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Parametric Study on Tubed Steel Reinforced Concrete Columns under Axial Loading

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Abstract— ***The decades have seen outstanding advances in the use of composite steel-concrete structural systems in the construction of buildings. Concrete-steel composite structure is defined as construction in which both steel and concrete materials are combined and maximize the structural and economic advantages of each material. Composite column increases the rigidity of the structure and provide significant axial load carrying capacity. Composite columns are classified as concrete filled steel tubular columns and encased columns .Encased column is also known as Steel Reinforced concrete columns. Tubed steel reinforced concrete column is special type of composite column in which reinforcing bars in the form of steel tube on the perimeter and steel shape at core of the column. When concrete filled steel tube is provided, the strength of concrete is increased by the confining effect of steel tube, and the strength reduction is not very severe, since the tube prevents the spalling of concrete. The purpose of the current research is conduct parametric study by varying steel shape, length of column and thickness of steel tube of tubed steel reinforced concrete column by using finite element analysis software ANSYS17.ISMB150, ISMB125, ISMB100 are used for steel shape. The results show that when the thickness of column is increased by one mm, 8.043 % reduction developed in deformation of columns under constant load. When length of the column is increased by 200 mm, deformation is also increased***
Keywords— ***Composite column, Steel tube, Encased columns, steel tube, Steel reinforced concrete column, Strength, Axial load, Confining effect***

I. INTRODUCTION

Concrete structural element is generally thick enough and less prone to buckle; but they are shows creep and shrinkage with respect to time. Steel structural members are fabricated with components such as thin plate and shell elements. So on loading; they are subjected to local and lateral buckling. Therefore, it is necessary to check the failure due to buckling and instability.

Hence, a novel technique called steel-concrete composite construction which can binds up the dynamic properties of both the materials. The most important and most frequently encountered combination of construction materials are steel and concrete, with applications in multi-storey commercial buildings ,factories

Generally concrete filled steel tubular columns and encased columns (SRC) are included in steel concrete composite columns. Encased columns are made up of standard I or H-beam sections with a circular, rectangular or square concrete section encasement in order to shape a solid composite section .Reinforced concrete encased steel structures are referred to as SRC structures. Concrete filled steel tubular (CFST) columns have the advantages of both steel and concrete. CFST comprise of a steel hollow section of circular, rectangular and square shape filled with plain or reinforced concrete. There are a number of advantages related in both terms of structural performance and construction sequence .Steel sections with concrete infill used as structural members, since filling the steel sections with concrete increases its strength and ductility without increasing the section size. Since steel confines the concrete, it will be act as formwork for concrete.

A tubed steel reinforced concrete (SRC) columns are special SRC columns where reinforcement cage is in the form of an outer thin steel tube. Thus steel tube prevents the concrete cover from spalling off. At the same time, the strength and ductility of the concrete core is increases owing to the confinement of the steel Tube. The outer circular or square tube does not pass through the beam-to-column connection, therefore no axial load is directly applied on the steel tube and the tube confines the core concrete more effectively

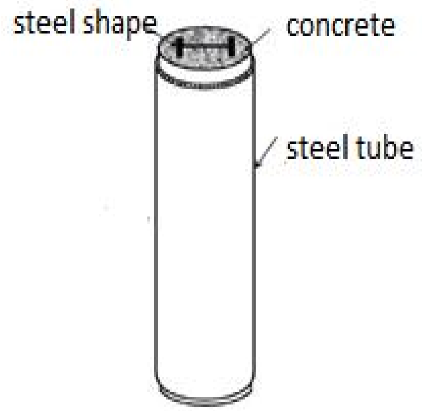

Fig.1 Tubed SRC in a Structural Frame

Johansson and Kent (2002) conducted an experimental and analytical study to find out the mechanical behaviour of circular steel–concrete composite stub columns, Zhou and Liu (2010) investigated the seismic behaviour of tubed SRC short columns by testing eight specimens subjected to combined constant axial compression and lateral cyclic load. Three circular tubed SRC columns (CTSRC) and three square tubed SRC (STSRC) columns were tested in this research with two common SRC columns for comparison, Kian Karimi et.al., (2011) investigated the cross-sectional behaviour of steel columns strengthened with fiber-reinforced polymers (FRPs).

Patidar (2013) conducted non-linear finite element analysis program ANSYS12 is used to predict the ultimate loads, and failure modes of hollow and in-filled light gauge steel section under hinged end conditions, Gajalakshmi and Jane(2013) conducted experiments on circular steel tube filled with steel fibre reinforced concrete and normal concrete to investigate the contribution of steel fibres on the load carrying capacity of short composite columns, Sharad et.al.,(2013) investigated the axial compressive capacity of concrete encased steel columns due to illustrate the effect of encasement of bare steel with concrete.

Numerical and experimental investigations of composite columns are confined by two interlocking spirals has been investigated as in the study of Chen et.al, (2013),Alani and Agarwal (2013) conducted the Nonlinear Finite Element Study on the circular concrete filled steel tubular columns, Bharatesh and Suresh (2014) conducted Experimental and Numerical Investigation of Hollow Sections with and without infill under compression and flexure, Patil (2014) studied the behaviour of concrete-filled steel tube columns under axial load by changing parameters, Ajel (2015) investigated the structural behaviour of concrete - filled steel tube (CFST) columns under experimental and analytical. Parameters are concrete compressive strength, thickness of steel tubes, stiffeners and longitudinal reinforcement.

The main objectives of this paper were, nonlinear behaviour SRC, RCC columns under axial load is investigated for compare the axial load carrying capacity of TSRC columns .In second stage parametric studies conducted on TSRC column, for study the behaviour of deformation under axial load. Length of column, thickness of tube and the dimensions of I-section are considered for parametric study.

II. FINITE ELEMENT ANALYSIS OF COLUMN

Finite Element model is developed to simulate the behaviour of tubed steel reinforced concrete column under axial load by varying the parameters such as length of column and thickness of steel tube. In order to create the models, Finite Element software ANSYS 17 is used. Following this, deformation is also studied by varying the steel shape at the core of column.

A. Model Description

Steel tube, steel shape and concrete. The steel shape (ISHB150) used in the circular TSRC columns are 150mm high and 150 mm wide. The flange thickness of the steel shape is 9mm. The web thickness of steel shape is 5.4mm.Length of column is 3700mm and dia of column is 370mm. TSRC column thickness of tube is 4mm

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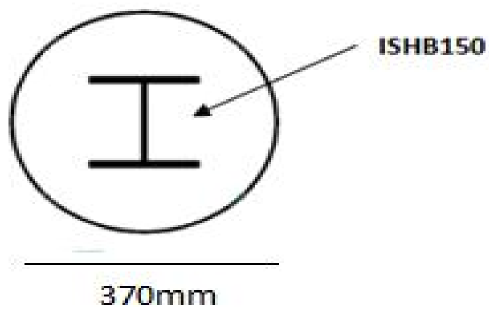

Fig. 2 TSRC Circular column

B. Element type

SOLID65 is used for the three-dimensional modeling of solid with or without reinforcing bar (rebar). It is capable of cracking in tension and crushing in compression. In concrete applications, the solid capability of the element may be used to model the concrete while the rebar capability is available for modeling reinforcement behaviour. Other cases for which the element is also applicable for reinforced composites and geological materials The element is defined by eight nodes with three degrees of freedom at each node: translations in the nodal x, y, and z directions. Up to three different rebar specifications may be defined

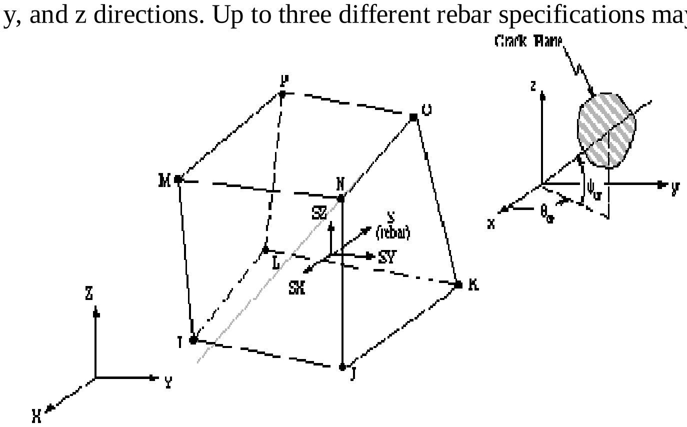

Fig.3 SOLID 65

BEAM 188 elements is used to model reinforcing steel and steel shapes .This is a 2-node linear or quadratic beam element in 3-D.BEAM188 is based on Timoshenko beam theory. Shear deformation effects are also included. BEAM188 has seven degrees of freedom at each node; Translations in the x, y, and z directions and rotations about the x, y, and z directions.Shell181 is suitable for analysing the steel tube. It is a four-node element with six degrees of freedom at each node: translations in x, y, and z directions, and rotations about the x, y, and z-axes.

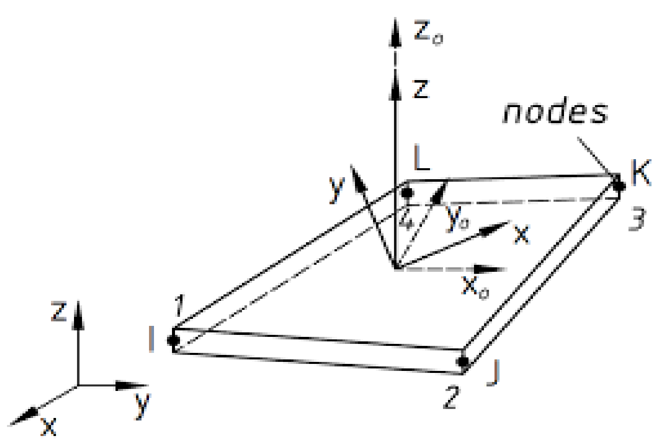

Fig. 4 shell 181

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C. Material properties

The Solid65 element requires linear isotropic and multilinear isotropic material properties for modeling of concrete. Linear properties of concrete is given in table 1.The multilinear isotropic material properties are defined by the von Mises failure criterion along with the Willam and Warnke model to define the failure of the concrete elements. Table 2 and 3 shows the bilinear properties of steel.

Table 1
Linear properties of concrete.

Material	Material model	Modulus of elasticity (MPa)	Poisons ratio
Concrete	Linear elastic	27386.12	.2

Table 2
Properties of steel within beam188 element

Material	Material model	Modulus of elasticity(MPa)	Poissons ratio
Steel	Linear elastic	200000	0.3

Table 3
Steel parameters beyond initial yield surface.

Yield strength	250Mpa
Tangent Modulus	200000

D. Loading and boundary conditions

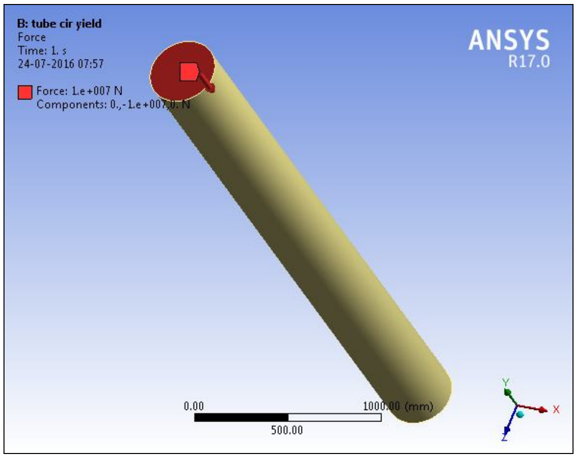

Fig 5 Axial load on columns

Fixed support at bottom and displacements are top of columns are provided. As Fig 6, the uniform compressive loading is applied to the top surface of the column directly in static analysis.

E. Analysis

Nonlinear static analysis is carried out to study the behaviour of TSRC circular column under axial loading. In a nonlinear analysis, the stiffness [K] is dependent on the displacement. Due to this, an iterative solution scheme is required. In ANSYS the Newton-Raphson method is used to solve nonlinear problem iteratively.

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III. PARAMETRIC STUDY

Table 4: Details of parameters

Length of column	Thickness of steel tube
3700mm	4mm-9mm
3900mm	4mm-9mm
4100mm	4mm-9mm
4300mm	4mm-9mm
4500mm	4mm-9mm
4700mm	4mm-9mm
4900mm	3mm-9mm

Thickness steel tube and length of columns are considered for parametric study. Effect of various steel sections on load carrying capacity of TSRC circular column is also studied. Table 4 & table 5 represent details of parameters

Table 5: Details of steel shape

Steel shape	ISMB150	ISMB125	ISMB100
Sectional area	19cm^2	16.60cm^2	14.60cm^2
Depth	150mm	125mm	100mm
Flange width	80mm	75mm	75mm
Flange thickness	7.6m	7.6mm	7.2mm
Thickness of web	4.8m	4.4mm	4mm

IV. RESULTS AND DISCUSSIONS

A. Deformation of columns by varying the thickness of steel tube

Effect of steel tube on load carrying capacity is studied by increasing the thickness of steel tube by 1mm. To investigate the performance of columns under various thickness of steel tube, deformation of column is compared under the constant load and constant length. Fig 7 shows the deformation of column with 4mm thickness steel tube. Length of 3700 mm.

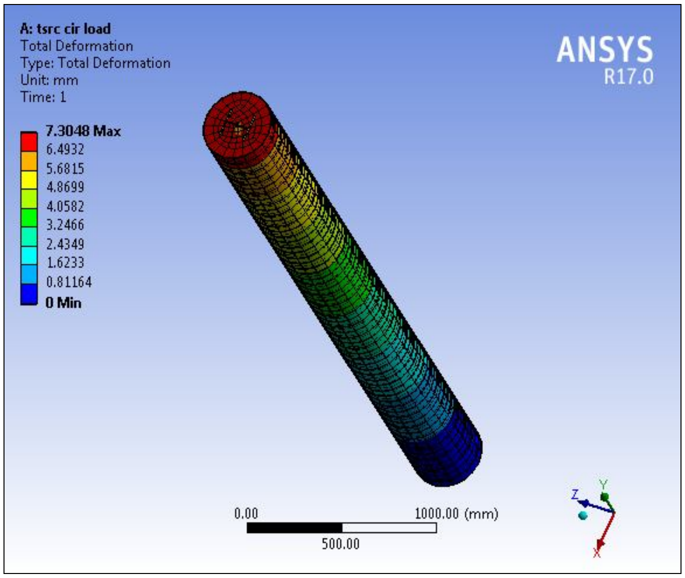

Fig 7. Deformation of column at 4mm thickness

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Table 6

Deformation for various thicknesses

Thickness of steel tube	Deformation
3mm	7.945
4mm	7.3048
5mm	6.78
6mm	6.2709
7mm	5.8796
8mm	5.5699
9mm	5.2819

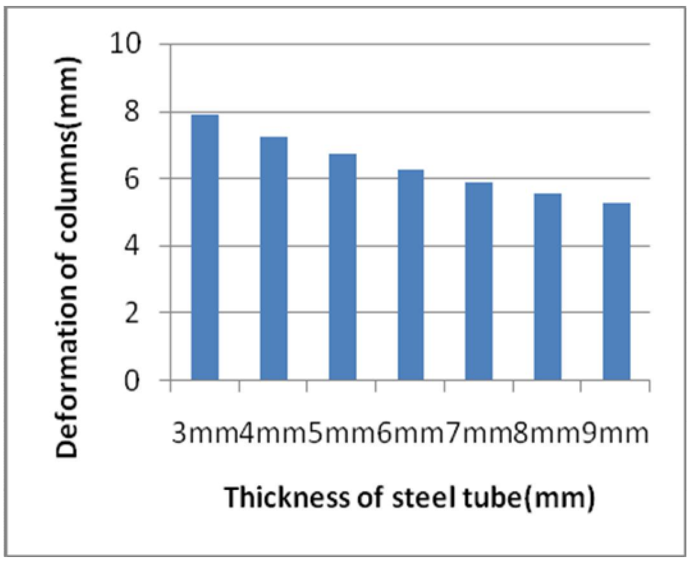

Fig.8 Deformation Vs thickness of steel tube.

B. Deformation by varying the length of column

Deformations are also increases with respect to increase in length of column under constant thickness. Columns act as short columns under the length of 3700, 3900, 4100 and 4300. Table 7 shows the deformation for various lengths of columns with 3mm thickness steel tube. Table 8 and graph 9 shown in below represent the effect of thickness and length on deformation

Table 7.

Deformation for various lengths

Length of column	Deformation
3700mm	7.945
3900mm	8.22
4100mm	8.58088
4300mm	8.898
4500mm	9.3606
4700mm	9.808
4900mm	10.22

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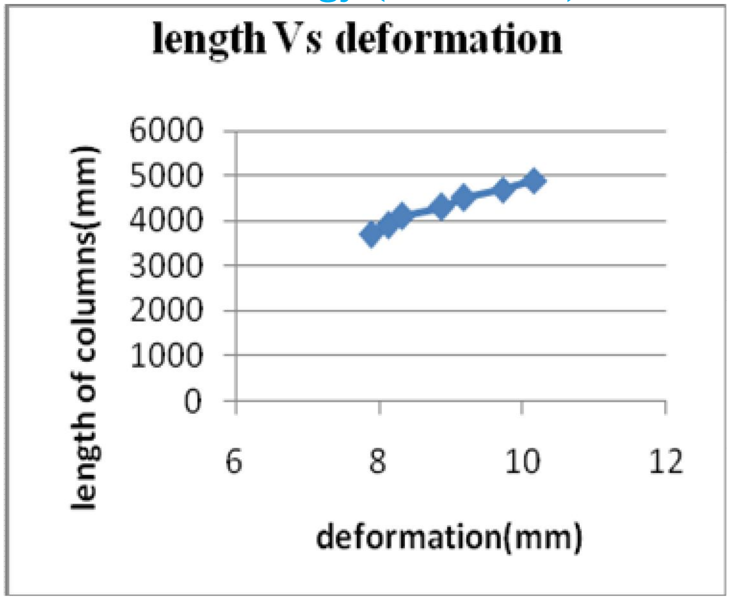

Fig 9 Length Vs Deformation graph

Table 8: Relation between parameters and deformation

length of column(mm)	deformation of W.R.T thickness of tube (mm)						
	3	4	5	6	7	8	9
3700	7.945	7.3048	6.78	6.2709	5.8796	5.5699	5.2819
3900	8.22	7.4613	6.9529	6.5172	6.1246	5.7832	5.4841
4100	8.5808	7.8254	7.2847	6.8068	6.4062	5.9486	5.7364
4300	8.98	8.143	7.5677	7.0864	6.6648	6.3006	5.9701
4500	9.3606	8.5437	7.916	7.4014	6.9723	6.5912	6.2409
4700	9.808	8.9486	8.2838	7.7746	7.2546	6.8597	6.4889
4900	10.22	9.3384	9.3384	8.6702	7.5567	7.1244	6.7699

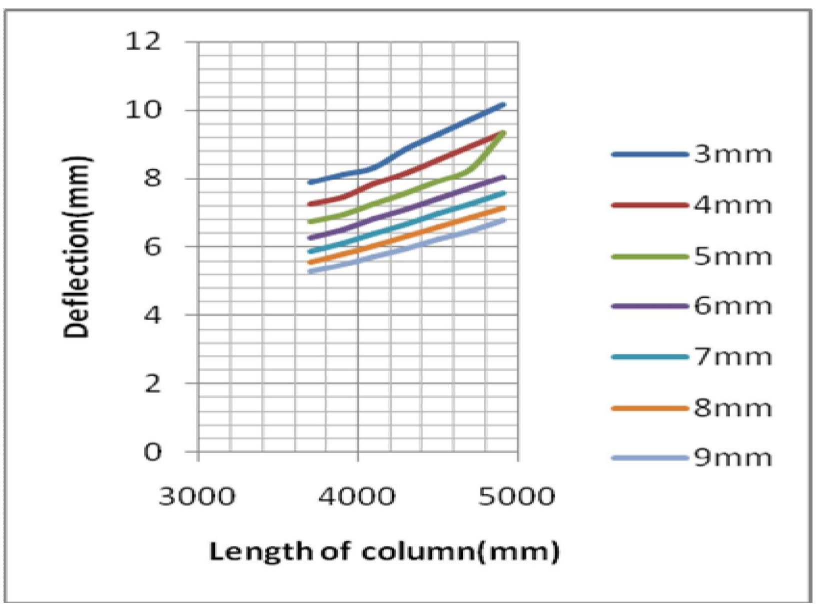

Fig.10. Relation between parameters and deformation

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C. Load carrying capacity of columns with different steel sections

Load carrying capacity of columns is varied at different I sections. It proves that area of steel shape have the role in load carrying capacity.

Table 9
Load carrying capacity of columns with different i section

STEEL SHAPE	ULTIMATE LOAD CARRYING CAPACITY
ISHB150	6350KN
ISMB150	5890KN
ISMB125	5730KN
ISMB100	5690KN

V. CONCLUSIONS

A. Parametric study conducted by varying the thickness of tube by one mm, deflections reduces up to 8.043%

B. Deformation of columns increased with respect to increase in length of columns. This is due to short column effect .2-4 % increase in deformation occurred when the length of the column is increased by 200 mm.

C. Ultimate load carrying capacity is varied with respect to changing the steel shape in the column. When ISMB 150 is used instead of ISHB 150, load is decreased from 6350 to 5890 KN.

After all the analysis, concluded that TSRC circular column with 9mm thickness of steel tube and length of column is 3700, shows better performance under the axial load. It shows that thickness of column, length of columns and Steel shape have significant role in the load carrying capacity of TSRC circular column.

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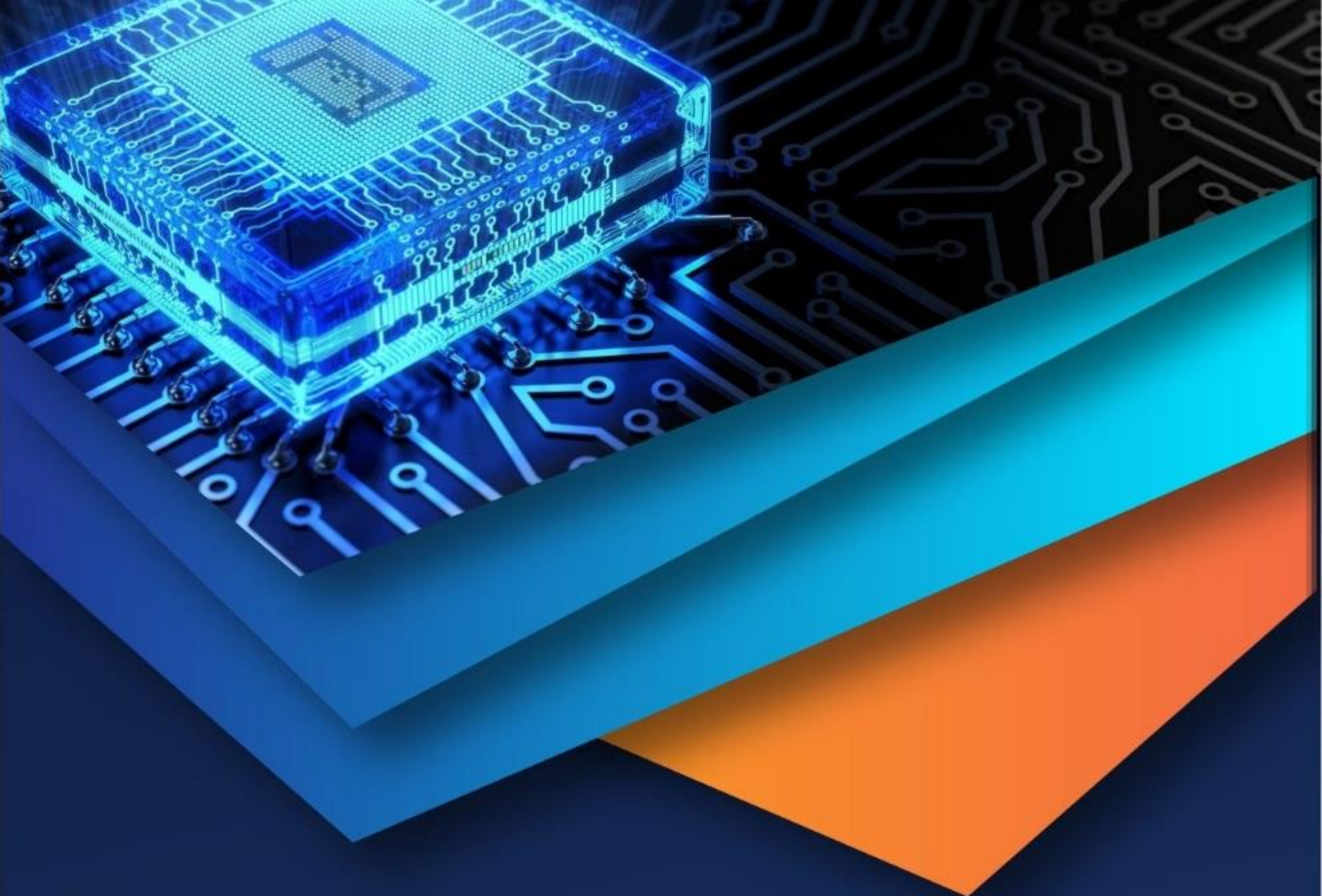

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