configuration of Metro-rail corridor.

Main challenges faced ca n be summarized .

1) Weak Soil Strata (Settlement)
2) Adjacent site excavation - Differential Settlement
3) Gradient of rail (Differential support)
4) Curved Route - Skew Deck/Girder)
5) Ground Clearance (Height)
6) Construction Ease, Speed, Duration - Precast (Time and Accessibility)
7) Noise & Privacy of citizen (Exposure)

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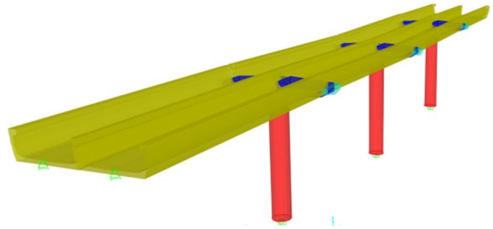
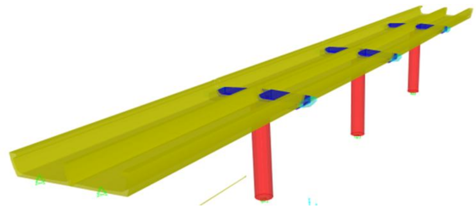
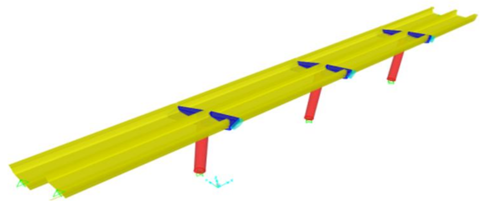
a) Uniformly settled Pier



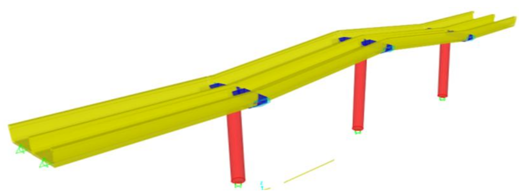
b) Differentialy settled Pier



c) Skew Profile of Corridor

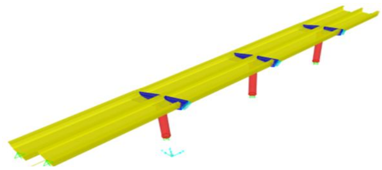


d) Longitudinal Gradient



Critical Configuration - Worst possible combination of each configuration case is considered in the critical case to get worst effect with two trains passing by in seismic case to simulate actual probability as per the frequency of metro.

Critical configuration of corridor (25° Skew + 250mm Differential settlement + 6/100 Gradient) is consider so the sound results are obtained for future reference.



D. Objective of Present Study

Analysis of variety of model of Metro rail elevated Corridor with variation in configuration using IRC 6:2017, IS 1893:2016, IS456:2000, IS875 (Part. I,II,III).

To do comparative study of metro-rail components for different cases with the reference metro-rail project.

Structural performance includes comparison of following performance parameters

1) Axial Force (P)
2) Shear Force (S)
3) Bending Moment (M)
4) Twisting Moment/Torsion (T)
5) Susceptibility to Wind Force and Seismic Force.

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II. NUMERICAL MODEL STUDY

This section includes the development of various types of models on SAP2000 Software and performing linear dynamic analysis.

A. Model Considerations

Scope of study **–**

To study performance of various configurations of Metro-rail Corridor to set the limits to various factors and suggest the optimum measures to reduce the effects.

Type of study**-**

3**-**D FE Model Study

Software**-**

SAP2000 – (2019 Version)

Project for reference- Metro Rail.

Span under study**-**

Station1 towards Station2 (P2 **-**(25m)**-** P3 **-**(25m)**-** P4 **-**(24m)**-** P5 **-**(18m)**-** P6)

Ground level to rail level difference (P2=12.38,P3=12.38,P4=12.17, P5=12.21,P6=12.15).

Superstructure support condition: It is considered that, both ends are hinge supported.

The rail is continuous over the girder offering sufficient resistance against the translation displacement but permitting rotational displacement due to negligible moment of inertia of track.

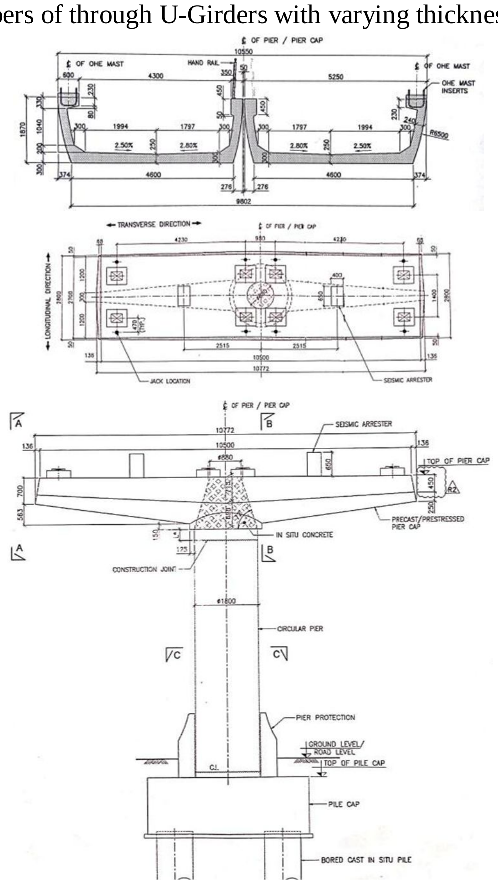
Material Properties**-**

fck = 55MPa , E=35000 MP

fck = 45MPa , E=34000 MP

B. Section Properties

The elevated corridor width is 9.802 m at Bottom and 10.55 m at Top with no provision for footpath and other vehicles to pass through. The corridor comprises of 2 numbers of through U-Girders with varying thickness along height.



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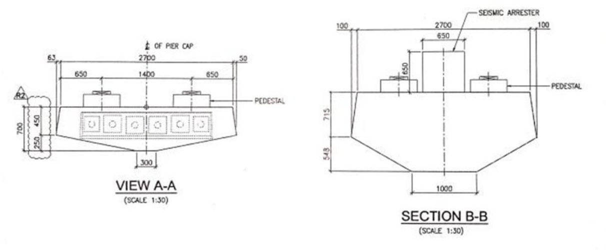


C. Load Cases

1) Dead load

a) Self Weight

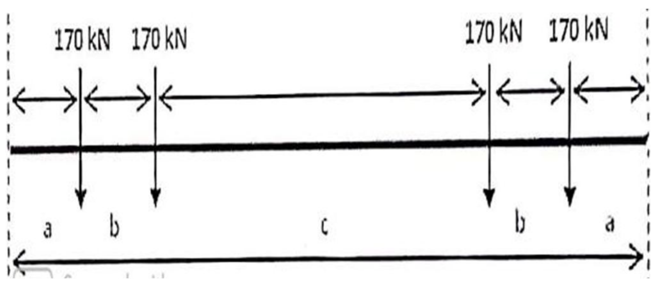
b) SIDL – 22 KN/m Single Track,
44 KN/m Two Tracks

Live Load – Vehicle Load

Maximum successive cars = 8

Maximum vehicle speed = 80 Km/h

Metro axle load and spacing



2) Metro Vehicle -I

a= 2.25m, b=2.5m, c=12.6m. (L = 22.1m)

Metro vehicle -II: Refer Fig.3.3.3

a= 2.605 m, b=2.29 m, c=12.31m. (L = 22.1m)

Wind load calculation (WL) –

Design Wind Pressure (Mumbai)

Pd = Kd x Ka x Kc x Pz

Along Span:

Pd = 0.9 x 1 x 0.9 x 1760.344 ,

Pd = 1.425878 KN/m2

Across Span:

Pd = 0.9 x 0.9 x 0.9 x 1760.344

Pd = 1.283291 KN/m2

3) Seismic load (EL)

Design Lateral Force (V_b), Manual and SAP :

Vb = Ah x W (Refer Fig.3.3.4)

Vbx = 0.1348 x 14858.159 = 2003.305 KN (SAP2000, 1912.64KN)

Vby = 0.1348 x 14858.159 = 2003.305 KN (SAP2000, 1912.64KN)

Temperature Effect (TL) - Design temperature = 5°- 42.5°

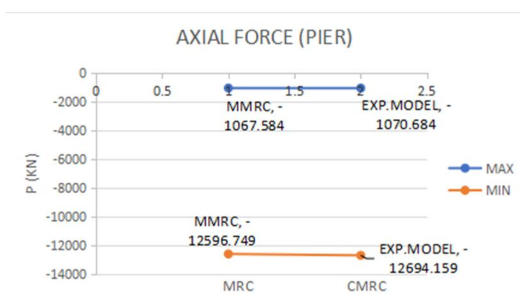
Braking Load = 18% Vehicle Load

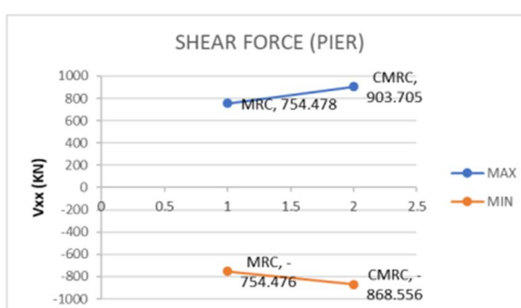
Traction Load = 18% Vehicle Load

Coefficient of Dynamic Augment (CDA) = (4.5/(L+6) Vehicle Load

III. RESULT

GRA 6%	SKEW 25°	DSETT 250mm	MMRC	EXP.MODEL
PIER	AXIAL	MAX	-1067.584	-1070.684
		MIN	-12596.749	-12694.159
			MMRC	EXP.MODEL
	SHEAR X	MAX	754.478	903.705
		MIN	-754.476	-868.556
			MMRC	EXP.MODEL
	SHEAR Y	MAX	754.544	762.478
		MIN	-754.544	-772.246
			MMRC	EXP.MODEL
	B.M Y	MAX	12554.297	12819.629
		MIN	-12548.254	-12928.72
			MMRC	EXP.MODEL
	B. M X	MAX	9605.25	11697.65
		MIN	-9606.6997	-11880.546
			MMRC	EXP.MODEL
	TORSION	MAX	9.8503	880.202
		MIN	-9.8501	-882.3054
PIER CAP			MMRC	EXP.MODEL
	SHEAR Z	MAX	-534.385	-535.239
		MIN	-5697.486	-5743.158
			MMRC	EXP.MODEL
	B. M X	MAX	-1370.2534	-1494.946
		MIN	-14694.052	-16330.819
GIRDER			MMRC	EXP.MODEL
	SHEAR Z	MAX	3052.782	3051.309
		MIN	-3052.136	-3056.544
			MMRC	EXP.MODEL
	B. M Y	MAX	18433.0737	17397.20
		MIN	1702.3188	1593.555
			MMRC	EXP.MODEL
		MAX	93.7195	1822.37
	TORSION	MIN	-93.9227	153.8809





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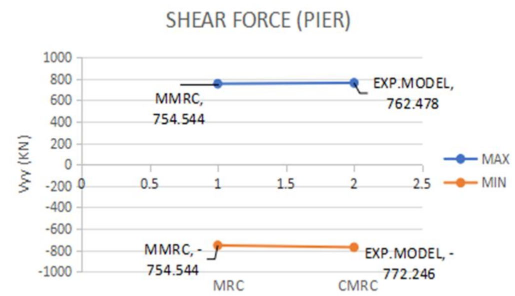

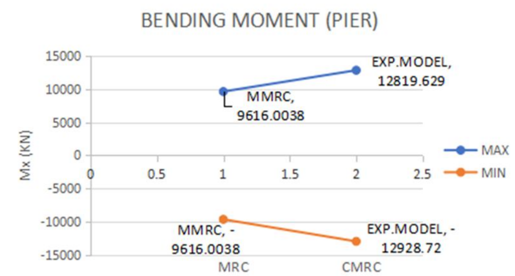

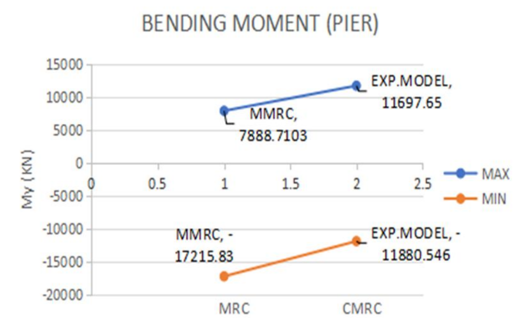

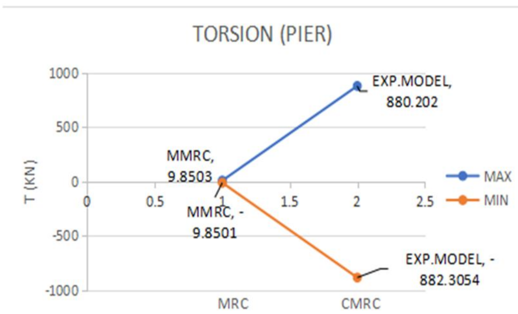

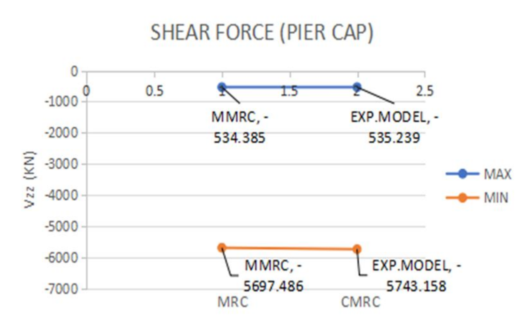

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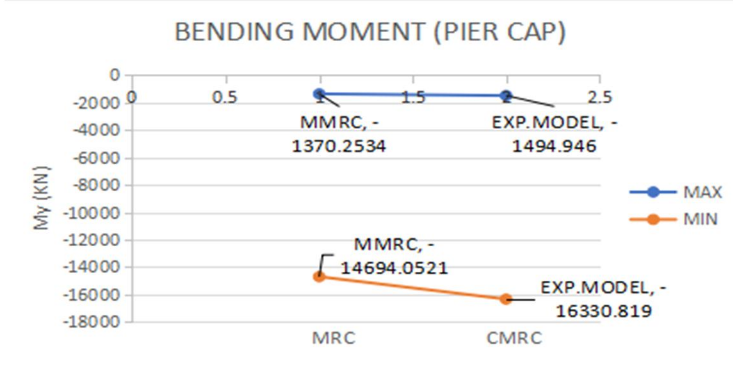

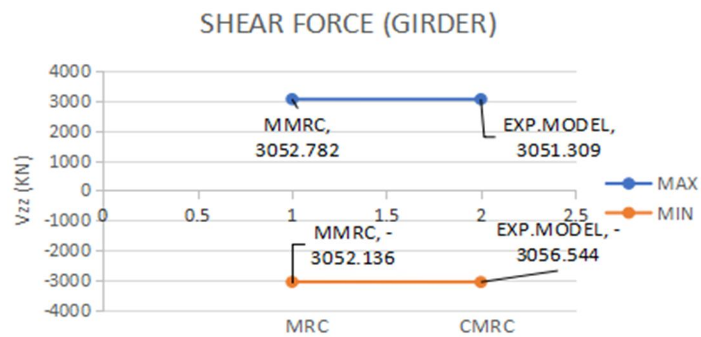

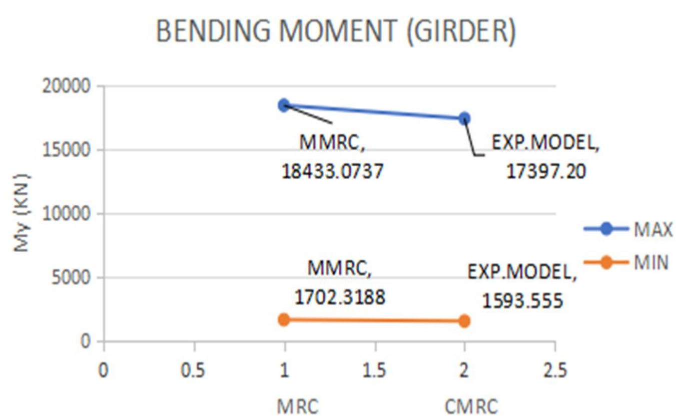

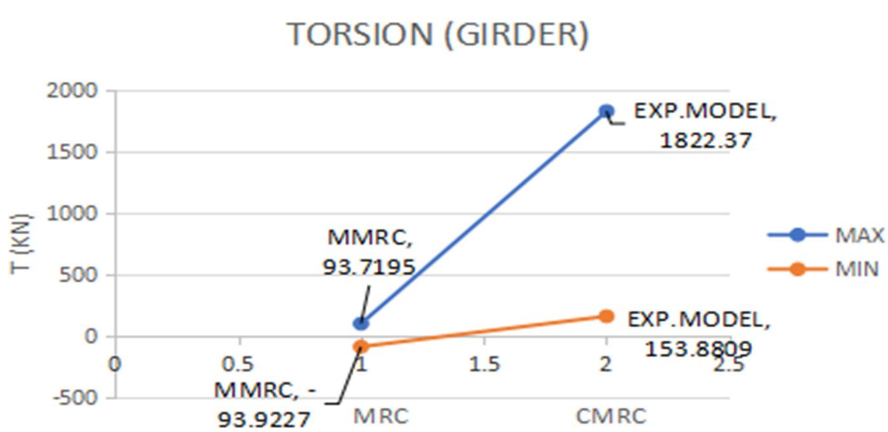

IV. CONCLUSION

The present study for Elevated metro rail corridor under limited factors and standard assumptions wherever required. The results obtained from the models analysed in SAP2000 are concluded in systematic manner in the chapter.

1) *Axial Force in Pier:* Axial force in the pier is not increasing considerably as, Axial force spectrum in the Pier for CMRC is increased by 0.29% and 0.773% as that of MRC for minimum and maximum force respectively.
2) *Shear Force in Pier:* Reverse shifting of spectrum for Longitudinal Shear force is observed. Spectrum in the Pier for CMRC is decreased by 20.30% and -54.12% as that of MRC for minimum and maximum force respectively.
3) Transverse Shear force spectrum in the Pier for CMRC is increased by 1.05% and 2.346% as that of MRC for minimum and maximum force respectively. Indicating no special change in nature.
4) *Bending Moment in Pier:* Longitudinal Bending Moment spectrum in the Pier for CMRC is increased by 48.28% and -30.99% as that of MRC for minimum and maximum Bending Moment respectively. It indicates that the design bending moment is increased by 48.28% Pier in longitudinal direction.
5) Transverse Bending Moment spectrum in the Pier for CMRC is shifted up by 33.31% and 34.45% as that of MRC for minimum and maximum Bending Moment respectively. Here the shifting is occur for B.M spectrum which is on favourable side for design.
6) *Torsion in Pier:* Torsion spectrum in the Pier for CMRC is widened by 8835.79% and -8857.32% as that of MRC for minimum and maximum torsion respectively. Torsion is found to increased drastically in Pier.
7) *Shear force in Pier Cap:* Shear force spectrum in the Pier Cap for CMRC is increased by 0.8% and 0.028% as that of MRC for minimum and maximum force respectively. As forces transferred to bearings is not increased considerably, There is a negligible effect on Pier Cap.
8) *Bending Moment in Pier Cap:* Bending Moment spectrum in the Pier Cap for CMRC is increased by 9.09% and 11.139% as that of MRC for minimum and maximum Bending Moment respectively. Due to skew arrangement of Girder the load transferred to outside bearing is increased leading to minor widening of spectrum for B.M.
9) *Shear Force in Girder:* Shear force spectrum in the Girder for CMRC is decreased by 0.048% and -0.1444% as that of MRC for minimum and maximum force respectively. Shear force on Girder is not changed considerably due to no major change in effective length of Girder.
10) *Bending Moment in Girder:* Bending Moment spectrum in the Girder for CMRC is decreased by 5.62% and 6.39% as that of MRC for minimum and maximum Bending Moment respectively. Due to skew shape and settlement the moment developed in Girder is increases by a small percentage.
11) *Torsion in Girder:* Torsion spectrum in the Girder for CMRC is widened by 1844.49% and -263.837% as that of MRC for minimum and maximum Torsion respectively. Girder is affected largely due to the critical conditions under consideration. Torsion is 20 times increases that of actual MRC. The girder is centrally loaded by the vehicle on track and approximately balancing self weight hence the development of torsion in girder is negligible for deferential settlement.
12) *Susceptibility to Seismic Action:* The height of the rail level is reduced due to adoption of U-Girder instead of I-Girder, Hence the major part of mass source (Superstructure) is lowered leading to the reduction in over all primary and secondary effects on corridor.
13) *Susceptibility to Wind Action:* The exposed area developed due to adoption of U-Girder is considerably less than that of area developed by adoption of i-Girder. Hence the total wind force acting on the corridor is reduced.

Following general conclusions can be made from above statistical conclusions-

Soil under the pier locations shall be explored by enough Bore holes for calculating SBC and Future settlement due to underground streams. Settlement shall be permitted within a acceptable limit.

If spread foundation is adopted, It should be such that traffic passes by both side to avoid differential settlement.

Before construction of metro rail structure, Chances of adjacent site excavation should be studied. And no excavation shall be allowed in future, prior construction of retaining wall.

Rail level shall be uniform as much as possible to avoid provision of high gradient. Gradual slope shall be provided to reduces lateral force and torsion on piers.

No pier shall be placed in the road unless a condition arrives to adopt skew profile.

Adoption of U-Girder avoids requirement of noise barrier as the machines used in metro vehicle are kept at lover part, Hence the noise is diverted upwards. The outdoor component of Air condition is placed on top but due to a minimum required distance from adjacent structures the noise reaching to residential buildings is negligible.

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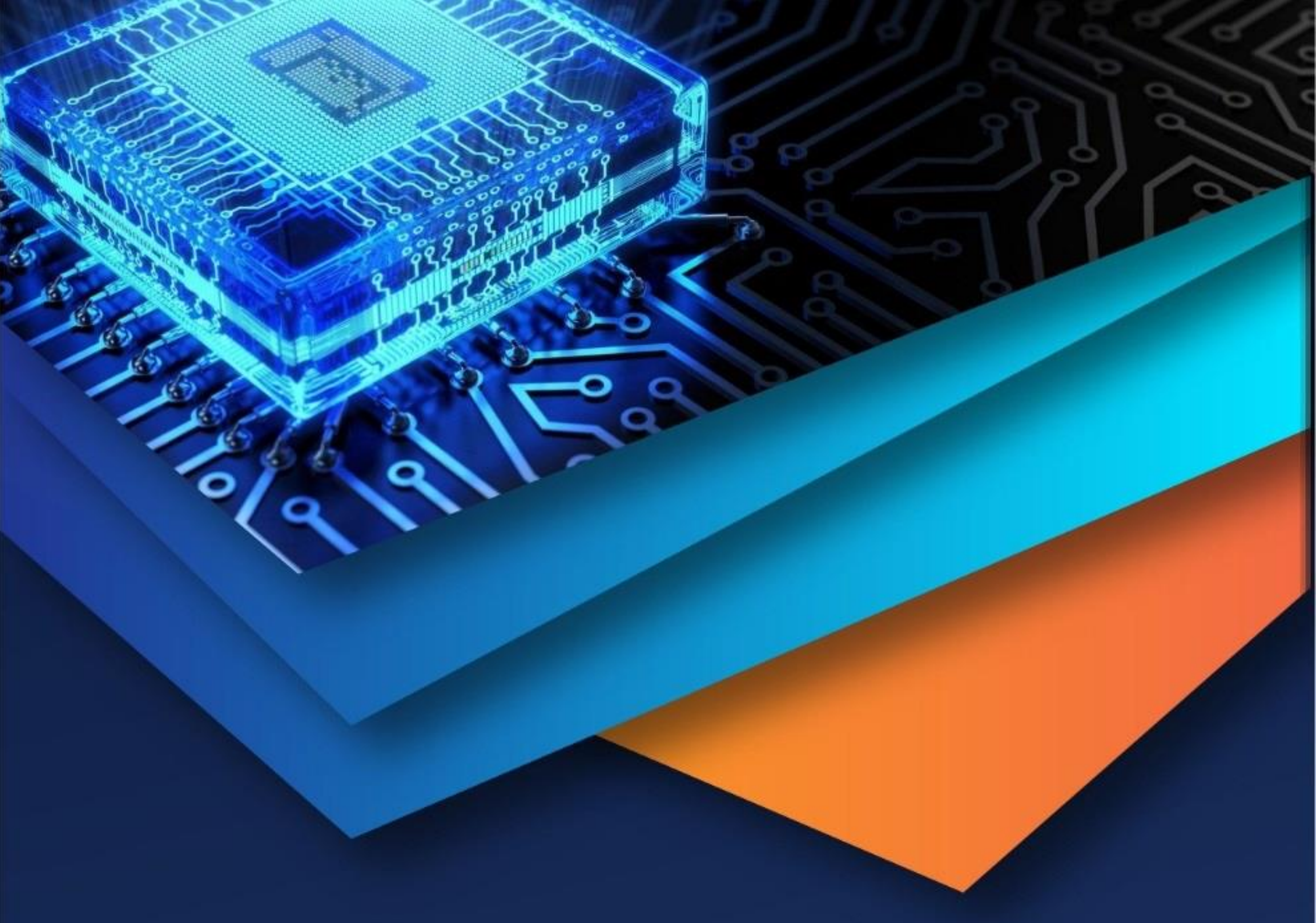

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