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Strengthening of Beam Using Glass Fibre Reinforced Polymer

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Abstract: Glass fibers reinforced polymer composites have been prepared by various manufacturing technology and are widely used for various applications. Initially, ancient Egyptians made containers by glass fibers drawn from heat softened glass. Continues glass fibers were first manufactured in the 1930s for high-temperature electrical application. Nowadays, it has been used in electronics, aviation and automobile application etc. Glass fibers are having excellent properties like high strength, flexibility, stiffness and resistance to chemical harm. It may be in the form of roving's, chopped strand, yarns, fabrics and mats. Each type of glass fibers have unique properties and are used for various applications in the form of polymer composites. The mechanical, tribological, thermal, water absorption and vibrational properties of various glass fiber reinforced polymer composites were reported.

I. INTRODUCTION

Every structure is built with a specific life span. However, despite the safety factors, structures tend to lose their structural integrity before serving their expected life. Many factors are attributed to this cause, for example excessive loading on the structure, natural calamities, etc.

Such factors weaken the structure throughout its life. In all such cases repair and strengthening are the primary cares. Many innovative strengthening techniques as well as materials have been introduced in recent years there has been an increase in the use of lightweight, nonmetallic fiber reinforced composite materials to strengthen, repair and retrofit concrete structures. Strengthening a structural member is done when the strength of the existing member is insufficient. A new method of flexural strengthening reinforced concrete beams by attaching fiber reinforced polymer (FRP) strip to the bottom surface has been investigated in this study.

For the past few decades strengthening of reinforced concrete flexural members by using external steel strip at tension side. With the advancement of technology the newer material FRP overcome the disadvantage of steel plates and proved the superior. This methods consist of bonding a FRP strip to the tension side of an existing flexural member with an epoxy.

The concrete surface had to be made smooth, which require careful grinding and priming. The two part base and hardener for epoxy was mixed in a carefully controlled manner, and then the FRP strip was placed into position until the epoxy cured. FRP is light weight, corrosion resistant, non-magnetic and thus efficient.

A. Problem Statement

It is recognized World Wide that RC structure are not permanently durable and free from maintenance. It is observed that recently constructed concrete structure have shown poor durability and loss of strength within a few year of their service life because of deficiency during designing, construction or maintenance. A large number of cases of damage and failure in RC structure has been strengthening of such strengthening involves challenging technical problems in identifying the causes of distress, repair material and techniques to be adopted.

For general building this period is 50 years and important building it may be 80, 90, 100 or 150 years depending upon importance, designers design assessment of period and factor of safety on required life.

In everyday life practicing engineer come across various civil engineering problems, both at construction stage as well as maintenance or retrofitting stage.

Strengthening of RC structure is gaining importance to increase the life span of existing strengthening during the service life the structure are subjected to different types of internal and external environment and in the process decoration starts. Major cause of damage to concrete structure malfunctioning and classification of damage and strengthening strategy demand high level of judgement on the part of rehabilitation engineer.

B. Objective

1) Experimental study of the failure mode of reinforced concrete beam strengthening by glass fiber reinforced polymer sheet with epoxy adhesive.
2) Experimental study of the behavior of cracked reinforced concrete beam strengthened by GFRP
3) Comparison of percentage increase in load carrying capacity of strengthened beam with control beam.
4) Comparison of deflection of control beam and strengthened beam.
5) To study the effect of increasing area of GFRP on the reinforced concrete beam.

II. LITERATURE REVIEW

A. National Papers

The use of fiber reinforced (FRP) as strengthening material has been gaining the interest of many researchers. This decrease in the cost, combined with the saving due to elimination of future maintenance and repair costs, makes the application of FRP economically competitive with their steel counterpart.

1) Name of Publisher:- M. Malek and Hamid Saadatmanesh.

Title:-Analytical Study Of Reinforced Concrete Beams Strengthened With Web-Bonded Fiber Reinforced Plastic Plates Or Fibers.
Date:- April 1999, vol. 95, No. 3.
Bonding fiber reinforced plastic (FRP) plates or fabrics to the web of reinforced concrete beams can increase the shear and flexural capacity of the beam. This paper presents analytical models to calculate the stresses in the strengthened beam, and the shear force resisted by the composite plate before cracking and after formation of flexural cracks. The anisotropic behavior of the composite plate or fabric has been considered in the analytical models. The companion paper extends this discussion into post cracking behavior at the ultimate load, where the diagonal shear cracks are formed. The method has been developed assuming perfect bond between FRP and concrete, and using compatibility of the strains in the FRP and the concrete beam. The validity of the assumptions used in this method has been verified by comparing the results to the finite element method. A parametric study has been performed to reveal the effect of important variable parameters, such as fiber orientation angle on the shear force resisted by FRP plates. The method has been developed for both uncracked and cracked beams, and it can be used for stress analysis of these types of beams.

2) Name of Publisher:- N.Pannirselvam, V.Nagaradjane, K.Cchandramouli and M.Rravindrakrishna.

Title:- Artificial Neural Network Model For Performance Evaluation Of R C Rectangular Beams With Externally Bonded Glass Fibre Reinforced Polymer Reinforcement.
Date:- March 2010, vol. 5, No. 3.
The effect of glass fiber reinforced polymer laminates on the performance of reinforced concrete rectangular beams having different internal steel reinforcement ratios was investigated. The parameters of investigation included yield load, ultimate load, yield deflection, ultimate deflection, maximum crack width, deflection ductility and energy ductility. Artificial Neural Network model was generated to predict the performance characteristics taking percentage of steel reinforcement, thickness of glass fiber reinforced polymer and the type of fiber used in glass fiber reinforced polymer as parameters.

III. SCOPE OF THIS STUDY

The purpose of this research was to investigate and understand the material components involved in the method, and to understand how the system was to be constructed, rather than an exhaustive examination of all factors and issues related to the development of a method of flexure strengthening reinforced concrete beams with Glass Fiber Reinforced Polymer.

IV. EXPERIMENTAL WORK

The objective of this investigation is to examine experimentally the benefits of external bonding of E-glass fiber to strengthen, rehabilitate the flexural members and to evaluate its effect on both load carrying capacity and nominal flexure.
The scope of this investigation is confined to beam of particular size 700x150x150 mm. fifteen beams were casted by M20 Grade concrete, tor steel of 10mm Φ 2no. at top and stirrups 6 mm Φ at 130 mm c/c were placed. The beams were kept in pure water for 28 days curing. After curing beams were externally bonded with GFRP sheet at tension side of specimen & moment region. Also three beams were loaded up to 100% of ultimate load & then externally bonded with GFRP sheet with full bottom length of specimen. All the beams are tested under same loading condition and parameters.

V. EXPERIMENTAL PROGRAME

Type 1 – Beam without reinforcement.
No. of beam: 1
Size of beam: 700mm x 150mm x 150mm
Nature of beam: It is a beam casted M20 grade concrete without reinforcement. Deflection is measured at the mid span with the help of dial gauge. The beam is tested for flexural under two point loading up to failure load. The load was applied to the beam using Universal Testing Machine (UTM) of 400KN capacity.

Type 2 – Control beam with reinforcement.
No. of beam: 1
Size of beam: 700mm x 150mm x 150mm
Nature of beam: It is the beam casted with M20 grade concrete. The reinforcement detail are as shown in table no. 3.1. Deflection is measured at mid span of beam with the help of dial gauge. The parent beam is without application of GFRP on surface at tension side was tested for flexural under two point loading up to failure load. The load was applied to the beam using Universal Testing Machine (UTM). The cracks are observed and results are recorded in table no. 5.2 and 5.3

Type 3 – Beam with GFRP applied on bottom throughout its length.
No. of beam: 1
Size of beam: 700mm x 150mm x 150mm
Nature of Beam: These type of beam are casted with same material that of control beam. The surface must be free from dust. Then the strip 700mm x 150mm of GFRP is applied to concrete surface in moment region. Then these are tested under constant rate of loading on UTM for flexural under two point loading. Then cracks are observed and results are recorded in table no. 5.4.

Type 4– Beam with GFRP wrapped three layers throughout its length.
No. of beam: 1
Size of beam: 700mm x 150mm x 150mm
Nature of Beam: These type of beam are casted with same material that of control beam. The surface must be free from dust. Then the strip 700mm x 450mm of GFRP is applied to concrete surface in moment region. Then these are tested under constant rate of loading on UTM for flexural under two point loading. Then cracks are observed and results are recorded in table no. 5.7 and 5.8.

VI. RESULTS AND DISCUSSIONS

The testing was done under two point loading condition as shown in figure no. 5.1. The load was applied to the beam using Universal Testing Machine (UTM) of 400KN capacity.
The deflection was measured at the mid-span of the beam. Deflection was measured using dial gauge having least count of 0.01 mm.
All beams were tested statically up to failure of the beam in a single load cycle. The experimental work to study the flexural strength of R.C. beam were carried out on rectangular beams. All the beams were tested and the results were tabulated and graphs of load v/s deflection are plotted.

A. Testing Procedure

The beam specimen of size 700mm x 150mm x 150mm setup as shown in figure no. 5.1 beam was kept on universal testing machine for loading on two roller support.
The dial gauge was fixed at mid span of the beam specimen and initial reading are noted. The beam was then loaded to check the effectiveness of test setup.
The beam is then subjected to loading through the 5 KN incremental loading stages up to the failure. Then failure mode of the beam were marked and identified.

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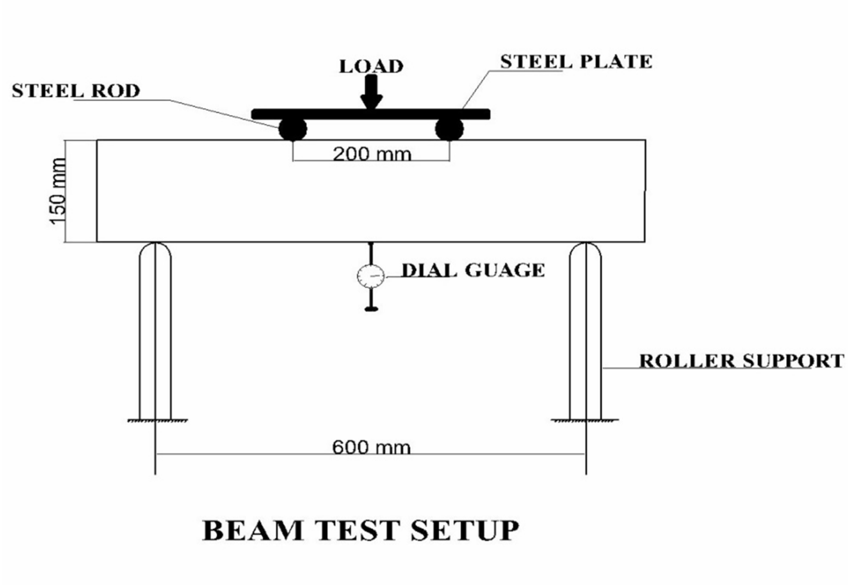


Figure no. 5.1 Setup for testing

B. Results Of Beam

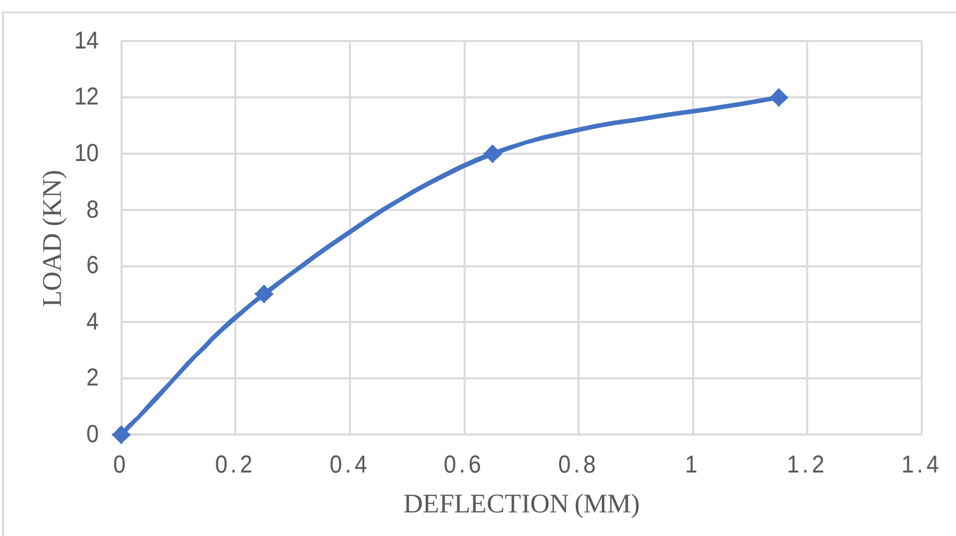
Load was gradually increased by 5 KN and mid span deflection was measured. Results are tabulated below:

1) Type 1 – Beam without reinforcement.

Beam with M20 grade of concrete. Load was gradually increased by 5 KN and mid span deflection was measured.
Size: 700mm x 150mm x 150mm.

Table No. 5.1 Beam without reinforcement.

LOAD (KN)	DEFLECTION (mm)
0	0
5	0.25
10	0.65
12	1.15



Graph No. 1 - Load Vs Deflection of beam without reinforcement.

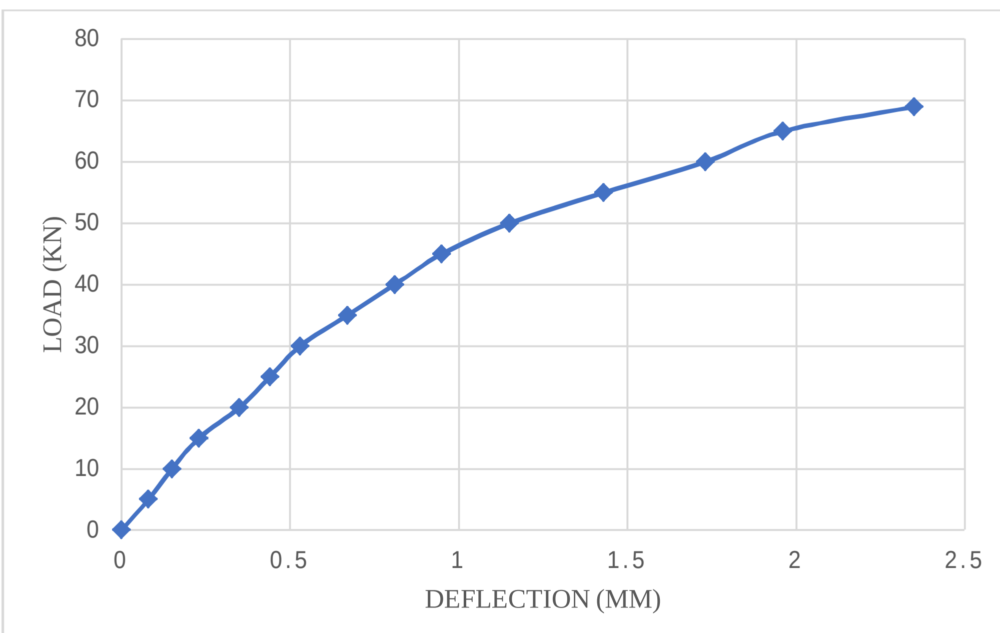
2) *Type 2 – Control beam with reinforcement. (Sample 1)*

Beam with M20 grade of concrete. Load was gradually increased by 5 KN and mid span deflection was measured.

Size : 700mm x 150mm x 150mm

Table No. 5.2 Control beam with reinforcement (Sample 1)

LOAD (KN)	DEFLECTION (mm)	LOAD (KN)	DEFLECTION (mm)
0	0	40	0.81
5	0.08	45	0.95
10	0.15	50	1.15
15	0.23	55	1.43
20	0.35	60	1.73
25	0.44	65	1.96
30	0.53	69	2.35
35	0.67		



Graph No. 2 - Load Vs Deflection of control beam with reinforcement.

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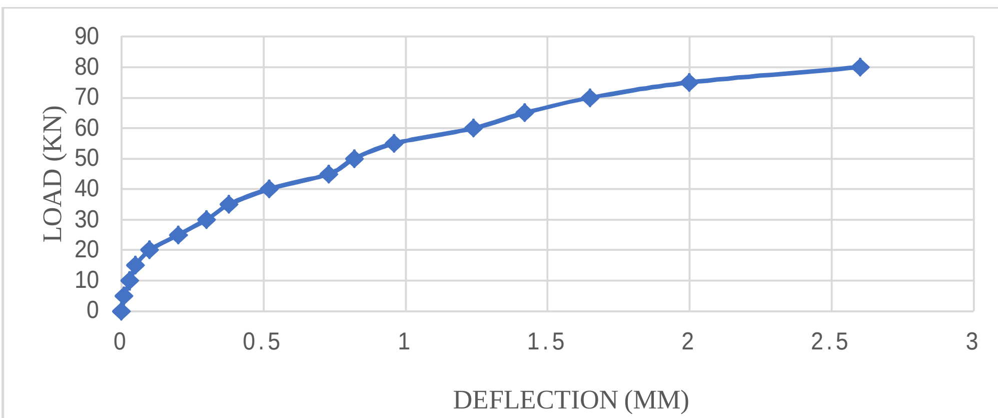
3) Type 3 – Beam with GFRP applied on bottom throughout its length.

Beam of M20 grade concrete strengthened with triple layer GFRP.
Size of beam = 700mm x 150mm x 150mm
Size of GFRP = 700mm x 150mm

Table No. 5.4 Beam with GFRP applied on bottom throughout its length.

LOAD (KN)	DEFLECTION (mm)	LOAD (KN)	DEFLECTION (mm)
0	0	45	0.73
5	0	50	0.82
10	0.03	55	0.96
15	0.05	60	1.24
20	0.1	65	1.42
25	0.2	70	1.65
30	0.3	75	2
35	0.38	80	2.6
40	0.52		



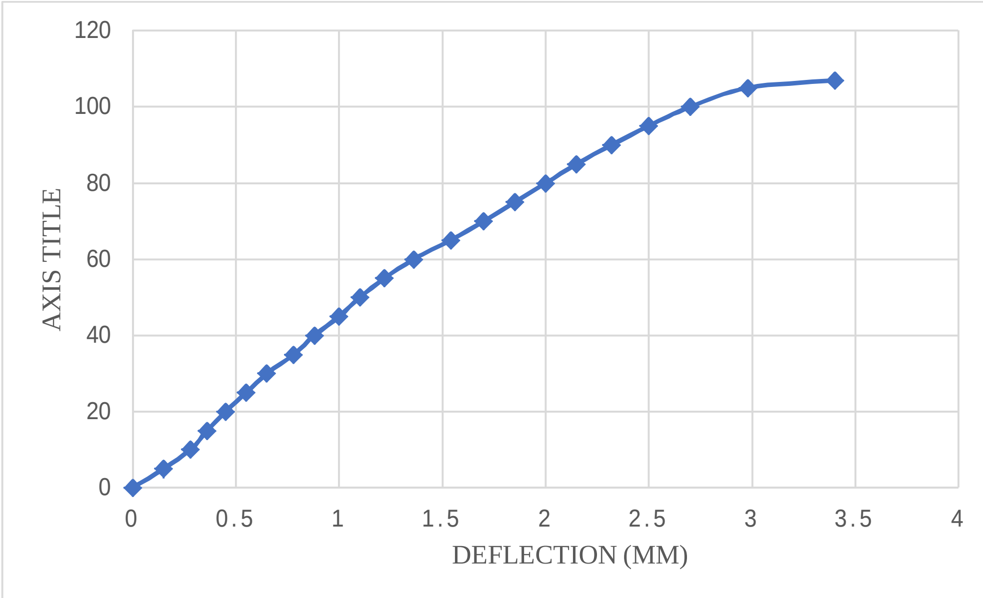
Graph No. 3 - Load Vs Deflection GFRP applied on bottom throughout its length.

4) Type 4

Beam of M20 grade concrete strengthened with triple layer GFRP.
Size of beam = 700mm x 150mm x 150mm
Size of GFRP = 700mm x 450mm

Table No. 5.8 Beam with GFRP wrapped three side throughout its length.

LOAD (KN)	DEFLECTION (mm)	LOAD (KN)	DEFLECTION (mm)
0	0	60	1.36
5	0.15	65	1.54
10	0.28	70	1.7
15	0.36	75	1.85
20	0.45	80	2
25	0.55	85	2.15
30	0.65	90	2.32
35	0.78	95	2.5
40	0.88	100	2.70
45	1	105	2.98
50	1.1	107	3.40
55	1.22		



Graph No. 5.8 - Load Vs Deflection GFRP wrapped three side throughout its length.

C. Analysis of Results and Discussion

1) *Type 1:* The graph no.1 and table no1 shows the mid span deflection of beam without reinforcement, the load deflection curve shows the yield load at 10 KN. Load deflection curve is straight from 0-5 KN and slightly divert up to 10 KN and curves up to failure load of 12 KN, with deflection of 1.15 mm. The beam breaks into 2 half.
2) *Type 2:* The graph no.2and table no. 2 shows the midpoint deflection of the control beam with reinforcement, the load deflection curve shows the yield load at 50 KN. The curve is straight from 0-30 KN and gets slightly curved up to failure load at 69 KN with deflection of 2.35 mm. The crack start from bottom center to top diagonally and failed by shear.
3) *Type 3:* The graph no.3 and table no. 3 shows the midpoint deflection of beam with GFRP 700mm x 150mm. It is seen that the load gradually increases from 0-80 KN. Load deflection curve is straight from 0-15 KN and gets slightly curved in nature up to the failure load of 80 KN, the deflection at 80 KN is 2.6 mm. as the load increases the crack width goes on increasing from bottom center to top of the beam diagonally.
4) *Type 4:* The graph no.4 and table no. 4 shows the midpoint deflection of beam with GFRP 700mm x 450mm. It is seen that the load gradually increases from 0-107 KN. Load deflection curve is straight from 0-60 KN and gets slightly curved in nature up to the failure load of 107 KN, the deflection at 107 KN is 3.40 mm, as the load increases the crack width goes on increasing from bottom center to top of the beam diagonally.

VII. CONCLUSION

The following conclusion are found on the basis of the experimental investigation carried out for flexural strengthening of RC beam using GFRP laminates.

1) The load carrying capacity of beam increased after strengthening with GFRP of length 700mm and width 150mm is 31%
2) The load carrying capacity of beam increased after strengthening with GFRP of length 700mm and width 450mm is 65%
3) Application of GFRP at full length takes more load than the application of GFRP at moment region.

From the above results it is concluded that the experiment of bonding GFRP laminates is feasible method of upgrading the strength of reinforced concrete beams.

VIII. FUTURE SCOPE

A. Experimental study of strengthening of RC beam by grouting the crack and externally bonding with GFRP.
B. Experimental study of strengthening of RC column by different strengthening techniques using GFRP.
C. Analytical an experimental for shear failure of beam using GFRP.
D. Further studies are needed to determine durability of fiber reinforced beam under aggressive environmental condition and cyclic loading.

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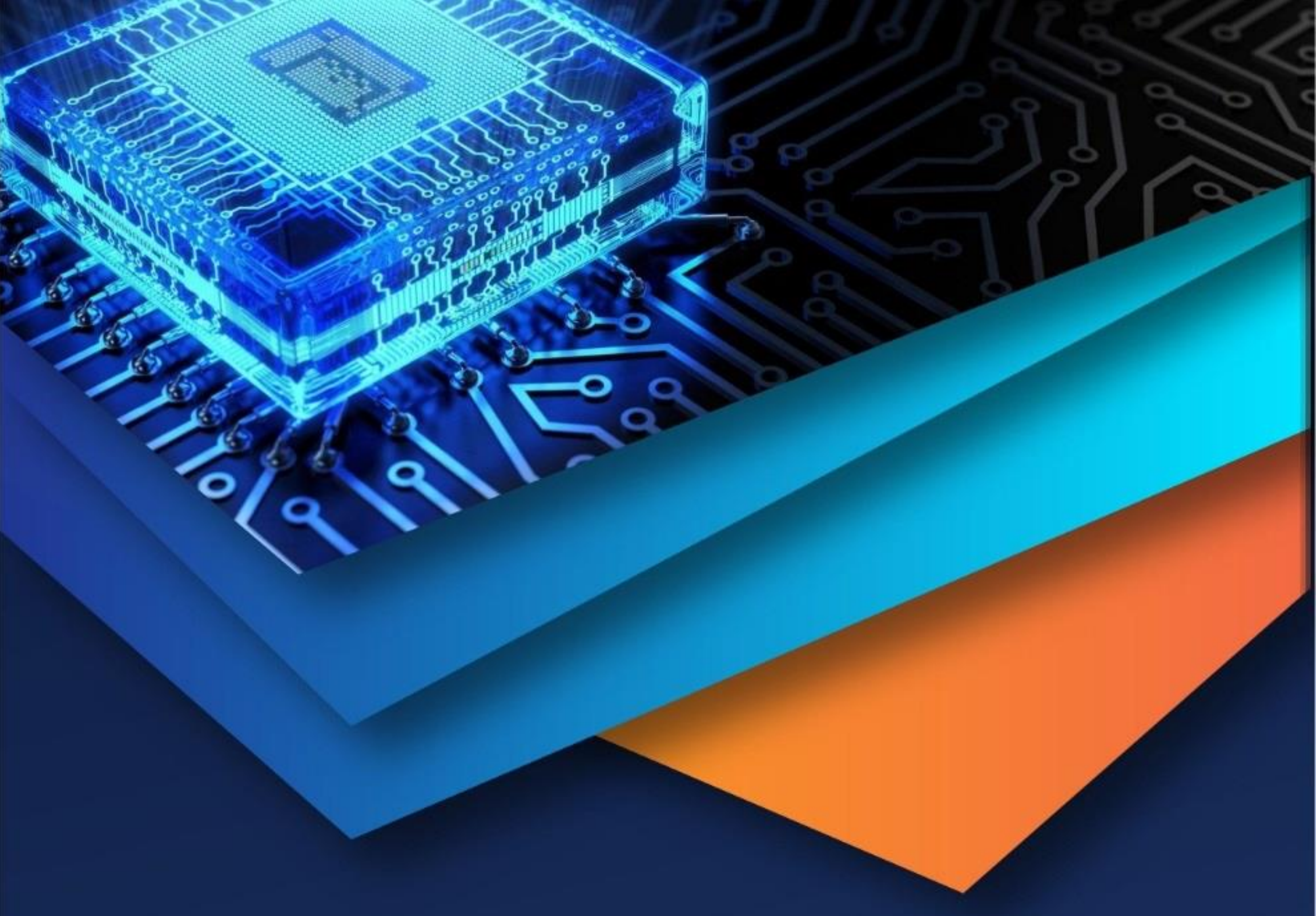

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