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Numerical Analysis of Tunnel Support System at Pune Metro

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Abstract: Pune has witnessed enormous industrial growth, rapid urbanization in the recent past and has put the city's travel infrastructure to stress. Being a densely populated area, Pune's traffic needs cannot be met by road-based transportation systems and additional flyovers. Considering this, the Pune Metro project a strong public transport system partly elevated, and partly underground Line 1 and the completely elevated Line 2 has been discussed and undertaken by Maha Metro Rail Corporation. With the rise in demand, the responsibility for a safe and efficient public transport system also increases hence proper planning, designing, and execution play a vital role. The underground tunnel stretch of the Pune Metro Line 1 project is carried out by TBM and by segmental lining as a support system. By geotechnical parameters and FEM, RS^2 software author analyses the ground behaviour and support system and conveys a basic understanding of ground behaviour and results in guidelines for designing the underground tunnel.
Keywords: Pune Metro, Tunnel, FEM RS^2 Software, Ground Behaviour, Support System

I. INTRODUCTION

A. Overview of Project

Pune Metro project has been undertaken by MAHA Metro Rail Corporation, a special purpose vehicle of the government of India and the Government of Maharashtra. The project will cover an aggregate length of 31.254 Km dividing it into Corridor 1 (N-S) PCMC to Swargate, a length of 16.589 km with 5.019 Km underground and 11.570 km elevated comprising 14 stations (9 elevated and 5 underground) and Corridor 2 (W-E) Vanaz to Ramwadi a length of 14.665 km entirely elevated with 16 stations. In corridor 1 Pune metro line 1 package UGC-01 & UGC-02 are entirely underground.

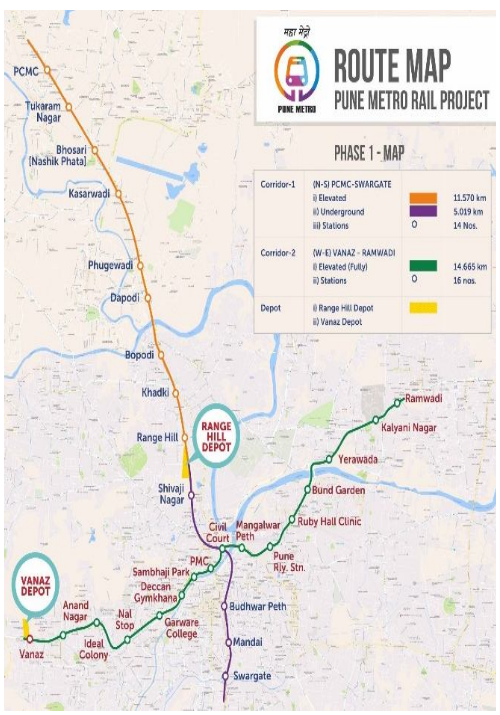

Figure 1: Location Plan of Project

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Package UGC-01 comprised the construction of twin-tube tunnels, ramp, cross passages, and 2 underground stations. Underground tunnel excavation carried out by TBM excavation. It is divided into 3 separate parts. The Earth Pressure Balanced (EPB) shield machine will be utilized for excavation of the twin bored tunnel from Agriculture College – Cut & Cover section to Shivaji Nagar station, Shivaji Nagar station to cross over section at civil court station, drag through between cross over section at civil court station and tunnel between civil court station and Budhwar Peth station which passes below or under the Mula-Mutha river. The total length of tunnel alignment under Package UGC-01 is equaled to 4,287m.
Package UGC-2 comprised the construction of Twin Tube tunnels, Cut & Cover Tunnels, Cross Passages, and 3 Underground stations. TBM is Launching from Swargate to Budhwar Peth and drag through is between Cross Over Section Mandai to Budhwar Peth and Tunnel Between Mandai to Budhwar Peth Station and then TBM is retrieval is done from Budhwar Peth.

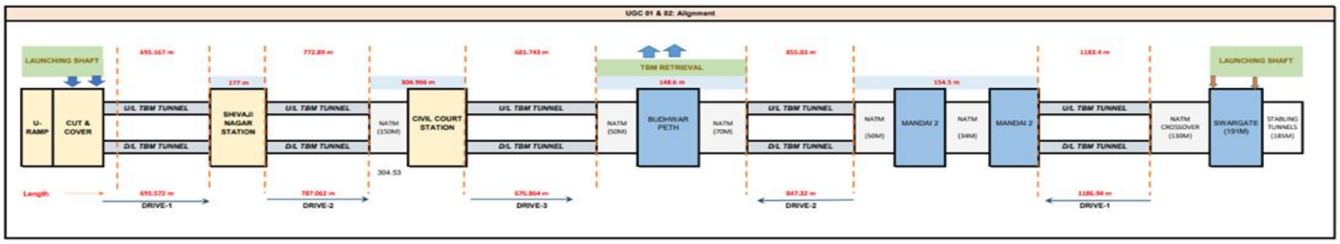

Figure 2. Overview of Pune Metro Tunnel Line 1 Alignment

II. GEOLOGY

A. General Overview of project geology

The rocks Present at the site belong to the Deccan trap series of peninsular India. The rocks occurring are compact basalts and amygdaloidal basalt with gas cavities filled with secondary minerals which give them a spotted appearance. Basalt, extrusive igneous rock that is low in silica content dark in colour, and comparatively rich in iron and magnesium. Some Basalts are quite glassy (tachylalic), and many are very fine-grained and compact. For purpose of numerical analysis following design parameters of the geology is taken under consideration.

B. Design parameters for Numerical Analysis

Sr. No.	Depth below GL (m)	For Soil						
		Strata Description	Unit Weight	c	phi	Stiffness	Poisson's Ratio
			kN/m^3	kPa	^{o}	MPa	-
1	0-2	Made ground/Filling	15	0	25	1.0 -3.5	0.45
2	2-5	Sandy Clay to Silty Clay	19	0	25	10	0.45

Sr. No.	Depth below GL (m)	For Rock								
		Strata Description	Grade of Rock	Unit Weight	Tensile strength of rock mass	Deformation Modulus	Poisson's Ratio	c	phi	Ko
				kN/m^3	MPa	MPa	-	MPa	^{o}	
1	5-14	Highly Weathered Basalt	IV	25	0.003	210	0.3	0.08	48	0.5
2	14-21	Moderately Weathered Basalt	III	25	0.035	1600	0.3	0.21	59	0.5
3	>21	Slightly Weathered	I & II	25	0.46	11000	0.3	1.40	64	0.5

Table 1. Design Geotechnical Parameters

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III.METHODOLOGY

The software used for the numerical analysis is the 2-dimensional finite element software RS^2 developed and distributed by RocScience group. It is used for 2D elastoplastic finite element stress analysis for underground excavation in rock or soil.
A circular tunnel in basaltic rock and support to be installed at 2m from the tunnel face is taken into consideration in the research.
For design and analysis of circular tunnel, geotechnical parameters and the following geometry parameters are used:

Sr. No.	Description	Value	Notation	Unit
1	Tunnel Diameter	6.35	d	m
2	Overburden	15	D	m
3	Stress Ratio	0.5	K	-

Table 2. Design Geometrical Parameters

A. Model Description

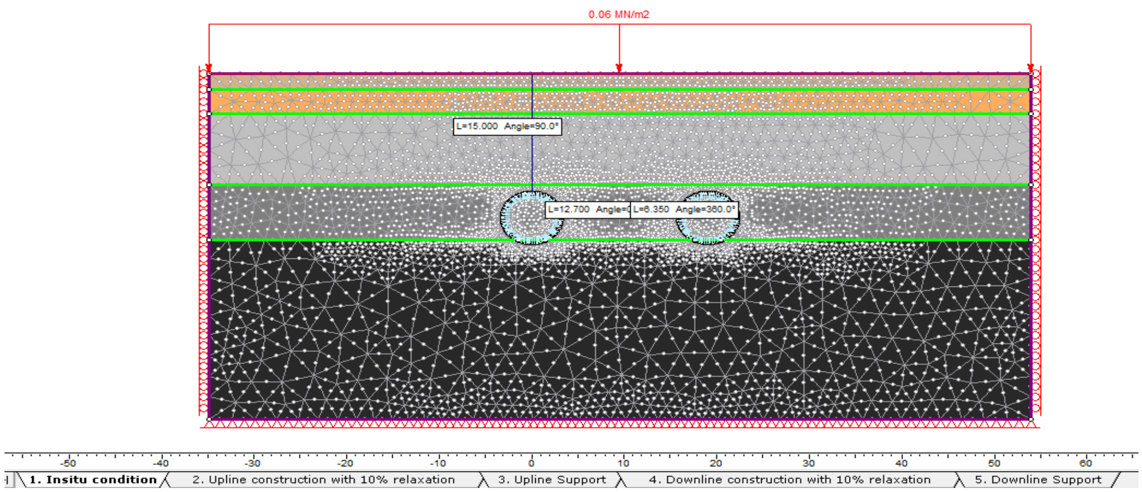

Figure 3: Model description of the problem

The problem has been analysed in following stages:

1) *Stage 1:* In-situ condition

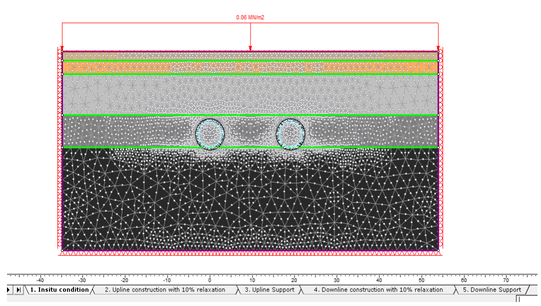

Figure 4: Model description at stage 1

2) *Stage 2:* Upline construction with 10 % ground relaxation

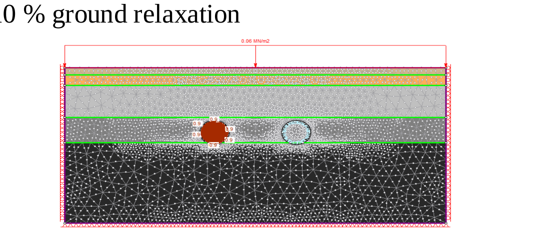

Figure 5: Model description at stage 2

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3) *Stage 3:* Upline support

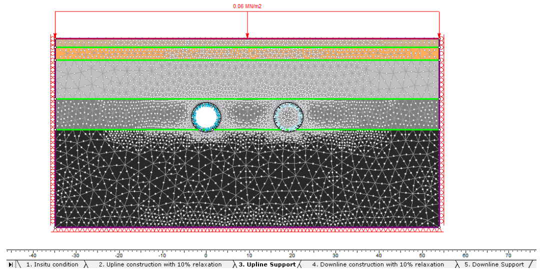

Figure 6: Model description at stage 3

4) *Stage 4:* Downline construction with 10 % ground relaxation

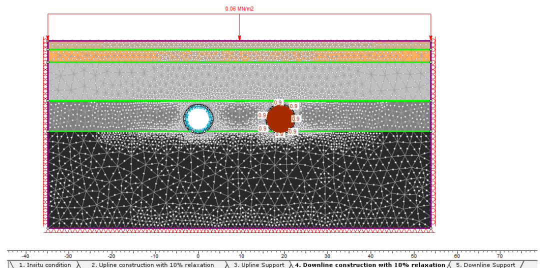

Figure 7: Model description at stage 4

5) *Stage 5:* Downline support

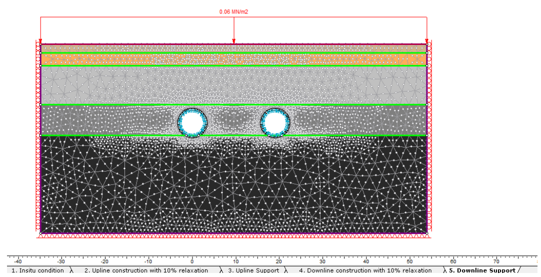

Figure 8: Model decription at stage 5

IV. RESULT AND DISCUSSION

A. *Stress Trajectories*

1) *Stage 1:* In-situ condition

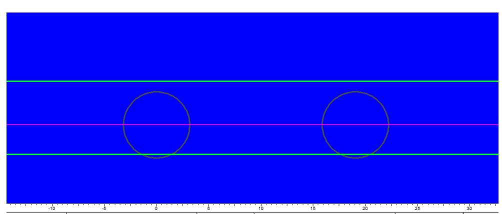

Figure 9: Stress trajectories at stage 1

2) *Stage 2:* Upline construction with 10 % ground relaxation

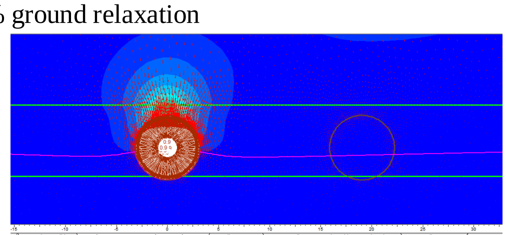

Figure 10: Stress trajectories at stage 2

3) *Stage 3:* Upline support

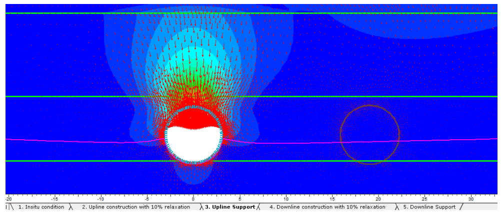

Figure 11: Stress trajectories at stage 3

4) *Stage 4:* Downline construction with 10 % ground relaxation

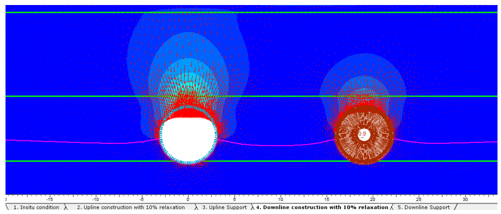

Figure 12: Stress trajectories at stage 4

5) *Stage 5:* Downline support

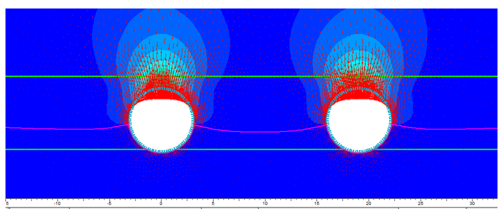

Figure 13:Stress trajectories at stage 5

B. *Maximum Liner Axial Force*

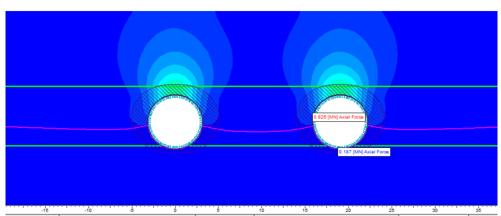

Figure 14: Maximum liner axial force

C. *Maximum Liner Shear Force*

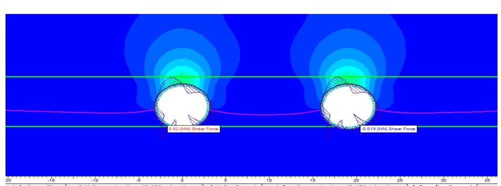

Figure 15: Maximum liner shear force

D. *Maximum Liner Bending Moment*

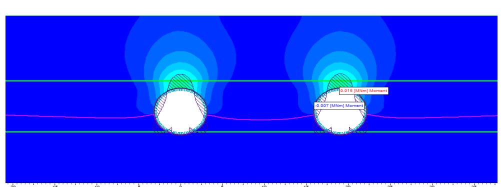

Figure 16: Maximum liner bending moment

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E. Maximum Liner Displacement

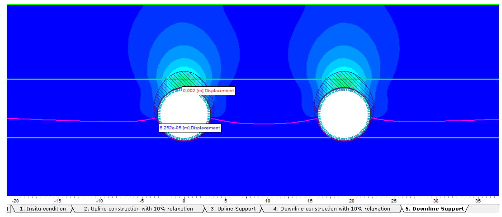

Figure 17: Maximum liner displacement

F. Maximum Total Displacement at Final stage

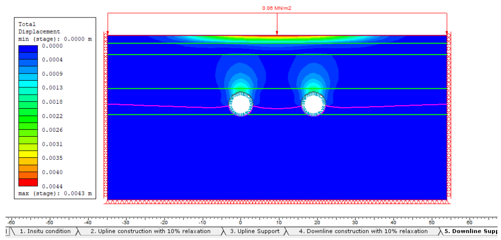

Figure 18: Maximum total displacement at final stage

G. Surface Displacement

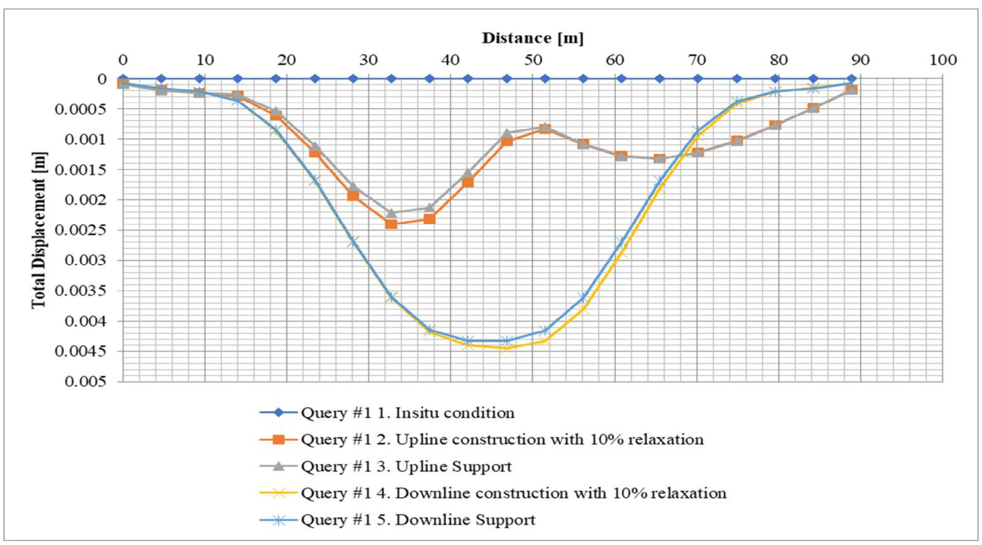

Figure 19: Surface displacement at different stages

H. Support Capacity Curves

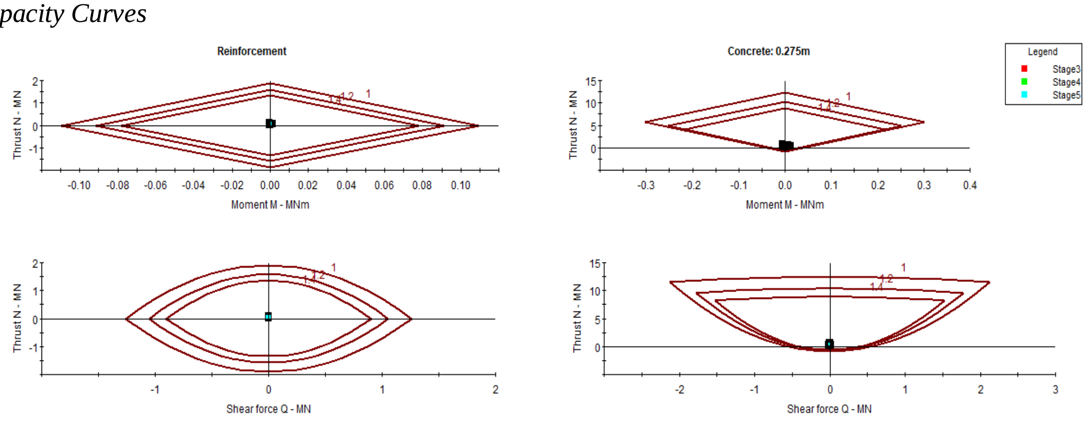

Figure 20: Support capacity curves for defined support system

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V. CONCLUSION

6) The numerical analysis calculations the result according to FEM RS2 software show that elastic-plastic deformations developed around the tunnel excavation boundary.
7) Considering the ground type with an overburden of 15m associated with different geotechnical conditions and rock mass parameters, the support designed are sufficient.
8) With the application of support system the occurred surface displacements are within the limit

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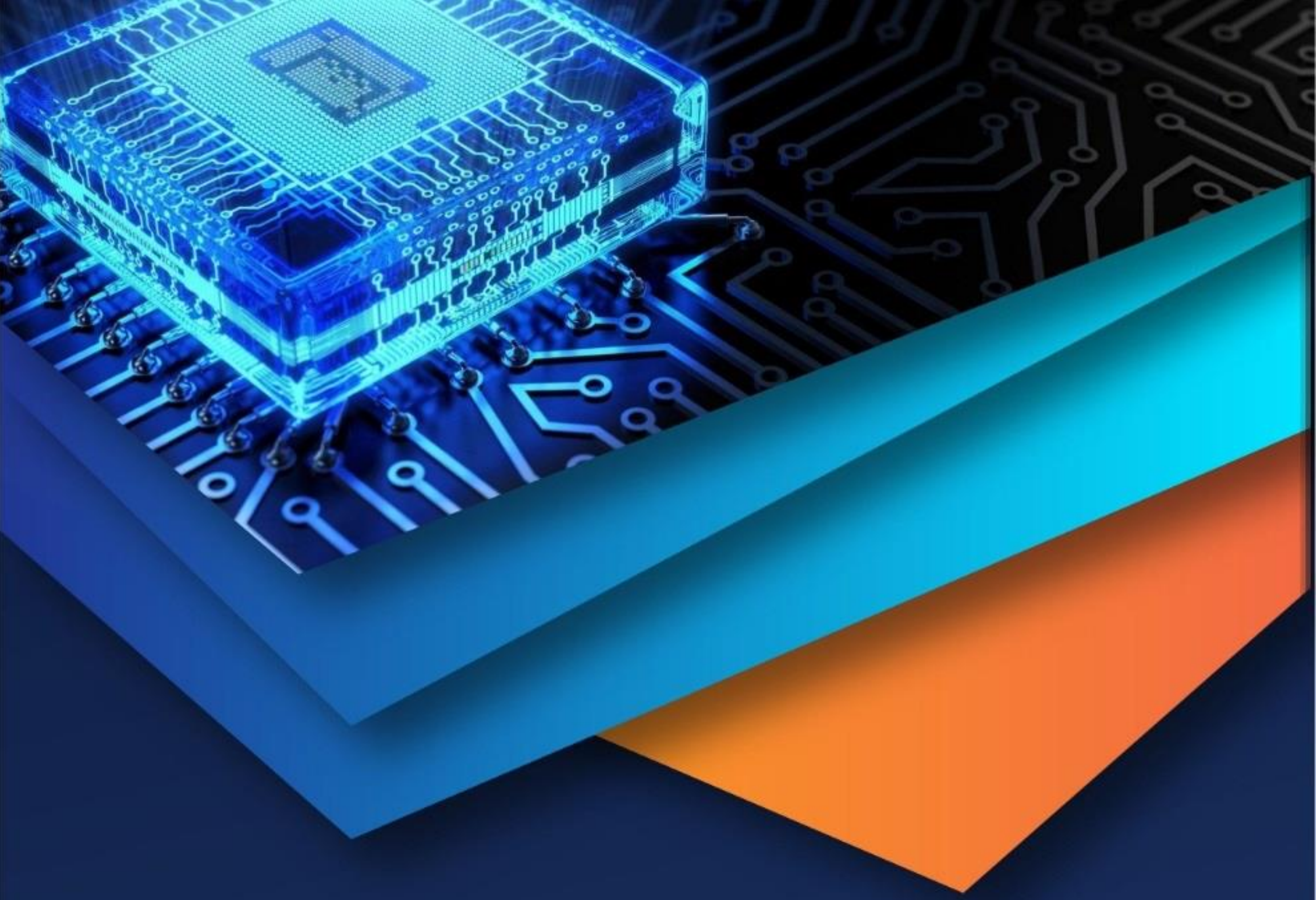

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