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Shear Strengthening of R.C. Beams by using GFRP

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Abstract: Shear is actually a very complex problem and is not completely solved for simple reinforcement concrete beams. The current codes (American Concrete Institute (ACI), ISIS Canada and I.S.456:2000) qualify the nominal shear strength by means of a simple sum of the contributions of the concrete (Vuc) and the steel (Vus). For RC beams with externally bonded fiber reinforced fiber polymer (FRP) sheets, the Contribution of the sheets (Vuf) is added.
Shear failure is catastrophic and occurs usually without warning; thus it is desirable the beam fails in flexure rather than in shear. Many RC members are found to be deficient in shear strength and needs to be repair. Externally bonded reinforcement such as FRP provides excellent solution in this case.
The aim of the work were to check shear capacity of RC beams with different FRP orientation, to check authenticity of available analytical method to calculate shear strength of strengthened beams and to evaluate percentage increase in load carrying capacity of shear strengthened beam. The result of this research pointed out a general improvement in terms of shear capacity for the strengthened beams.
Keywords: GFRP Sheet, Shear Failure, Control Beam, Shear strengthening, Flexural strength of beam.

I. INTRODUCTION

The shear failure was the expected dominant mode of failure. The attention of this work is on the study of shear strength of the RC beams. The failure of the RC beams in shear was expected to study the shear behavior of the beams. Hence it is proposed to keep the flexural strength of the beams more than its shear strength. The shear strength is expressed in terms of the total load carrying capacity of the beams under the two point loading. Side-bonded wrapping configuration of GFRP is considered as a bi-axial directions. The shear contribution of GFRP is calculated by the equations and the comparison of the results is done from it.The design equation presented does not address the use of bi-axial FRP reinforcement, where the fibers are oriented in two perpendicular directions. Using the truss analogy, it can be shown that the beam and column elements subject to a shear force will experience axial tensile forces, additional to those due to bending. However, in reality the displacement has a horizontal component as well resulting from rigid body rotation about the shear crack tip. If only vertical piles of FRP are used ($\beta = 90°$) there is nothing to resist this horizontal strain component. (In the case of steel stirrups, this component is resisted by dowel action of the stirrup.) Therefore use of additional horizontal fibers ($\beta = 0°$) to resist this movement and further limit shear crack opening. The horizontal ply also acts to arrest the vertical crack that starts at the bottom of the section (for positive bending) below the longitudinal steel. Due to this crack control mechanism, the horizontal ply should always be located as close as possible to the bottom of the section for positive bending and as close as possible to the top of the section for negative bending as possible.

II. LITERATUREREVIEW

KhalifaA„ Gold J.W. and Ash A presented a paper on, "Contribution of Externally Bonded FRP in Shear Capacity of RC Flexural Members", Journal of Composites for Construction, November 1998. The paper reviewed researches on shear strengthening with FRP and proposed design algorithms to compute the shear contribution of FRP to shear capacity of RC flexural members. Two methods were proposed. One was based on stress level that causes tensile fracture of the FRP sheet. The stress may be less than the ultimate stress due to stress concentration and can be calculated on the basis of the effective strain in FRP. The other method was based on the delaminating of the FRP sheet from the concrete surface due to the effect of the effective bond length of the FRP.

N.F. Grace, G. A. Saved, A.K. Soliman and K.R. Sale presented a paper on, "Strengthening RC beams using FRP Laminates", ACI Structural Journal September/October 1999. The behavior of RC beams strengthened with various types of FRP laminates is presented in this paper. The experimental program included strengthening and testing of simply supported beam of rectangular cross section. Each beam was axially loaded above its cracking load. The cracked beams were strengthened with FRP laminates and then tested until complete failure. The effects of strengthening on deflection, failure load, failure mode, and strain and beam ductility are discussed. It is concluded that, in addition to the longitudinal layers, the layer oriented in vertical direction forming a U-shape around the beam significantly reduce the deflections and increase the load carrying capacity. Furthermore, the presence of vertical FRP sheets along the entire span eliminates the rupture in flexural (horizontal) strengthening fibers. The combination of vertical and horizontal sheets, can lead a doubling of ultimate load carrying capacity of the beam.

Ahmed Khalifa, Abdeldjelil Belarbi and Antonio Nanni presented a paper on, "Shear performance of RC members strengthened with externally bonded FRP wraps ", in the get going of 12thWorld conference on Earthquake Engineering, January- February 2000. This study presents the shear performance and the modes of failure of RC beams strengthened with externally bonded CFRP wraps, The variable! investigated in this research Included steel stirrups (I. a, beer as with end without stirrups), shear span to depth ratio (1,0. a/d ratio 3 versus 4), CFRP amount end distribution (i.e. continuous wrap versus strips), bonded surface (I.e. lateral sides versus U-wrap), fiber orientation (i.e.90°/0° fiber combination versus 90° direction), and end anchor (i.e. end anchor with and without end anchor).The experimental results indicated that the contribution of externally bonded FRP to the shear capacity is significant and dependent upon variables investigated.

III. METHODOLOGY

This work contains check shear capacity of RC beams with diagonally wrapped GFRP orientations, to check authenticity of available analytical methods to calculate shear strength of strengthened beams and to evaluate percentage increase in load carrying capacity of shear strengthened beams with diagonally wrapped GFRP sheets. This work presents results of 09 beams – with and without strengthened using diagonally wrapped GFRP sheets bonded to both sides of the beams. The results of this research pointed out a general improvement in terms of shear capacity for the strengthened beams with this pattern

A. Design of the Beam

We designed RC beam is as per IS 456:2000. The actual length of the beam under loading is 600mm. The breadth and the depth is 150 mm each.

We tested RC beam in flexure under two point loading. The point loads are applied at middle third points.

B. Testing of the Beams

All the beams were tested under simply supported condition. The testing was done under two point loading using the Universal Testing Machine of 60 ton capacity. Each beam was instrumented with dial gauge to observe the mid-point deflection. The deflections were recorded for each incremental load of 10 kN. All the beams were tested up to the failure of beam in a single load cycle. The crack pattern was observed during the testing. The beam testing set up is shown in Fig. 1.

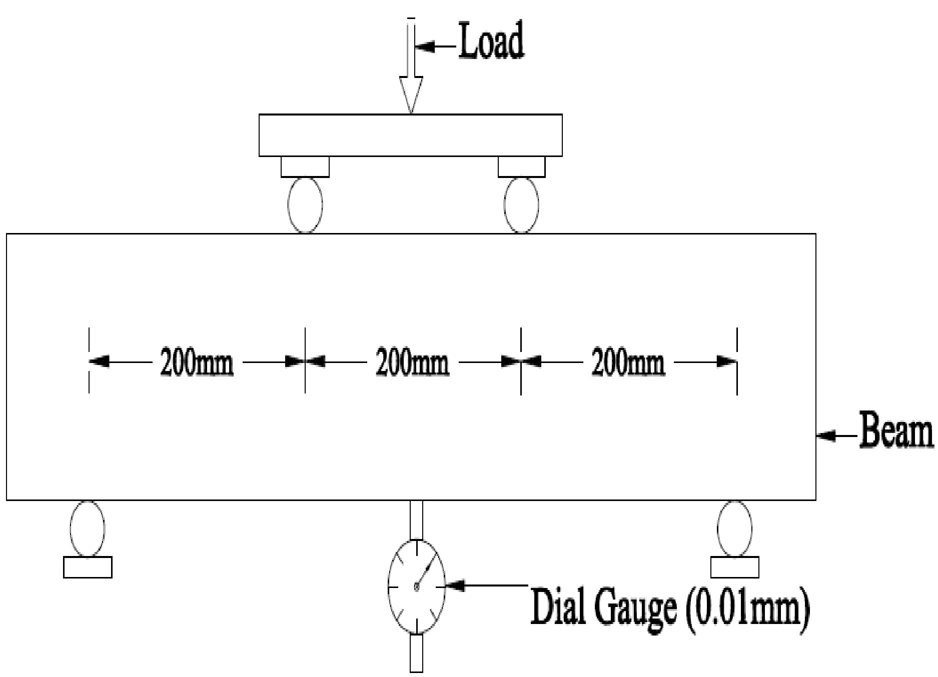


Fig. 1 Experimental Set-Up

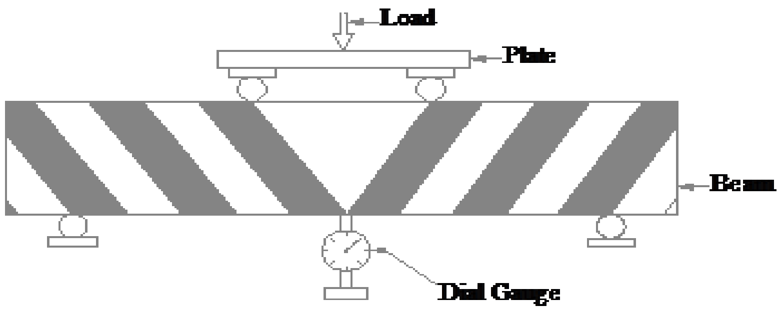


Fig. 2 Beam without shear reinforcement with FRP-50 mm Strip

IV. RESULT ANDDISCUSSION

For the control beams, first shear crack was seen in the shear zone of the beam at a load of about 38 kN. The crack inclination was about 45 degree to the axis of beam. The crack was started at neutral axis of the beam and proceeds in compression zone with further increase in load. As the load increases, the inclination of the crack slightly reduced and additional shear cracks were developed. The beam finally failed in shear at the ultimate load of 45-55 kN.

It is clear from graph that, the mid span deflection increases gradually with increase in load up to the development of first shear crack. Afterword's, deflection increases at slightly higher rate.

A. Beam Strengthened with Side Bonded GFRP in Biaxial Strip

In case of the beams strengthened with side bonded GFRP in vertical strips, the diagonal shear stretch of GFRP sheet was observed in shear zone. With further increase in load, the shear stretch propagated in the compression side with reduced inclination.The

Table I Comparison of Analytical and Experimental results

Beam type	Analytical		Experimental	
	Load (kN)	% Increase	Load (kN)	% Increase
Control beam	30.19	-	107.67	-
GFRP: Bi-axial	56.49	76.98	206.80	91.23

V. CONCLUSION

The following conclusions are drawn on the basis of the analytical and experimental work carried out.

A. GFRP significantly increases the ultimate shear strength of R.C. beam.
B. Ultimate of shear strength increase by, FRP in 50mm biaxial strips without shear reinforcement 76.98% as compared with control beam.
C. The results shows that, the ultimate load carrying capacity of R.C. beams can be nearly doubled by using a proper biaxial
D. GFRP sheets coupled with the proper epoxy.
E. The increase in amount of GFRP may result in a proportional increase in shear strength. Because, shear strength is significantly depends on the interfacial bond between GFRP and concrete.
F. GFRP strengthened RC beams exhibited greater mid-span deflections prior to the initial cracking of concrete as compared to the control beams.
G. Experimental values of ultimate load of GFRP wrapping are more than theoretical values.
H. The use of biaxial GFRP sheets in strengthening the R.C. beams reduces the deflection and increases the load carryin capacity. Cracks do occur are smaller and more evenly distributed.

VI.APPENDIX

Beams strengthened with Side-bonded GFRP for Control Beams Table II

Load (kN)	0	10	20	30	40	50	60	70	80	90	100	105.5
Deflection (mm)	0.0	1.2	2.4	3.2	4.0	4.6	5.2	6.0	6.8	8.0	9.8	13.0

Table III

Load (kN)	0	10	20	30	40	50	60	70	80	90	100	107.5
Deflection (mm)	0.0	1.3	2.3	3.0	3.9	4.7	5.4	6.3	7.1	8.2	10.1	13.4

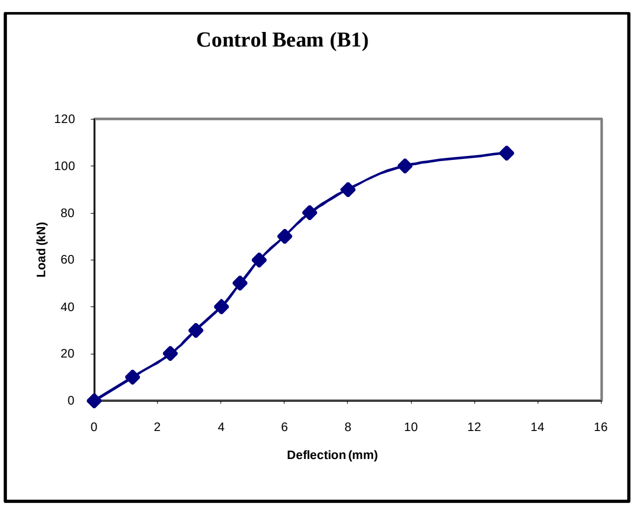
Table IV

Load (kN)	0	10	20	30	40	50	60	70	80	90	100	110
Deflection (mm)	0.0	1.2	2.4	3.2	4.0	4.6	5.2	6.0	6.8	8.0	9.8	13.6

Table V

Load (kN)	0	10	20	30	40	50	60	70	80	90	100	107.7
Deflection (mm)	0.0	1.2	2.4	3.1	4.0	4.6	5.3	6.1	6.9	8.1	9.9	13.3

Load–Deflection curves for Control Beams :



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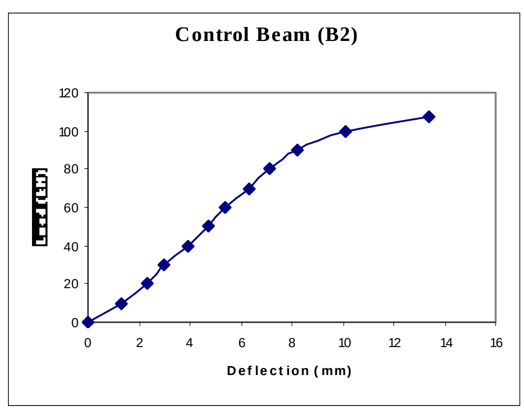

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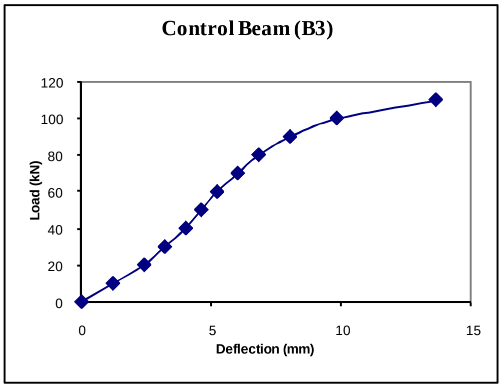

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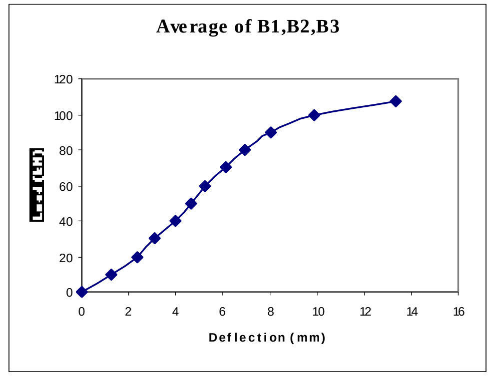


(iv)

Graph:Control Beam

Beams strengthened with Side-bonded GFRP in Bi-axial directionsTable VI

Load (kN)	0	20	40	60	80	100	120	140	160	180	200	204.5
Deflection (mm)	0.0	2.0	4.2	6.8	6.5	8.3	10.8	13.9	17.1	20.6	23.8	30.2

Table VII

Load (kN)	0	20	40	60	80	100	120	140	160	180	200	208
Deflection (mm)	0.0	1.4	3.8	6.6	8.4	11.2	14.6	18.0	21.4	24.1	28.8	31.5

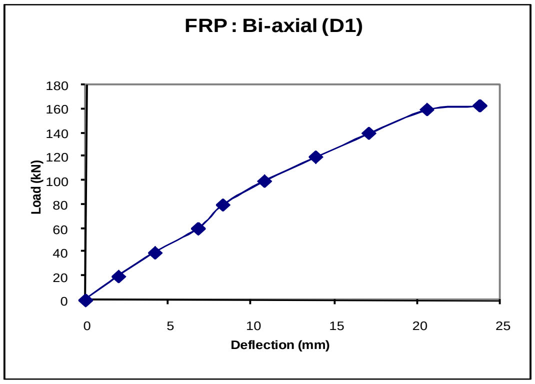
Table VIII

Load (kN)	0	20	40	60	80	100	120	140	160	180	200	208
Deflection (mm)	0.0	2.2	4.1	6.9	8.8	11.1	14.3	16.8	19.6	23.0	28.5	30.4

Table IX

Load (kN)	0	20	40	60	80	100	120	140	160	180	200	206
Deflection (mm)	0.0	1.87	4.03	6.9	8.5	11.0	14.27	17.3	20.5	23.6	28.5	30.7

Load–Deflection curves for Beams strengthened with Side-bonded GFRP in bi-axial directions**:**



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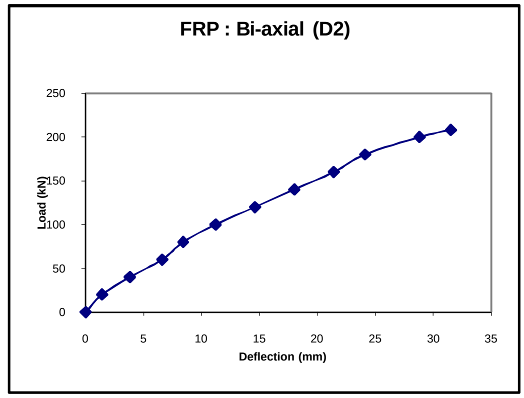

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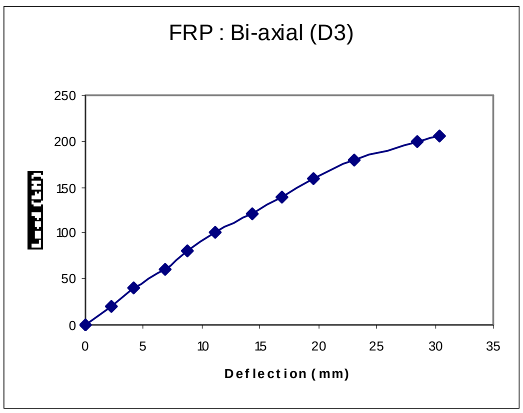

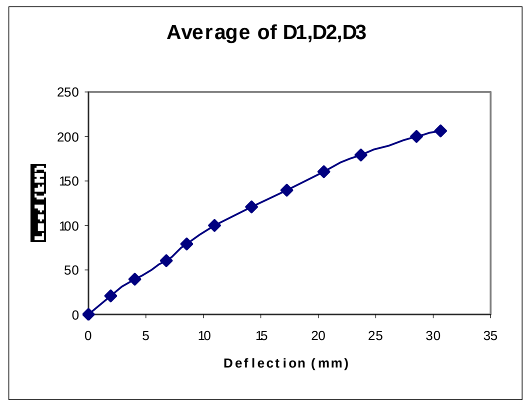

Graph: GFRP in bi-axial directions

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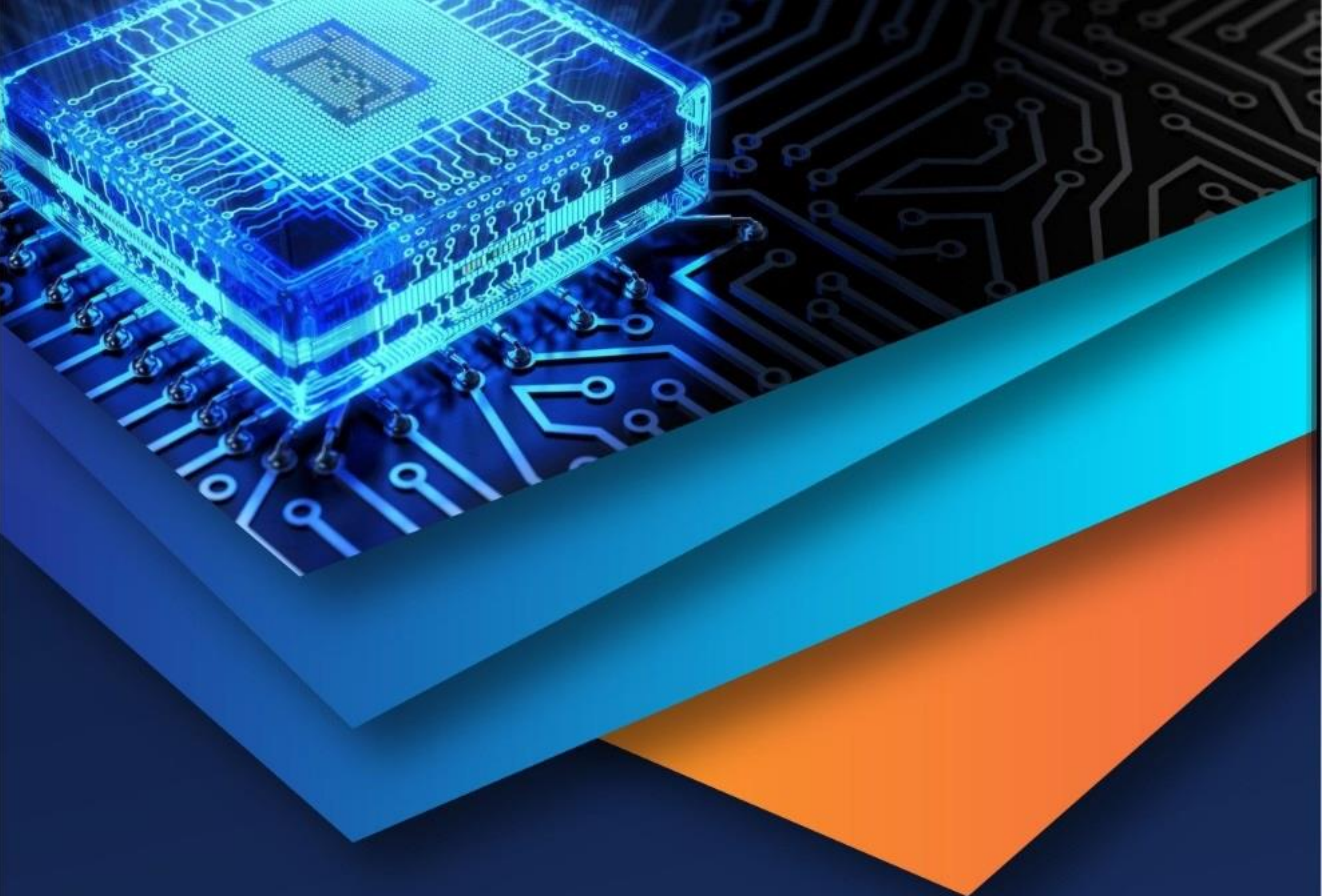

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