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Flexural Behaviour of SFRC Curved Deep Beams

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***Abstract:** As per IS 456:2000, deep beams can be defined as the structures that having span to depth ratio less than 2 for a simply supported beam and 2.5 for a continuous beam. Also these members are loaded on one face and supported on the opposite face. Uses of curved deep beams are increasing in structures like rounded corners of buildings, circular balconies, water tanks etc. Steel Fiber Reinforced Concrete (SFRC) is a concrete with short, discrete lengths of steel fibers which are randomly dispersed. The load deformation behavior of curved deep beam of different curvatures gives an idea about the effect of curvature on the performance of curved deep beam. The structure that generates comparatively small deformation within the applied load can be considered as relatively safe. This paper illustrates the effect of curvature or central angle on the ultimate load behavior of SFRC curved deep beam and analyzing its flexural behaviour. Steel Fiber Reinforced Concrete with 1% steel fiber is used in the current study. The central subtended angles adopted for the study are 0^0, 45^0, 60^0, 90^0, 120^0, and 180^0. As the central subtended angle increases, curvature also increases. The analysis of the structure has been carried out using ANSYS Software.*
***Keywords:** Ultimate load carrying capacity, steel fiber reinforced concrete, curved deep beams, central angle, curvature*

I. INTRODUCTION

A deep beam can be defined as a structural member having a depth comparable to span length. According to IS-456 (2000) Clause 29, simply supported beam acts as deep beam when the ratio of its effective span (L) to overall depth (D) is less than 2.0 and that for continuous beam when the ratio is less than 2.5.[11] Deep beams have high load bearing capacity compared to the normal shallow beams. The behaviour of deep beams is also different from normal beams because of due to its non-linear stress strain distribution. Therefore, a lot of research has been carried out on deep beams to study their structural behaviour both by experimental and analytical methods. The behaviour of deep beams with different materials, effect on changing depth, effect of shear span to depth ratio, influence of openings in deep beam, etc. are some of the fields studied by the previous researchers. As the use of curved structures is increasing nowadays due to its aesthetic appearance and energy efficiency, need for curved deep beams are also more. Steel Fibers can be used in the concrete to improve its structural behaviour which also improves the performance of deep beams. In the current study, analysis of the ultimate load carrying capacity of Steel Fiber Reinforced Concrete (SFRC) curved deep beams has been carried out in order to find the effect of central angle in its performance.

II. EXPERIMENTAL STUDY ON SFRC

Experimental study was conducted to obtain the optimum percentage of steel fiber to be incorporated to get maximum strength and to give input values in software. OPC 53 Grade cement which is conforming to IS 12269 was used. Fine aggregate used was M Sand which conforms to Zone 2. 20mm sized coarse aggregate is used to impart strength. Potable water is used. As the steel fibers in the concrete reduce the workability, polycarboxylate ether based super plasticizer was also used. From the literature studies, end hooked steel fibers were preferred for the current work.

TABLE I
PROPERTIES OF STEEL FIBER USED

Geometry	End Hooked
Length	35mm
Diameter	0.7mm
Density	7850kg/m^3
Aspect Ratio	50
Volume Fraction	1%

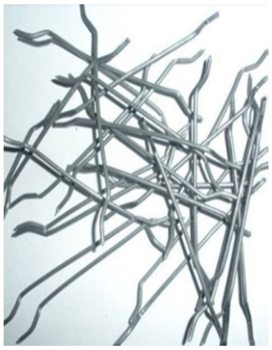

Fig. 1 End Hooked Steel Fiber

TABLE III
MECHANICAL PROPERTIES OF SFRC

Mechanical Properties	**Results**
Modulus of Elasticity	34130 MPa
Compressive Strength	43 MPa
Split Tensile Strength	4.60 MPa
Flexural Strength	5.2 MPa
Poisson's Ratio	0.224
Density	2445.93kg/m^3

III. DETAILS OF DEEP BEAM

The deep beam is modelled with a clear span of 2300mm. The cross section of the deep beam is 1200mm depth and 300mm width. The curvatures adopted for the study are 0^0, 45^0, 60^0, 90^0, 120^0, and 180^0. As curved deep beams are to be modelled fixed supports are provided to give more stability. A lower shear span to depth ratio is adopted for more strength.

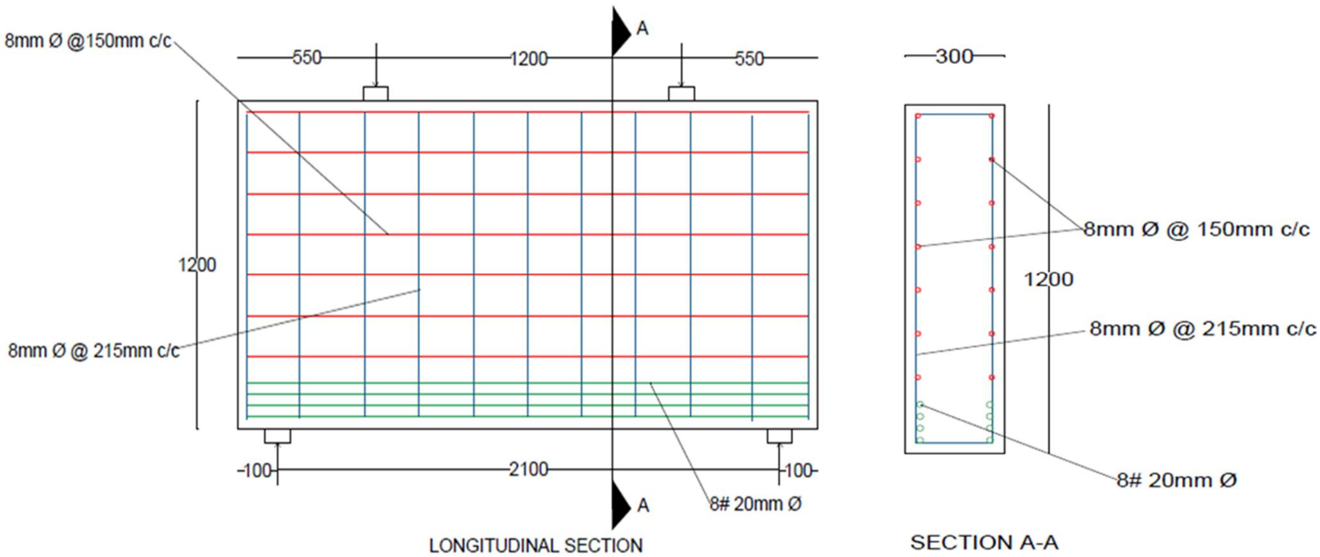

Fig. 2 Detailing of Deep Beam

IV. FINITE ELEMENT ANALYSIS

Finite element analysis was performed by using the ANSYS program. ANSYS is finite element modeling package which helps in solving even complex problems. In Finite Element Analysis, the complex analysis gets simplified in order to make the analysis easier.

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A. Modelling in ANSYS

Model of SFRC deep beams for the analysis is created in ANSYS Workbench 17.2. After the modelling, meshing has been done to get accurate result of analysis. It breaks up a whole body into pieces, where each piece represents an element. The mesh was set up such that square or rectangular elements were created. Mesh sizing is also a factor which determines the accuracy of the results obtained.

B. Non Linear Analysis

Total load applied to a finite element model is divided into a series of load increments called load steps. Two loading plates and two support plates were provided. Total load is divided into two loading plates and two point loading is applied. Chart is plotted with the Force Reaction on Y axis and corresponding deformation on X axis. Ultimate load value corresponding to each curved deep beam is noted. After applying load steps by changing analysis settings, non-linear analysis has been carried out. From solutions, force reaction and total deformation were inserted. The geometry of model, meshed model and deformed shape of deep beams obtained after the analysis are given below.

C. Load Deformation Curve

Total force reaction and the total deformation obtained from the analysis were plotted on Y axis and X axis respectively. Ultimate load carrying capacity corresponding to each curved SFRC deep beams are also given in the Table III.

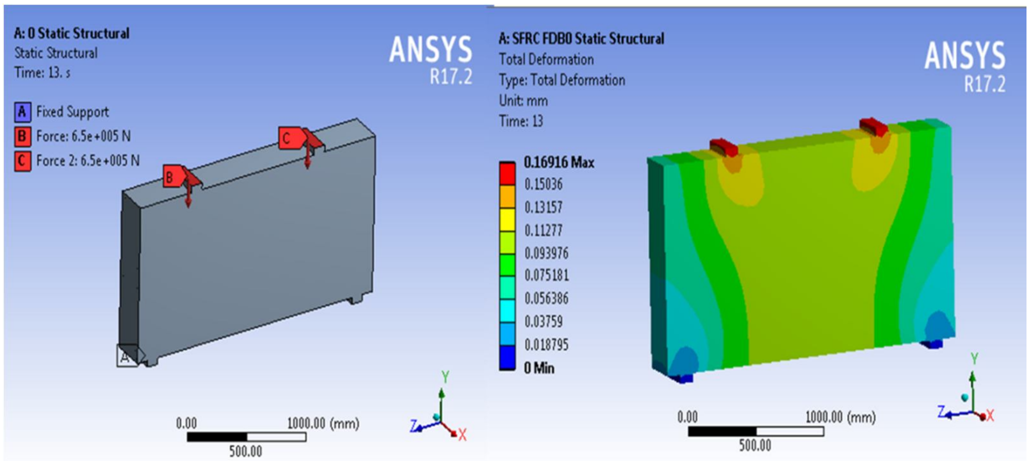

Fig. 3 Geometry and Deformed Model- SFRC FDB0

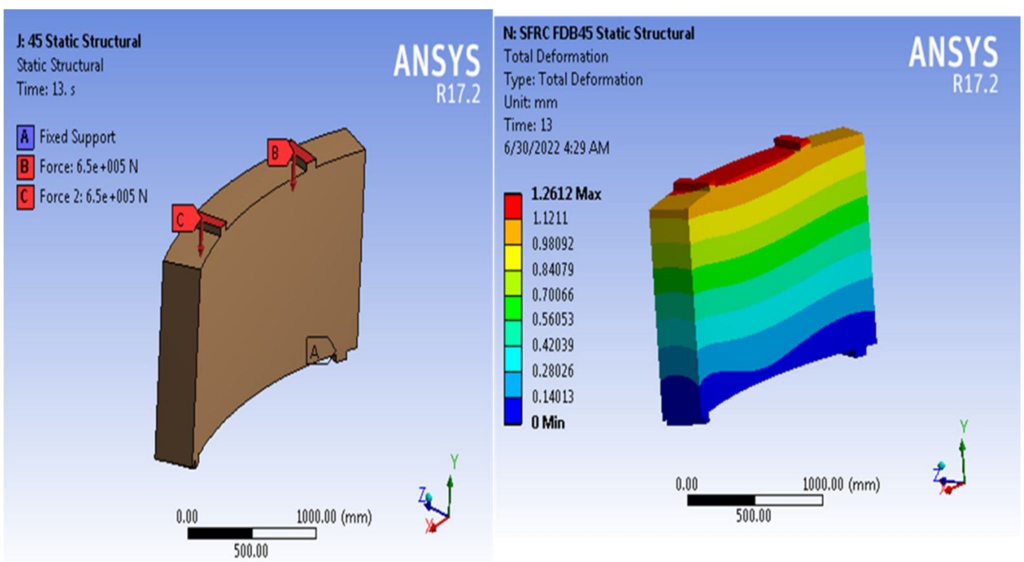

Fig. 4 Geometry and Deformed Model- SFRC FDB45

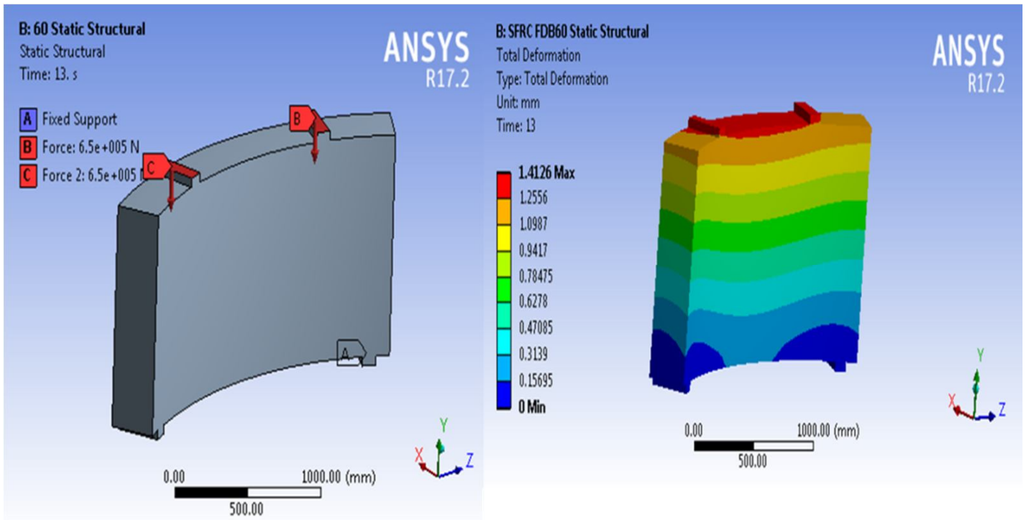

Fig. 5 Geometry and Deformed Model- SFRC FDB60

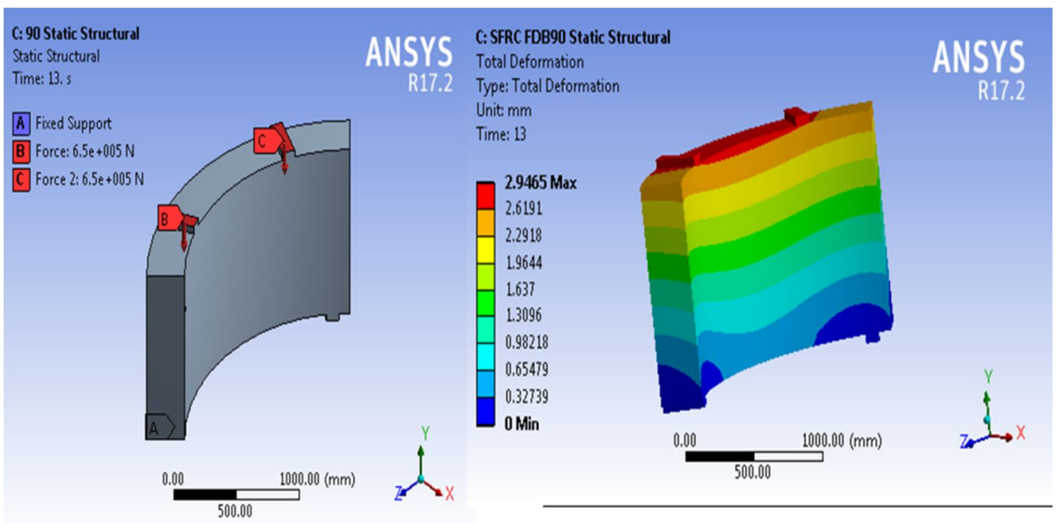

Fig. 6 Geometry and Deformed Model- SFRC FDB90

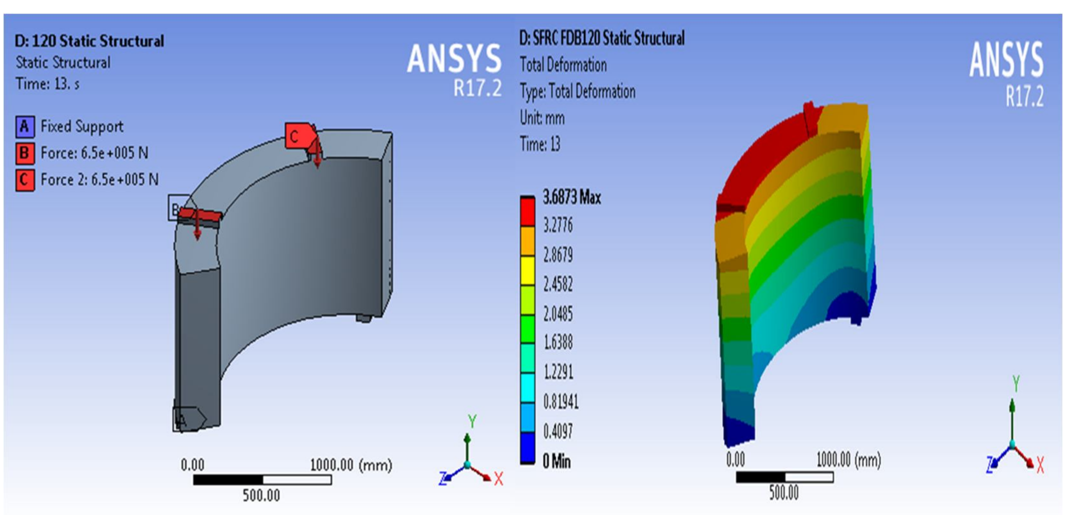

Fig. 7 Geometry and Deformed Model- SFRC FDB120

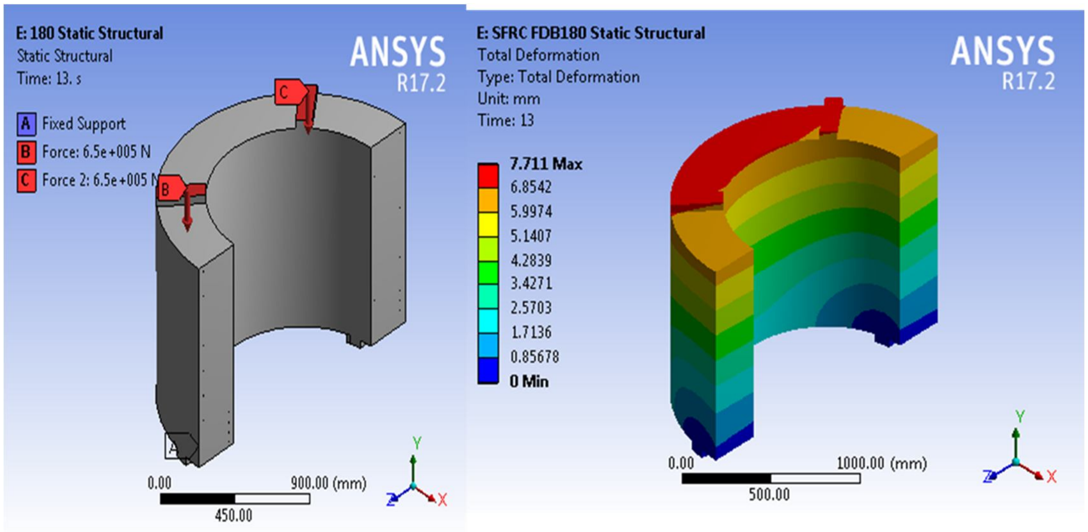

Fig. 8 Geometry and Deformed Model- SFRC FDB180

V. RESULTS OF FINITE ELEMENT ANALYSIS

SFRC Deep Beam with different curvatures was analysed using ANSYS software. The numerical results include ultimate load and load deformation curves.

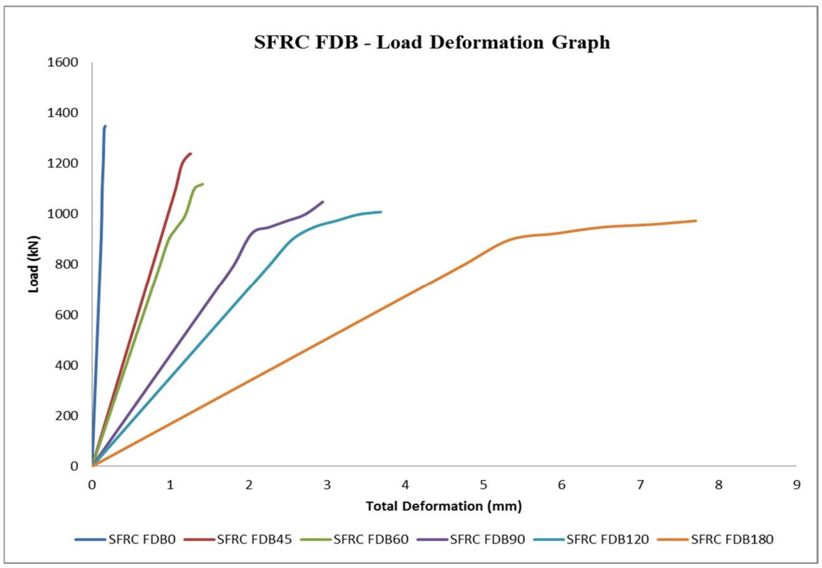

Fig. 9 Load Deformation Graph

TABLE IIIII
ULTIMATE LOAD AND DEFORMATION

Specimen Name	Ultimate Load (kN)	Maximum Deformation (mm)
SFRC FDB0	1350 kN	0.16916
SFRC FDB45	1240 kN	1.2612
SFRC FDB60	1120 kN	1.4126
SFRC FDB90	1050 kN	2.9465
SFRC FDB120	1010 kN	3.6873
SFRC FDB180	975 kN	7.711

VI. CONCLUSIONS

1) Central angle is one of the important factors that affect the load carrying capacity of the deep beam.
2) Increase in the central angle leads to increase of the curvature, which is reciprocal of radius.
3) As the central angle increases, the ultimate load carrying capacity of the deep beam decreases and deformation increases.
4) Straight deep beams have much more load resisting capacity and less deformation compared to curved deep beams.
5) Total deformation is maximum at the point of application of load and minimum at the fixed supports.

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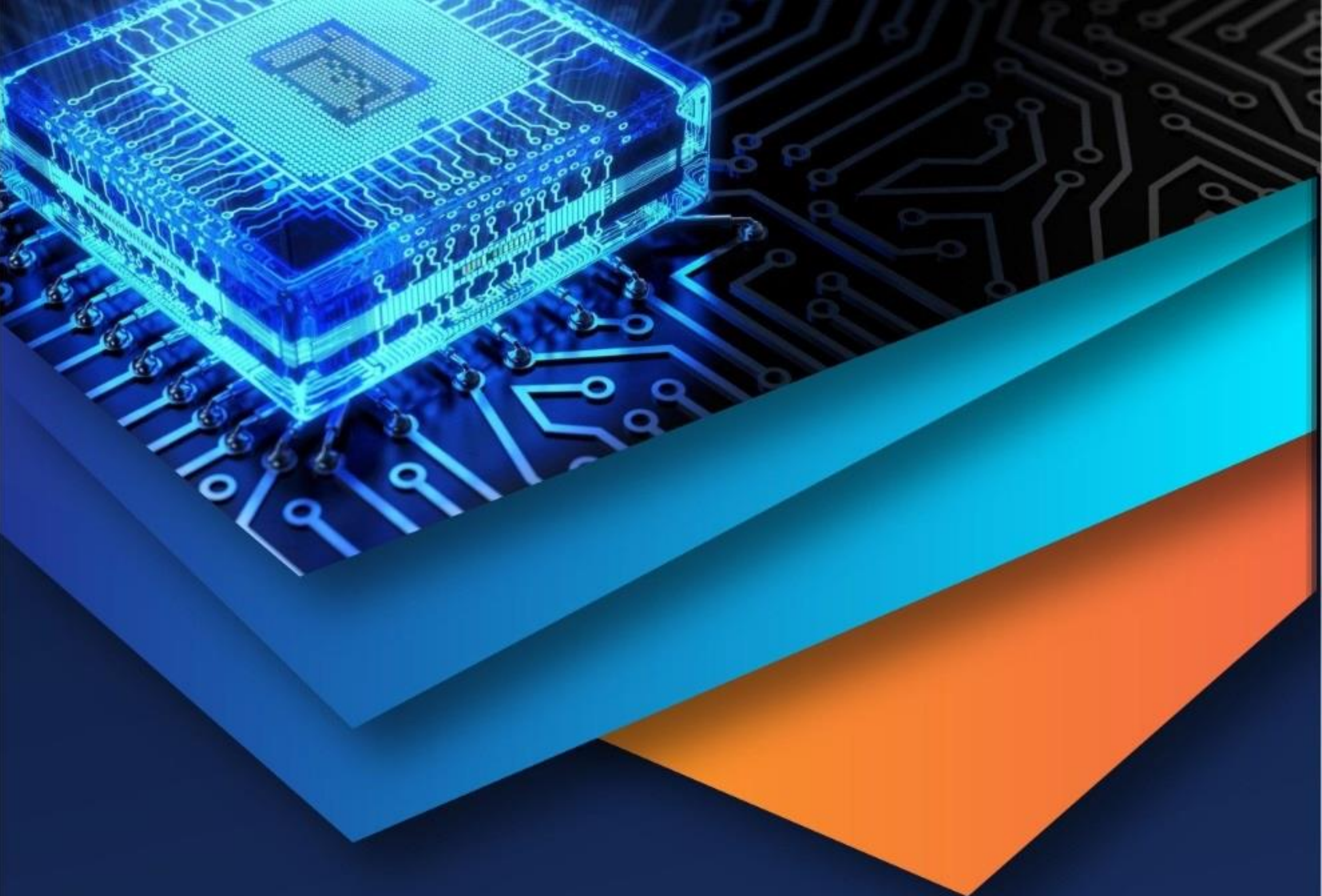

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