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Finite Element Analysis of Bond Behaviour Between Concrete and Steel Reinforcing Bar by Pull Out

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***Abstract*: Bond strength is very important in reinforced concrete and it is necessary to create suitable bond between steel and surrounding concrete. Bond strength is the means by which load is transferred between steel and concrete. Sufficient bond strength thus ensures that there is little or no slip between the steel and concrete and helps in safe transfer of stress between them. As the first phase of the project various factors are analyses using the pull out test specimens with the help of the finite element software ANSYS These results are checked on a beam column joint using the software as a second phase of the project. This helps to compare the results obtained from a test specimen to a structural application.**
***Keywords*: Bond strength, Pull out, Beam column joint, Fiber reinforced concrete, Finite element analysis ,**

I. INTRODUCTION

Bond strength is most commonly used in reinforced concrete. The bond between steel and concrete is essential for the existence of reinforced concrete structures, as both materials act together to absorb structural strain. The bond phenomenon is considered to be complex regarding many factors that affect it. Several types of bond tests have been proposed over years. Factors that influence the bond are bar geometry, bar surface conditions, concrete confinement, mechanical interlocking provided between steel and concrete, concrete properties etc. The steel-concrete bond is one of the most important mechanisms in reinforced concrete structures, since both materials must act jointly to absorb internal forces. This bond is responsible for anchoring the reinforcement in the concrete and also serves to prevent slippage of the bar segments between cracks, thus limiting the opening of the cracks.

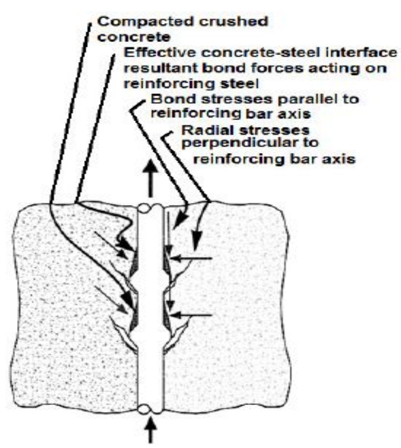

Fig1:Force components parallel and perpendicular to the steel concrete interface

Pull out test is to determine the of the pullout strength of concrete. Pull Out test is measuring the force required to pull an embedded metal insert and the attached concrete fragment from a concrete test specimen or structure. The insert is either cast into fresh concrete or installed in hardened concrete. This test is based on the principle that the force required to pull out a cone of steel embedded in concrete is proportional to the strength of concrete.

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)

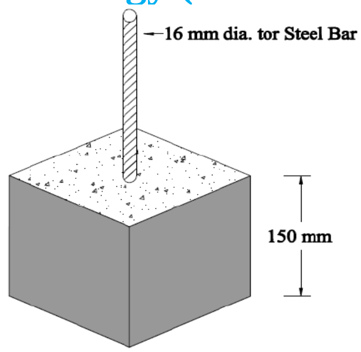

Fig 2: Pull out specimen

II. LITERATURE REVIEW

Various literatures reviewed on bond strength and pull out tests are carried out below.

A. Zhimin Wu et.al(2013).

This paper presents an experimental investigation into the bond behaviour of plain round bars embedded in concrete subjected to biaxial orthogonal lateral tensile-compressive stresses. A total of 174 pull-out specimens with different strengths of concrete, bar diameters, and combinations of lateral stresses were tested. For a given lateral tensile stress, the bond strength increases, but the slip at the peak bond stress decreases with an increase in lateral compressive stress. Ultimate bond strength and residual bond strength are influenced by the strength of concrete and lateral stresses.

B. Facundo et.al(2015).

This research study on a series of experimental pull-out tests consisting of different types of steel fibers with different inclinations extracted from various types of matrix is presented. From this study Fiber inclination affects fibers pull-out strength. smooth straight fibers, hooked fibers also resist the pullout action by adherence and friction hook provides a local effect at the fiber ends that increases the pull-out strength

C. De Nardin, S et.al(2005)

Paper represents experimental were developed using 10 mm reinforcing bars and concrete compressive strength of 30 MPa in pull-out test. In numerical study, the concrete and reinforcing bars are represented by non-linear materials behaviour, combined with a model of the interaction between reinforcing bars and concrete. Finite Elements Method was used by the softwares Abaqus and Ansys to represent bond-slip relationship. software Abaqus has a better representation of the ultimate load.

D. R.M. Lawson et.al(2013

In this paper aim to investigate a non-linear elasto-plastic finite element model of a composite beam with web openings was used to investigate this mode of pull-out failure A simple model is proposed for the combined effect of longitudinal shear and compression or tension acting on the shear connectors used in composite floor slabs. Maximum shear force may be transferred to the floor slab when limited by pull-out of the shear connectors.

E. Xue Zhang et.al(2015)

This paper investigated that the ultimate bond strength and the slip at the peak bond stress are greatly influenced by equi-biaxial lateral tension. Increase of equi biaxial lateral tension, the ultimate bond strength first decreases and then keeps almost constant. Slip at the peak bond stress first increases and then decreases.

F. E.Garcia et.al(2015)

Paper studied that the behaviour of steel fiber reinforced concrete. Bond of rebars to concrete, fibers provide passive confinement and improve bond capacity in terms of bond strength. SFRC specimens with embedded rebars are used to conducting the Pull out Test. And obtain the bond stress–slip curves, retaining the bond strength and the area under the curve as measures of the bond capacity of concrete. Increasing the concrete cover has been shown to improve the ductility of bond failure.

G. Xing-wen Liang et.al(2016)

Volume 5 Issue V, May 2017
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This paper aims to investigate the seismic performance of FRC beam-column joints experimentally and numerically. A total of eight beam-column joints, including both FRC beam-column joints and RC beam-column joints, using of FRC can effectively restrain the crack widening and eliminate the damages caused by the spalling of concrete cover.

H. Wang Lei et.al(2016)

Paper based on an acoustic emission test system, pull-out tests were conducted to study the bond behavior between corroded steel bars and concrete with different corrosion degrees. The results showed that the AE location was consistent with the actual crack development the stress distribution tends to be uniform along the steel bar with increasing degree of corrosion, and the peak value gradually shifted toward the free end.

III. ANALYTICAL STUDY

A. Methodology

In a concrete specimen, the geometry selected from the various literature reviews. . The study can be divided to 4 sections in the pull out test and also check in column beam joint as an application of this study.

Section 1

1) In Pull out test, used ordinary concrete

2) Different loads are applying and also checking the confinement effect checks in pull out test.

Application of pull out specimen – column beam joint

Section 2

In the column beam joint, Various axial loads are applying the top of the column and pull out test is considered.

B. Material properties

1) Concrete-M30concrete,Elastic Modulus=5000√fc, Poisson ratio=0.2

2) Steel- Elastic Modulus=20000MPa,Fe 415, poisson ratio=.3

C. Elements used

The suitable elements are selected from the ansys library. The concrete is modelled using SOLID65, eight-node brick element, which is capable of simulating the cracking in tension and crushing in compression behavior. Also simulates the elastic and plastic deformations that would happen in concrete and steel reinforcement inclusive of cracking until ultimately concrete crushing as the load is stepwise increased. It is a dedicated three-dimensional eight node element with three degrees of freedom at each node.Reinforcement is modeled using SOLID45 element. Which is includes a 8-node 3D element In Column beam joint, the concrete is modelled by SOLID 65 and the reinforcing bar is modelled by Link 8. . Two nodes are required for this element. Each node has three degrees of freedom, translations in the nodal x, y, and z directions. The element is also capable of plastic deformation.

D. Geometry

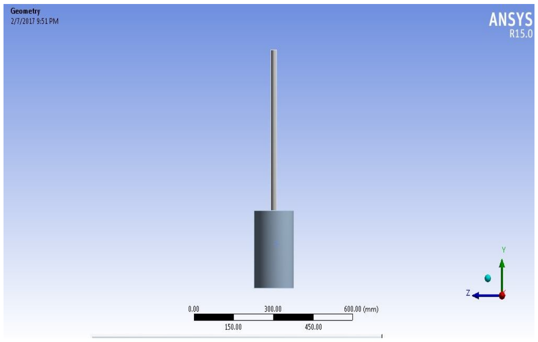

Fig. 3: Pull out specimen

E. Boundary and load conditions

By the analysis, Boundary conditions are provided. Giving displacement in X & Z directions are zero. And 6mm in Y direction.

Volume 5 Issue V, May 2017
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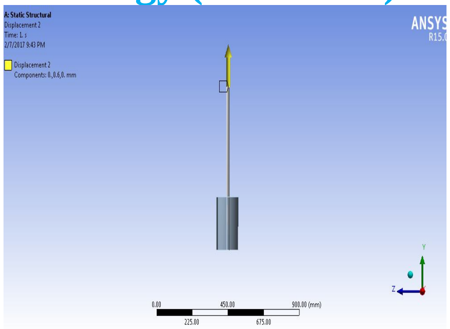

Fig. 4: Boundary conditions in pull out specimen

F. Meshing

A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model.Mesh size of 5 mm is provided to obtain accurate results.

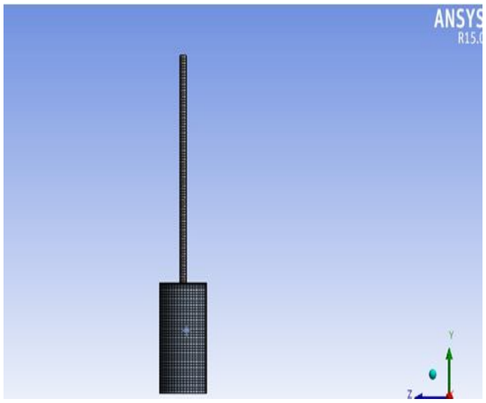

Fig 5: Mesh of pull outspecimen

G. Results and discussions

First section, Ordinary concrete specimen:

The fig 6 shows the stress developed in the ordinary concrete specimen after the analyzing,

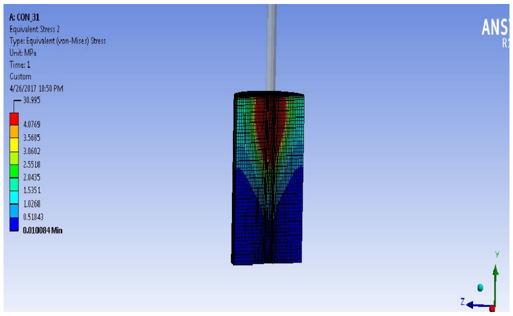

Fig 6: Stress at concrete specimen in the case of ordinary pull out test

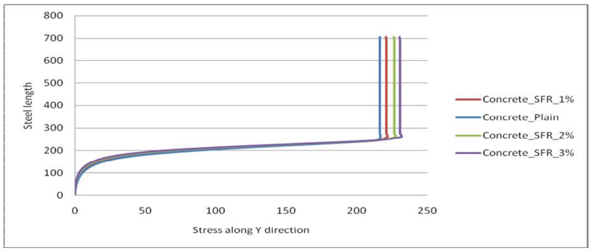

Fig.7: Steel Length Vs Steel Stress

Volume 5 Issue V, May 2017
ISSN: 2321-9653

The difference in the stress between steel and surrounding concrete at the upper part of specimens is found significantly large and also have possibility of slip. Concrete with higher compressive strength develops more stress to generate crack in it.
In the case of applying loads on pull out specimen, the loads are 300KN, 400KN, 500KN, 600KN.

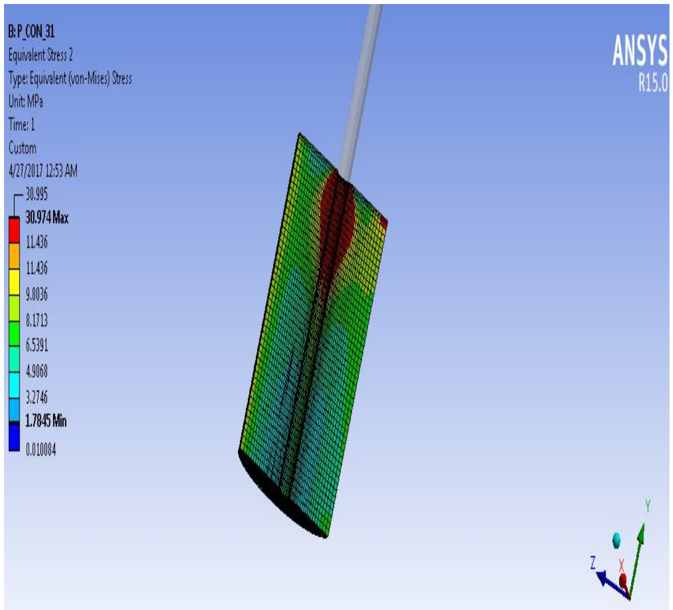

Fig.8 Applying load as 600KN in pull out specimen

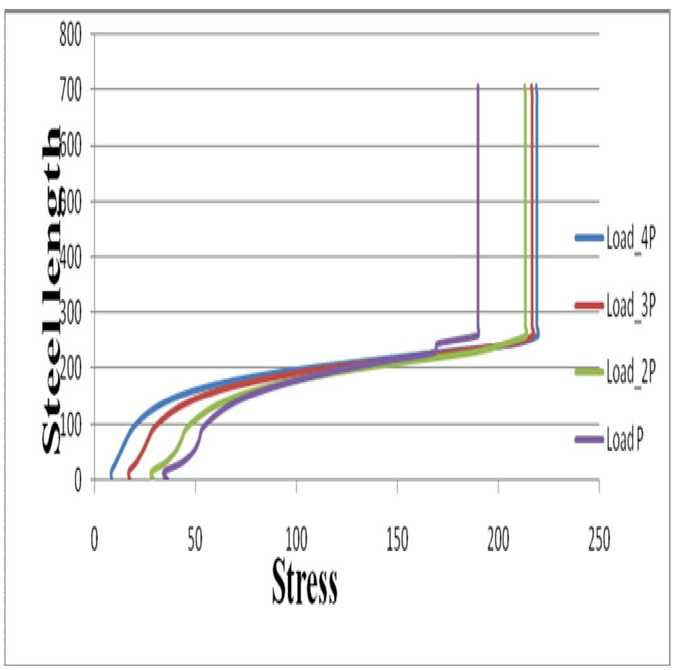

Fig.9: Stress in steel 300KN, 400KN, 500KN, 600KN

In this section results shows that the stress is increasing with increasing when applying the axial loads. The axial confinement effect is increased with increasing the bond strength.

H. Application

This part of the thesis is to study the effect of axial confinement. Also study this effect in pull out specimen. So the application of this test conducted in column beam joint. With different loads are applying, the loads are 300KN, 600KN, 900KN, 1200KN.

Volume 5 Issue V, May 2017
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I. Geometry and Modelling

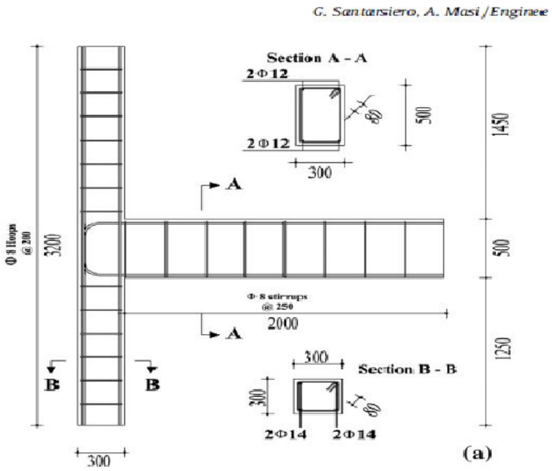

Fig.10 Geometry of column beam joint in the journal

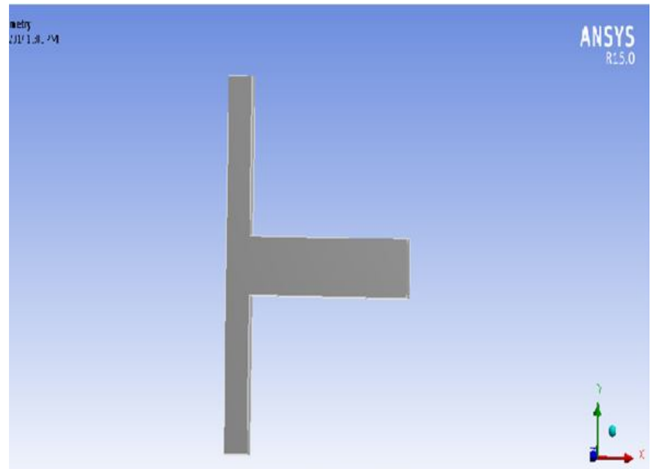

Fig.11 Geometry of column beam joint from the ANSYS

J. Mesh

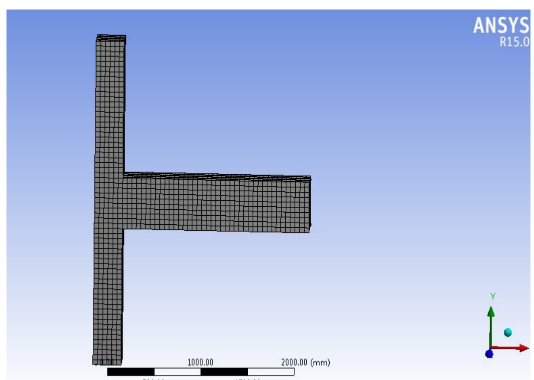

Fig. 12 Meshed Model

K. Observations and Results

When axial loads are applied, we can see that the total deformation of the joint increased. And also the equivalent stress increasing with increasing axial loads. Applying 1200 KN, the stress is maximum, as shown in fig.13

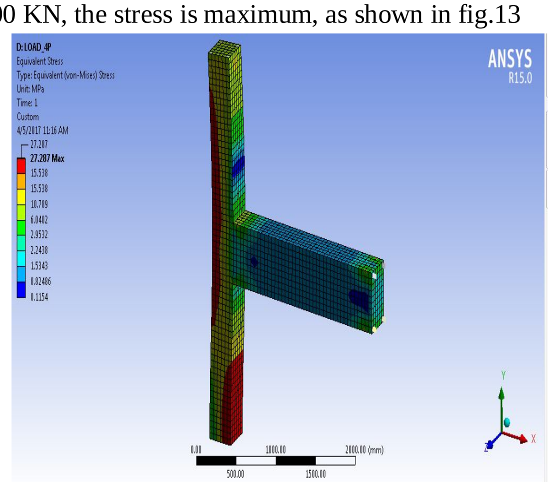

Fig. 13 Equivalent stress in beam column joint at 1200KN

Volume 5 Issue V, May 2017
ISSN: 2321-9653

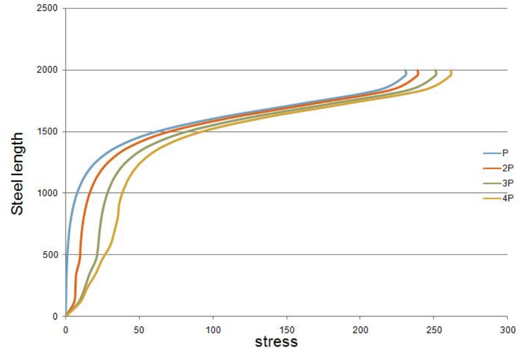

Fig.14 Tensile stress (Y direction) distribution along the length of steel

From the graph, The stress is maximum in the applying load case 1200KN, Minimum at 300KN. Up to 1500mm steel length the stress varying slowly, Then the 1500mm to 2000 mm the steel stress increasing gradually.

L. Slip in the column beam joint

Slip is defined as the relative displacement of rebar with reference to the surrounding concrete. The relative displacement of the bar is always measured with reference to the undisturbed concrete and consists of relative slip at the interface and shear deformations in concrete.

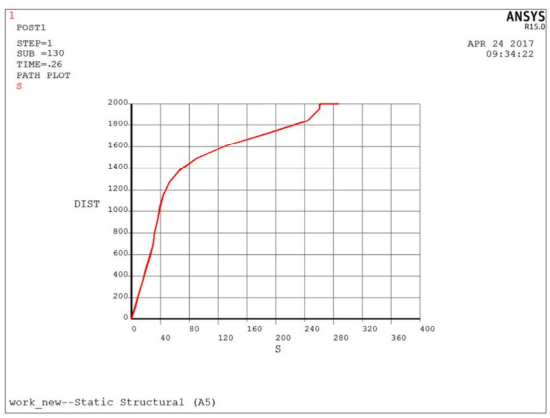

Fig.15 Slip at 1200KN loading condition

IV. CONCLUSIONS

Pull out test indicated that the bond strength and the initial stiffness increased as the amount of concrete surrounding the reinforcing bar increased. Bond strength of FRP rods with surface configuration is increases by increasing confining pressure. Bond stress decreases with increase in crack width and the bond strength is decreases with increasing bar diameter. In deformed bars, it was shown that the bond strength increases by increasing lateral pressure. The stress is increasing with increasing when applying the axial loads. The axial confinement effect is increased with increasing the bond strength The slip continued to increase when the bond stress reached a constant value in the post-peak region of the bond stress-slip curve.

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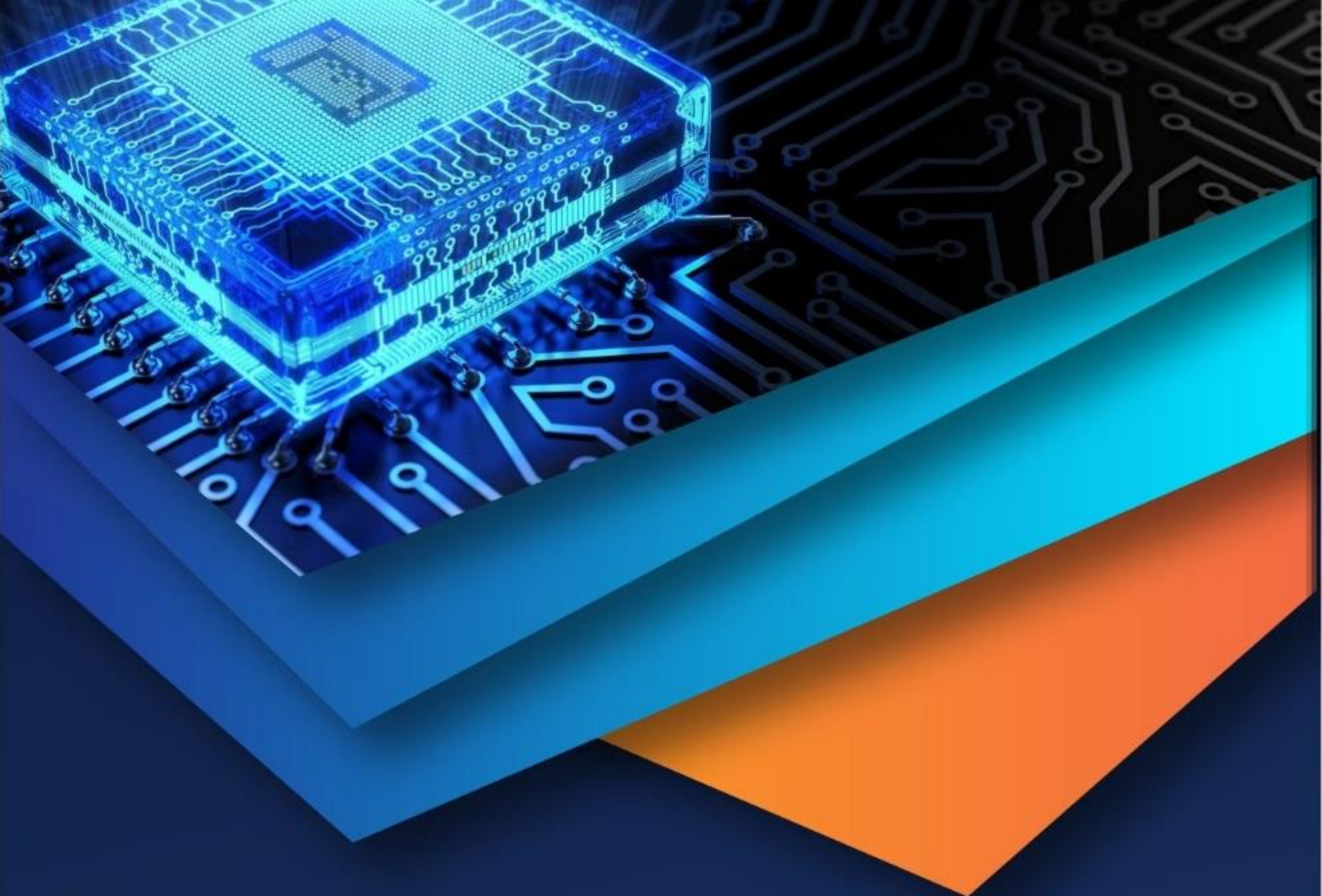

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