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Effect of Discontinuity Orientation and Geological Overbreak in Tunnels: Case study of Tunnel T 74 R (A) [1]

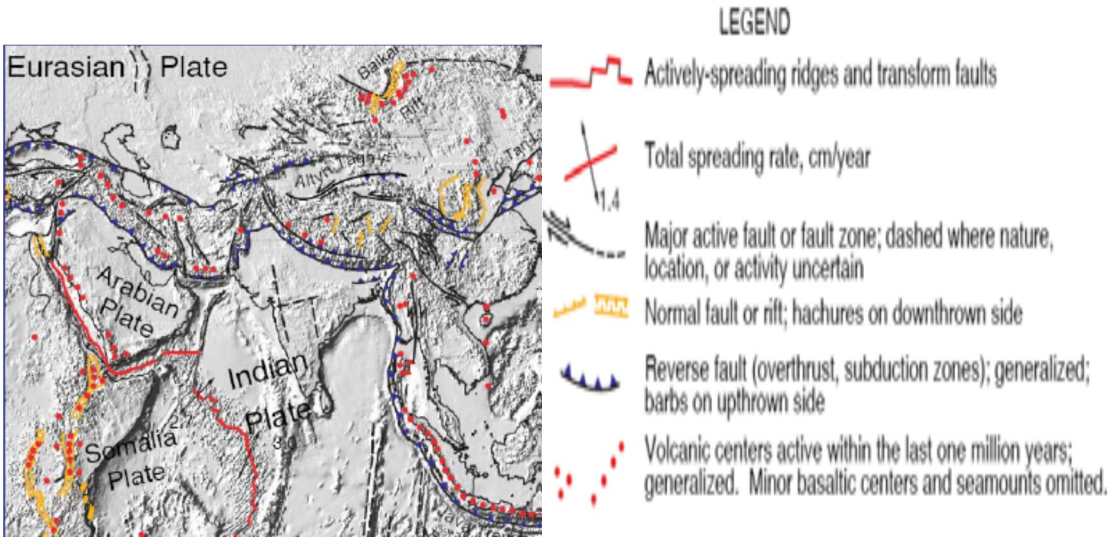
Avinash Mehra
Senior Geologist, LOMBARDI Engineering India Limited.

Abstract: ***Tunnel Stability is affected by so many factors. These may include Rock Quality Designation, Rock Strength, Groundwater Conditions, Vertical rock Cover or Overburden and Discontinuity or joints Conditions. This paper is going to encompass effects of Geological parameter 'Discontinuity Orientation' which is commonly used to Calculate RMR Value in Tunnels. This factor affects the stability of the Underground structure. But its impact on time and money is also seen. Various preventive measures to mitigate discontinuity induced Geological over breaks is also discussed in this paper with special reference to Tunnel T-74 R (Section of Udhampur-Srinagar-Baramulla-Rail Link) between KM 127.660 to KM 130.950.This paper is helpful for those who are executing tunnels in foliated and bedded rock mass.***

I. INTRODUCTION

Tunnel T 74 R is 8.6 KM long Tunnel which was divided into 3 different packages. Northern Railway being the Owner of the Project. IRCON International Limited was awarded the work and Execution was done by AFCONS on two of its packages. Excavation works of Tunnel T 74 R (A), section of Udhampur Srinagar Baramulla Rail Link was started in 2013 through an ADIT. Tunnel excavation was done using New Austrian Method (NATM). The depth of the the ADIT was 595 M. Main Tunnel and Escape Tunnel Works started on the either side (Towards Katra Side and towards Banihal Side) after completion of ADIT. The bedrocks exposed along the tunnel alignments belong to Ramsu and Macchal Formation of early Palaeozoic age (540 MA) comprises of Foliated Metamorphic rocks phyllites, quarzitic phyllites, micaceous quartzites, and quartzites.

In Foliated and bedded rocks, the *orientation* of the discontinuities of the rock mass has an important influence on the displacements and failure mechanisms occurring around an underground excavation and considered as one of the most important parameters in Rock Mass Rating.Considerably, in this study the discontinuity parameter compared to other factors, and its serious effect has been studied.



Digital Tectonic Activity Map of the Earth (south Asian and Indian Region). Tectonic and volcanism of the last 1 Million Years, NASA, 2002)

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II. REGIONAL GEOLOGY

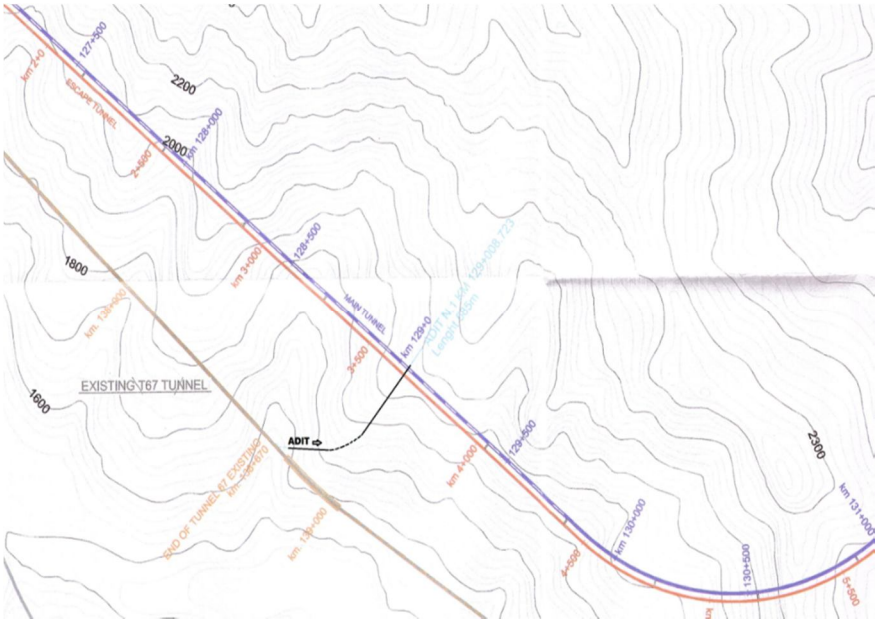
The Kashmir railway link, heading northward from Katra, crosses, up to Banihal, a main part of the Indian margin of the Himalayan collisional range, being this margin by now concordantly constituted by three major Units, the Sub Himalaya and the Lesser and the Higher Himalaya Crystalline (HHC), respectively divided, in this chain sector, by the Murree thrust and the Panjal thrust. These main thrusts as well as most of the belts and units of this NW region of Himalaya orogeny show a regional strike of NW-SE to WNW-ESE with moderate to steep dips either towards north or the south. Geological investigation was done prior to excavation which includes Borehole data and permeability tests provided by M/S DBM Geotechnics Pvt. Limited. Besides, IT Bombay had also contributed to investigation by doing Point load Test, Tensile strength, and compression test etc. Based on test reports and field reports, a comprehensive Rock class was anticipated by client through DDC. But orientation of Foliation/discontinuity/joint and its effect might not be taken into consideration during investigation stage which lead to anomaly in anticipated vs actual encountered Geology as shown in table below

Variation in Anticipated and Actual Encountered Geology in Main Tunnel T 74 (RA)						
Rock Support Class	A	B	C1	C1F/C1*	D	E
Anticipated Geology	0%	25.30%	23.80%	27.80%	14.80%	0%
Actual Geology	0%	0%	51.70%	47.30%	1%	0%

Main discontinuties (ISRM 1981)							
type	dip/dir	spac. (mm)	pers. (m)	rough.	open.(mm)	alterat.	infill.
J1	55/025	60-600	>10	Smooth	0.1-1.0	sl.weathered	Hard / Soft
J2	50/220	200-600	2-5	Smooth	0.1-1.0	sl.weathered	Hard / Soft
J3	45/180	200-600	<10	Smooth	0.1-1.0	sl.weathered	Hard / Soft
J4	75/010	600-2000	<10	Smooth	0.1-1.0	sl.weathered	Hard / Soft
JR	75/270	600-2000	<10	Smooth	0.1-1.0	sl.weathered	Hard / Soft
Others parameters							
Ucs [Mpa]-20 to 100 Mpa			RQD [%]=20-35%				

Foliation and joint set data

A. *Role Of Discontinuity Orientation Strike With Respect To Tunnel Axis*



Plan view Tunnel 74 R (A)

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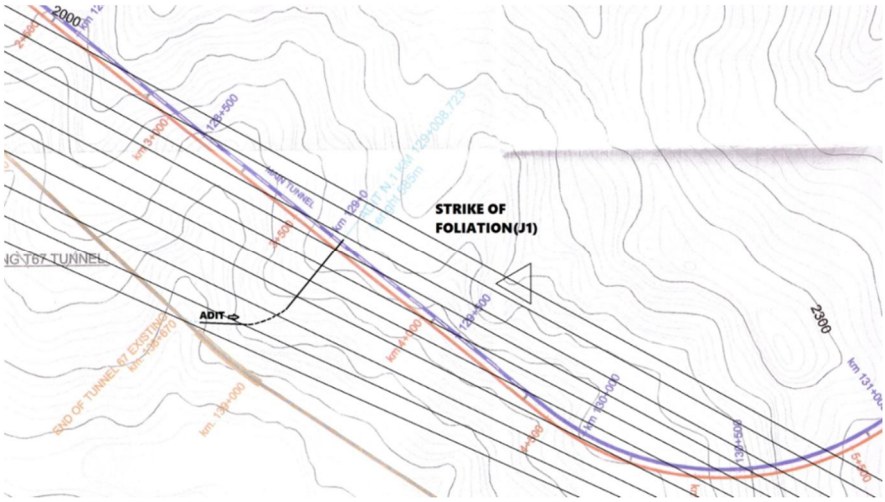
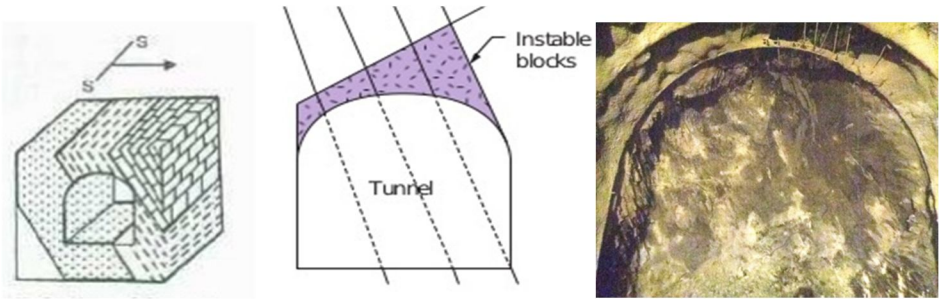


Strike of foliation Discontinuity with respect to tunnel Axis

Excavation works started from 585 M long ADIT. The first 300 M of same was problematic due to usability and over break from Left Crown. But after 300 M until 585 M there was gradual stability of crown with very less over break. Initially, the phenomenon was difficult to understand. But keeping in view, the orientation of Foliation discontinuity (Joint 1), it became easy to know and predict the excavation behavior of stable and unstable rock mass locations which had to be encountered in Main and Escape tunnel well in advance.In Plan view, there is curve reach in ADIT and Tunnel towards Banihal Side (Main and Escape) while there is straight reach in tunnel towards Katra Side (Main and Escape). As the ADIT was near completion, the properties of Rock Mass were more or less same, but there was change in orientation due to change in tunnel axis. Prior to excavation of Main and Escape Tunnel, strike of Foliation ($N60^0$ W – S 60^0 E) with dip amount $55\text{-}60^0$ projected on Tunnel Plan to determine the stability of crown (on either sides) or rock mass. Tunnel was aligned with direction $N32^0$ W – S 32^0 E Wherever, the strike of foliation/discontinuity was parallel to tunnel axis, there was over break on the either side of crown and wall as well. Besides, where the strike of foliation/discontinuity was perpendicular to tunnel axis, rock mass was stable. The envisaged behaviour of rock mass according to 'orientation of discontinuity' parameter found to be exact until complete excavation of Tunnel T 74 R (A). To mitigate the problem of over break at right crown in Tunnel towards Katra side, Fore polling was done to stabilize the crown. Due to Parallel striking foliation orientation towards Katra side (straight reach), 65% of the tunnel gone through using Fore poles. However, in Tunnel towards, Banihal side was in straight as well as in curve reach. Therefore, in straight reach the Strike of foliation discontinuity was parallel to tunnel axis. Due to this there was instability of crown at left side. In culminating reach (approx.300 M) of same, the strike of foliation was sub perpendicular to perpendicular (Very Favorable). In this stretch the rock mass found to be stable and with very less or no over breaks.

Following are the photos and sketches showing the orientation of discontinuity strike (Parallel and perpendicular) in Tunnel T 74 R (A) at different reaches.

B. Towards Katra Side



Parallel striking foliation discontinuity caused unstable crown at Right Side (Katra Side)
Very unfavourable condition

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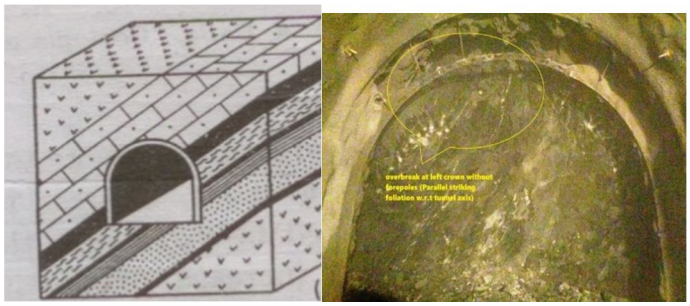
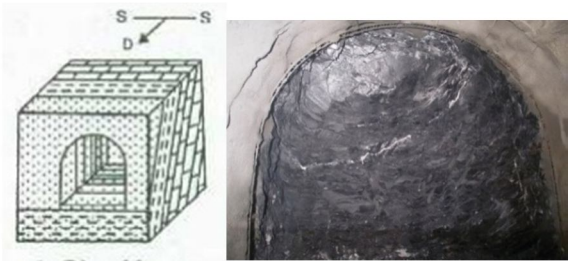
C. Tunnel towards Banihal Side



Parallel striking foliation discontinuity caused unstable crown at Left Side (Banihal Side)



Perpendicular striking foliation discontinuity with stable crown (Banihal Side)
Very favourable condition

III. IMPACT OF GEOLOGICAL OVERBREAK DISCONTINUITY ORIENTATION CONDITION ON TIME AND MONEY.

Discontinuity induced geological Overbreak lead contractor to spray extra shotcrete and consumption of extra time to fill the crown overbreak areas. On an average,3 hours of additional time were consumed per round due to this Geological Overbreak which also affected the Tunnel completion key dates and Project was delayed by 6 Months. Contractual Clauses from client had restriction to pay back the financial losses incurred by Contractor.By proving the effects of Discontinuity orientation on Tunnel approximately 60% of the Geological overbreak claims were settled from Client.

A. Remedial Measures to Mitigate the losses due to Parallel Orientation

1) *Line Drilling and Controlled Blasting:* Tunnels in which there are over breaks, especially from crown needs special attention to prevent extra mucking time and extra shotcrete. Geologist should monitor the overall stability of the tunnel in addition to Geological face mapping and 3-D Geological Logging. Trained drilling Jumbo operators with coordination of Geologist can help to mitigate the Geological Overbreak. Line drilling is closely spaced (less than 200 mm hole to hole spacing) drilling holes in the periphery or Face Profile of the Tunnel. Stretches which are prone to overbreak should be left dummy or uncharged. This is initial practice to control geological overbreak induced by Parallel striking foliation. Average Geological Overbreak recorded was 22% in Tunnel T 74 A. After using the practice of Line drilling and controlled blasting, Overbreak was reduced to 14%.
2) *Fore Polling On The Either Side Of The Crown:* In Parallel striking foliation with respect to Tunnel Axis, either side of the crown becomes unstable and always prone to overbreak. Prior to next excavation of next round The Overbreak area needs filling with Shotcrete which is not possible in one go. Installation of fore poles in Alternate or every round helps to prevent toppling failures from one side of crown and prevents major over breaks. Fore polling of 32 mm diameter,3-4 M long Steel bars or Self Drilling Anchor Bars can be used. Self-Drilling Bars are costly as compared to SN steel bars. Based on in-situ condition of rock mass, selection of fore poles can be done. Use of fore poles found to be most effective and can minimize overbreak up to 5%

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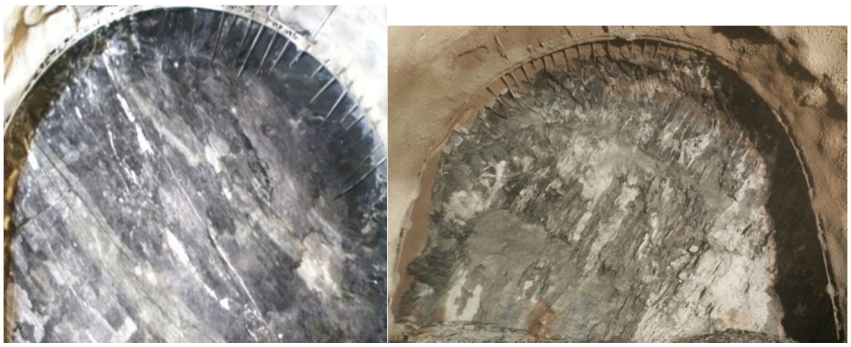

Crown stabilization using fore poles at Right Side (Towards Katra end) & left side (Banihal end)

IV. CONCLUSION

Although, it is necessary to investigate the geological aspects which can bring about risk events. But the detailed study of Joint/Discontinuity and structural features of rock mass like folds and faults and their effects should also be taken into consideration. In T74 R (A), the Geologist have given advance prediction of Rock mass stability based on Orientation of Foliation and found to be almost correct until completion of excavation works.

REFERENCES

[1] IS: 11315 (Part 1) – 1987 Indian Standard METHODS FOR QUANTITATIVE DESCRIPTION OF DISCONTINUITIES IN ROCK MASSES
[2] IS 13365(Part1):1998 Indian Standard QUANTITATIVE CLASSIFICATION SYSTEMS OF ROCK MASS – GUIDELINES
[3] Modifications to RMR for mining Table 4.4: Rock Mass Rating System (After Bieniawski 1989).

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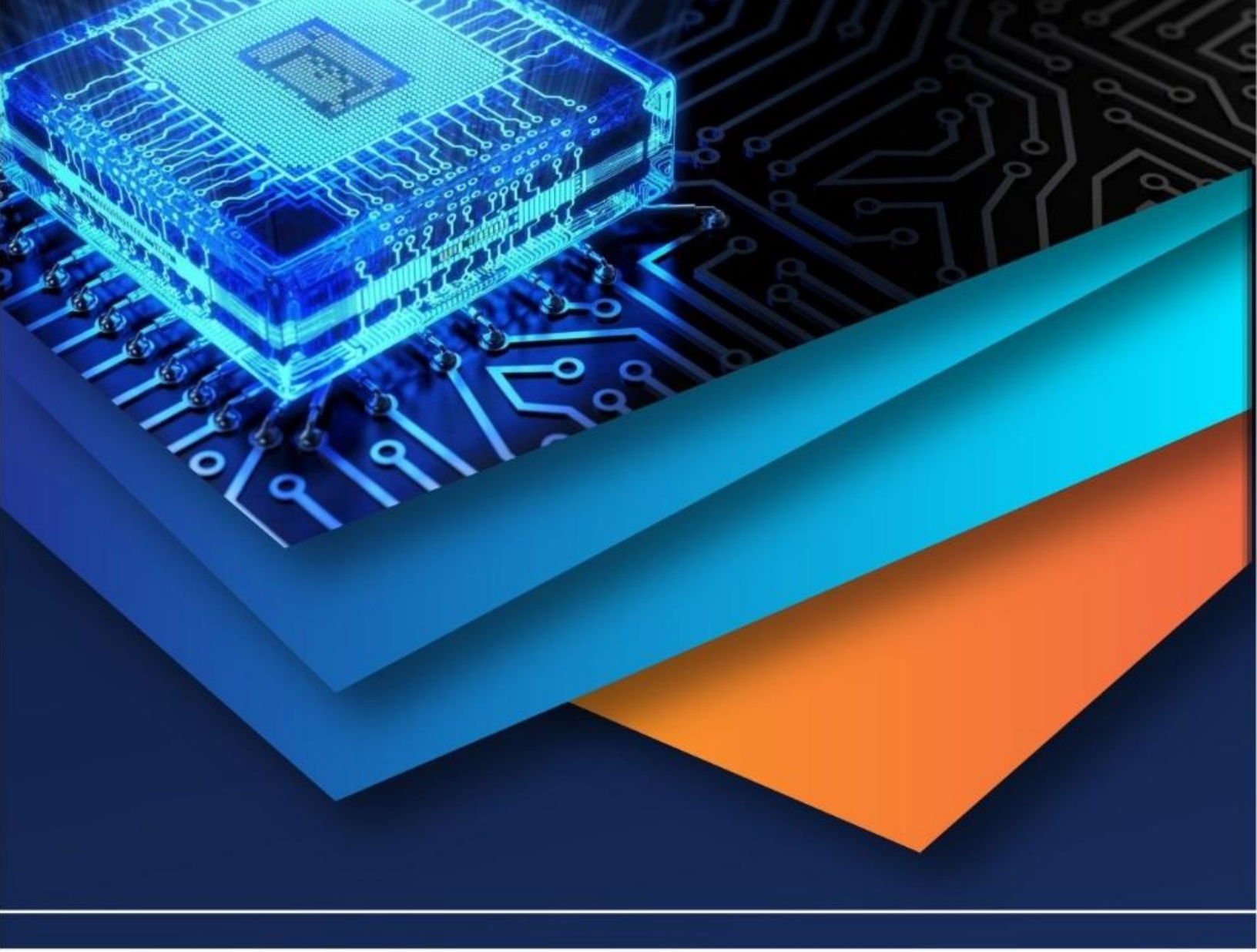

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