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Anchorage Zone Stress Mapping using ANSYS

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Abstract: This paper presents a comprehensive analysis of stress development in the anchorage zone of prestressed post-tensioned concrete beams using the finite element method with ANSYS. Focusing on both concentric and eccentric loading scenarios, the study varies the loaded area ratio (k) to investigate its effect on stress distribution. The obtained results are meticulously compared with existing literature, enhancing understanding of the behaviour of anchorage blocks within prestressed concrete members. Beyond stress assessment, the study evaluates the performance and structural integrity of the anchorage zone, providing valuable insights for design optimization and construction practices.
Keywords: anchorage block, anchorage zone.

I. INTRODUCTION

Many studies have been carried out in pre-stressed concrete beams. Always a special consideration was given to the anchorage zone or end block in Post tensioned beams. The anchorage zone is the zone between the end of the beam and the section where only longitudinal stress exists.

In the post-tensioned concrete beams, a duct is formed inside the beam and prestressing cable is kept inside this duct. Once the concrete gets harden, prestressing cable is stressed and anchored at the end of beam that induces internal stresses in the concrete beam. The stress distribution inside the post-tensioned concrete beam is very complex, especially near the end of beam where prestressing cable is anchored. This zone is called as Anchorage Zone

In the past, few researchers attempted to analyse stress distribution in anchorage zone in post tensioned Concrete beam using different techniques, which include analytical techniques, experimental methods, and numerical methods. [1]

A. Bursting Force

A portion of a pre-stressed member surrounding the anchorage is the end block. Through the length of the end block, pre-stress is transferred from concentrated areas to become linearly distributed fiber stresses at the end of the block. The theoretical length of this block, called the lead length is not more than the height of the beam. But the stress distribution within this block is rather complicated.

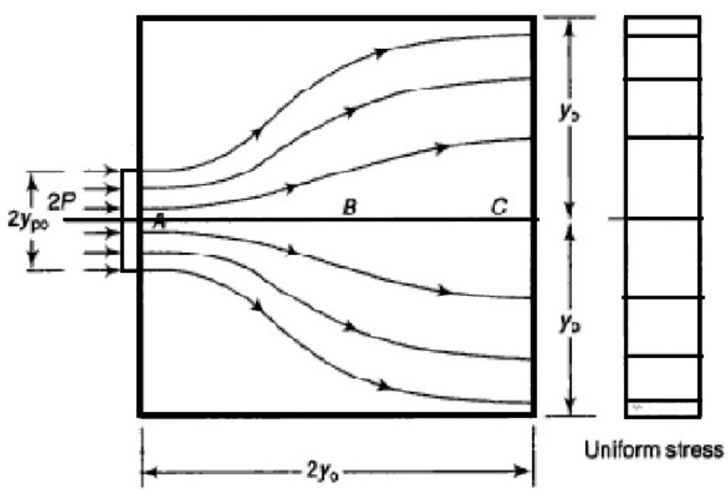

Fig 1. Stress trajectories in end of zone [6]

Figure 1. shows the lines of pressure transfer which spread out from the area bd along the end block. The length of end block is usually taken equal to d. these lines of pressure may be taken to act as individual slender strut.

The larger transverse dimension of the end zone is represented as y_o. The corresponding dimension of the bearing plate is represented as y_{po}. For analysis, the end zone is divided into a local zone and a general zone.
The transverse stresses developed in anchorage zone are tensile in nature over a large length and since concrete is weak in tension as shown in figure 2. So adequate reinforcement should be provided to resist this tension. Hence, from the point of view of designer, it is essential to have good knowledge of the distribution of stresses in the anchorage zone, so that he can provide an adequate amount of steel, properly distributed to sustain the transverse tensile stress [6]
The local zone is the region behind the bearing plate and is subjected to high bearing stress and internal stresses. The behaviour of the local zone is influenced by the anchorage device and the additional confining spiral reinforcement.
The general zone is the end zone region which is subjected to spalling of concrete. The zone is strengthened by end zone reinforcement. The transverse stress (σt) at the CGC varies along the length of the end zone. It is compressive for a distance 0.1yo from the end and tensile thereafter, which drops down to zero at a distance yo from the end.

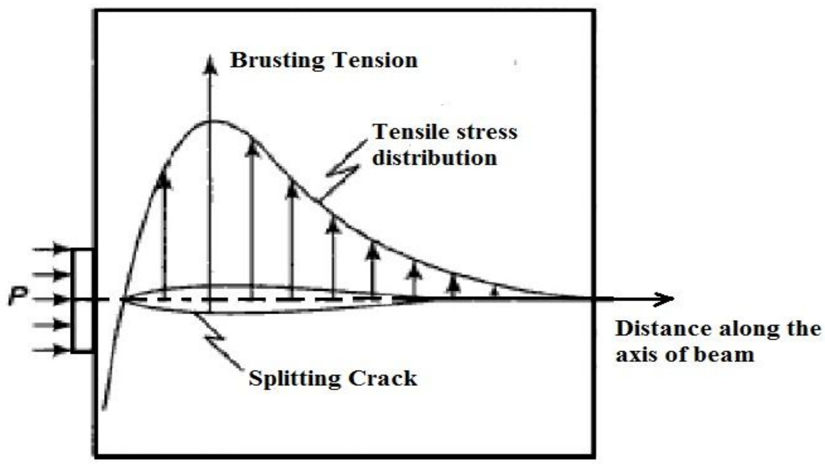

Fig 2. Transverse tensile stress distributions [6]

The effect of transverse tensile stress is to develop a zone of bursting tension in a direction in a direction perpendicular to anchorage force, resulting in horizontal cracking as shown in fig 2. The transverse tensile stress is known as splitting tensile stress. The resultant of the tensile stress in a transverse direction is known as the bursting force (F_{bst}). [6],[9]
F_{bst} for an individual square end zone loaded by a symmetrically placed square bearing plate according I S Code 1343 (Clause 18.6.2.2) is calculated by given equation. [6],[9]

$$\text{Fbst} = \text{Pk}\left[0.32 - 0.3\frac{yp0}{yo}\right]$$

Where, Pk = pre-stress in the tendon;
ypo = length of a side of bearing plate;
y0 = transverse dimension of the end zone.
It can be observed that with the increase in size of the bearing plate the bursting force F_{bst} reduces.

II. ANALYTICAL STUDY SOLUTION

The most critical portion of the post-tensioned concrete members is the anchorage zone. Since the tensioned concrete is weaker than the untensioned concrete, there is a very high risk of bursting in this region. Hence, understanding the behavior of the anchorage zone and the amount of force generated to prevent bursting in this section becomes extremely crucial.[5]
Following is problem statement selected as shown in figure 3. for the analysis and solved by By using ROW'S Method
Cross section of end block 200mmX300mm
Concentric Anchoring force 200KN
P_k =200KN
Anchorage Diameter =100mm

Equivalent side of square $2y_{po} = \sqrt{\frac{\pi}{4} X 100^2}$

$2y_{po}$ =88.62mm
Side of surrounding Prism $2y_o$ =150mm
$= \frac{2yp\,o}{2yo} = 0.59$

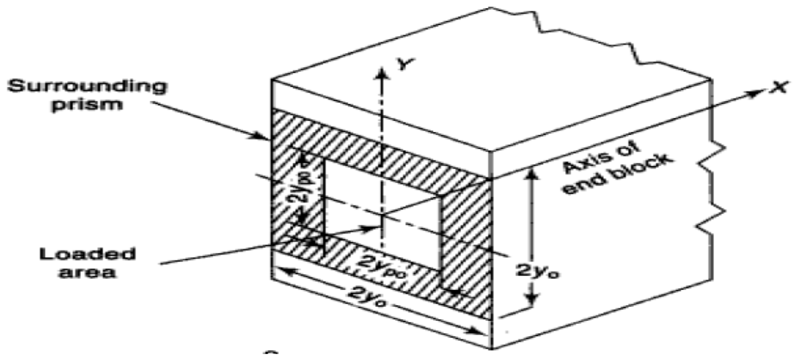

Fig 3. End block [6]

Average compressive stress $f_c = \left(\frac{200\,X10^3}{150X150}\right)$ =8.9 N/mm^2
Tensile stress $f_{v(max)}$=8.9[0.98-0.825(0.59)]
=4.45 N/mm^2
Transverse tension f_{bst} $= 200\,X10^3\,[0.48 - 0.4(0.59)]$
=50000N =50KN

III.PARAMETRIC STUDY USING ANSYS

In this study ANSYS software is used for analysis. And a discrete model is modelled of size used in analytical solution with given force. Following are the material properties given as input to software and further analysis is carried out.
Material properties for concrete
Density -2400kg/m^3
Grade of concrete M35
Young's modulus =33721.65 MPa
Poisson's ratio =0.18
Compressive strength of concrete =32.4 MPa

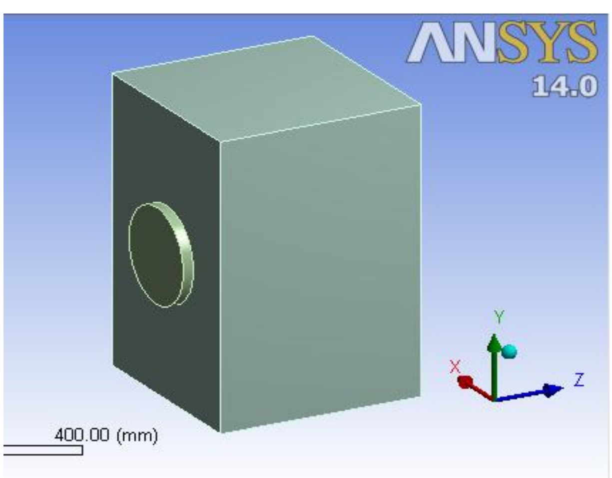

Fig. 4 Geometry of end block

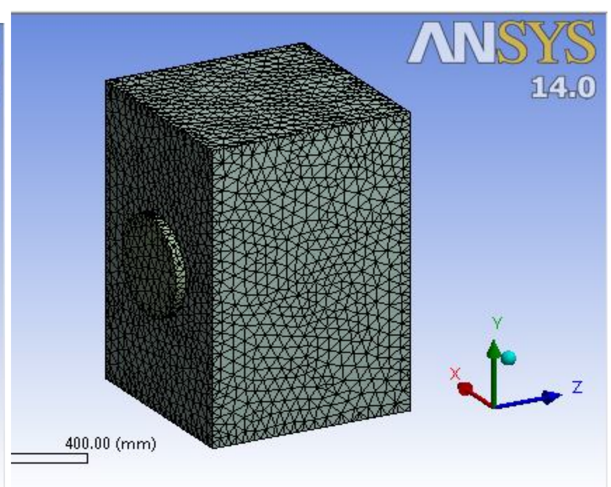

Fig 5. Tetrahedral 4 noded element meshing.

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This block is discretized using 26021 tetrahedral elements with 41437 nodes for performing finite element analysis. [8] To get accurate results, the mesh is kept advance fine with relevance center as shown in figure 4 and 5 And the prestressing force of 200KN magnitude is applied on circular plate as shown in figure 6. the direction of prestressing force is along the Z direction that is perpendicular to X and Y direction. Simultaneously the back face of end block is either fixed or the displacement along the Z direction is restricted because of that through the plate the compressive stress is distributed over the block.

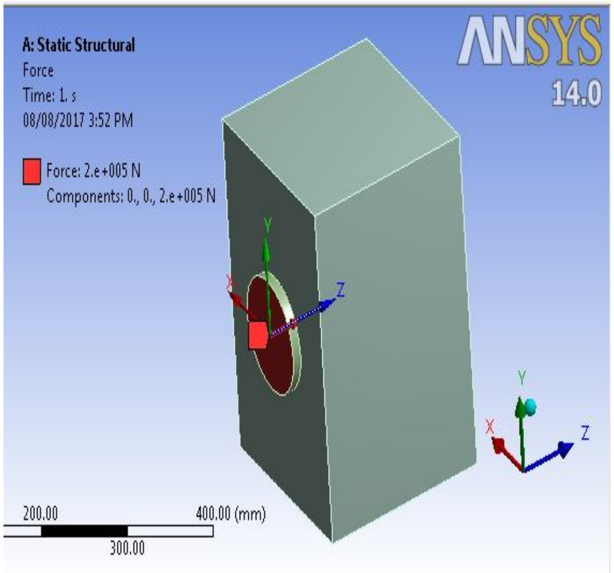

Figure 6 shows direction of applied load with magnitude

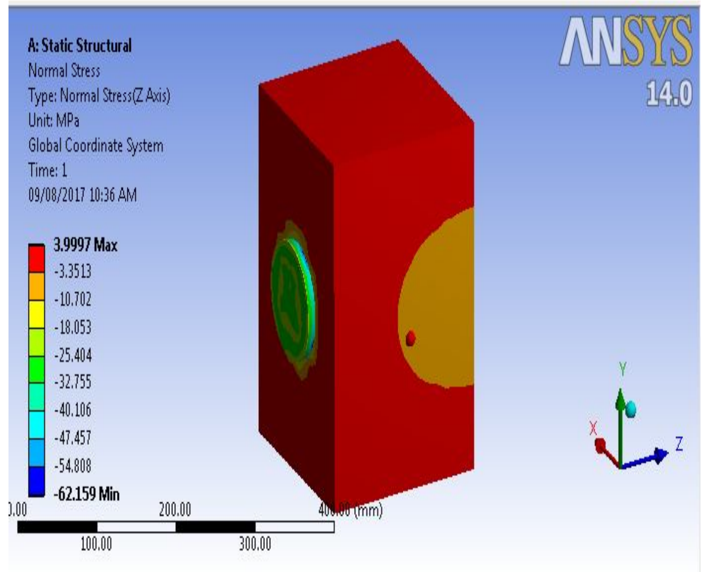

Figure 7 shows the transverse tensile stress variation in anchorage zone subjected to concentric loading i.e. e =0.0.

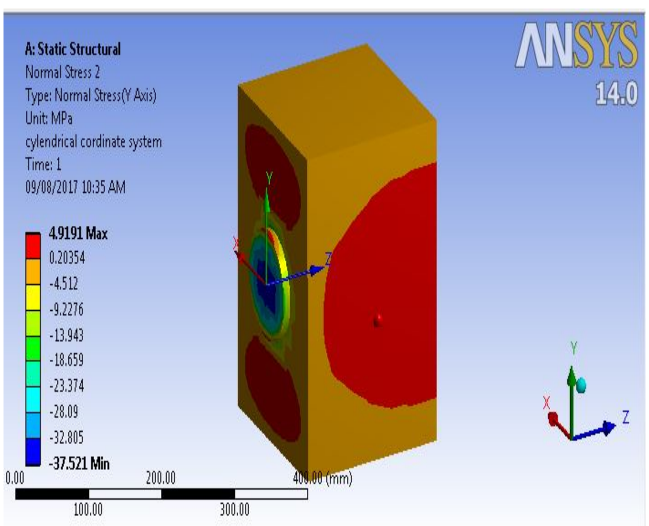

Fig 8. The vertically cut portion of anchorage zone showing development of transverse tensile along the axis of loading

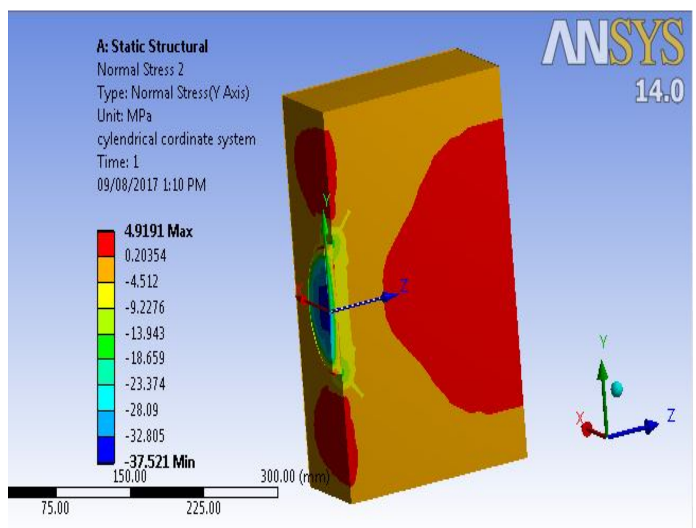

Fig 9. Vertical cut section of Transverse stress variation in anchorage zone

As shown in figure 8 and 9 above Normal stress distribution and transverse stress distribution is obtained for eccentricity 0.0 and for distribution ratio (K) is 0.60. Similarly, the stress distribution for different value of K is obtained using ANSYS and same procedure is repeated for eccentricity 0.1 the obtained result is compared.

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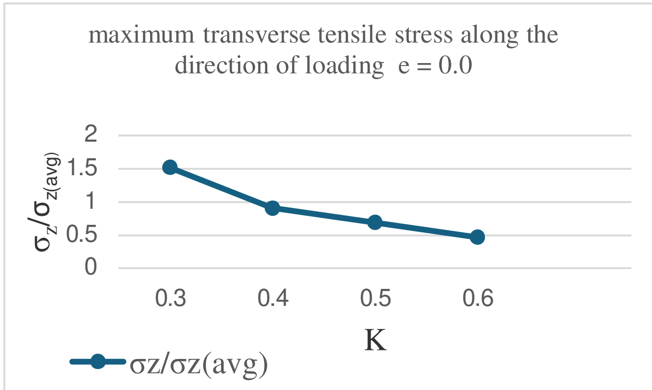
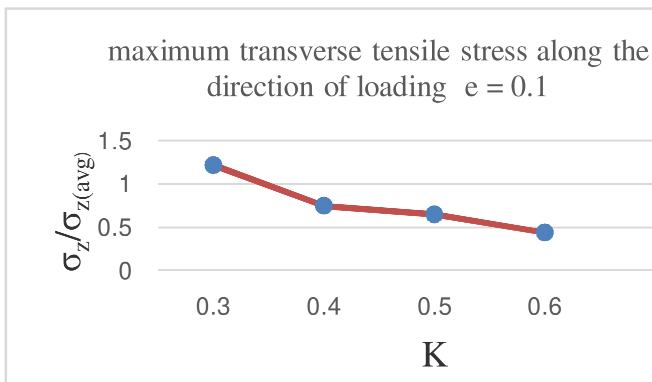
IV. RESULT

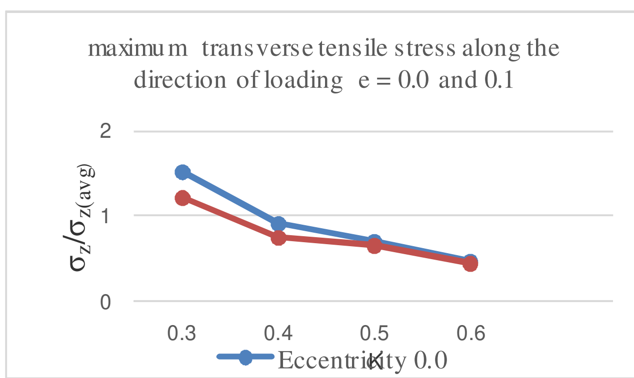
Following are the result obtained for different values of k and varying the value of eccentricity. Also the effect of stress are studied in the direction of loading. Below given graph 1 shows the Maximum transverse tensile stress along the direction of loading at eccentricity 0.0 and graph 2 shows the Maximum transverse tensile stress along the direction of loading at eccentricity 0.1. and together graph 3 shows the variation of result due to eccentricity 0 and 0.1 with varying value of k



Graph 1 Maximum transverse tensile stress along the direction of loading at e = 0.0



Graph 2. Maximum transverse tensile stress along the direction of loading at e = 0.1.



Graph 3 Comparison of Maximum transverse tensile stress along the direction of loading at e = 0.0. and e=0.1.

Graph 3 illustrates a comparison of the maximum transverse tensile stress along the loaded face. The data indicates a consistent trend: under concentric loading, regardless of the specific value of k, the maximum transverse tensile stress is consistently higher compared to the corresponding values observed under eccentric loading conditions. Additionally, as the value of k increases, the discrepancy in stress magnitude between scenarios with e = 0.0 and e = 0.1 diminishes. This suggests that higher values of k lead to a more gradual reduction in stress difference between eccentric and concentric loading configurations.

V. CONCLUSIONS

This study presents a comprehensive three-dimensional finite element analysis of the anchorage zone in post-tensioned prestressed concrete, utilizing the commercial software ANSYS. The analysis included investigations under both concentric and eccentric loading conditions, examining a range of values for the parameter k. Stress variations were meticulously studied and are comprehensively presented across different combinations of k and e.

It was observed that.

1) Magnitude of maximum transverse tensile stresses measured along the axis of loading or along the loaded face reduces with the introduction of eccentricity in prestressing forces.
2) Difference in magnitude of maximum transverse tensile stress at e = 0.0 & e = 0.1 reduces with the increase in value of *k*.

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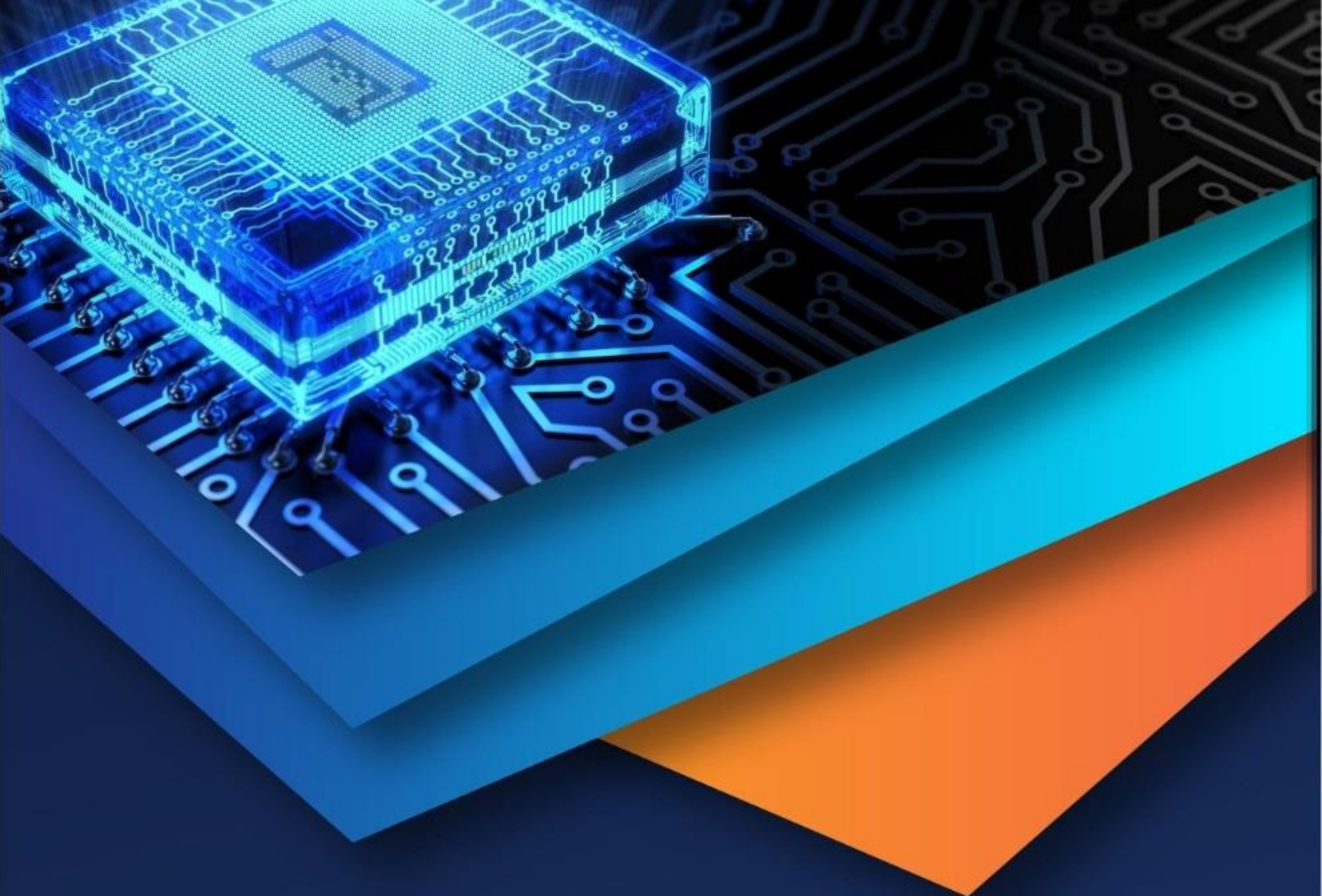

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