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Study of Seismic Behavior on Multi-Storied Buildings with Composite Columns

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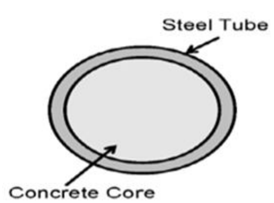
Abstract: The present work seeks to investigate the seismic behaviour of typical SMRF framed structure with two types of composite columns. The main objective of this paper is to evaluate the comparison of composite columns i.e., Concrete filled steel tube (CFST) and Concrete encased I section (CES). This paper is mainly emphasis on structural behaviour of multi-storied structure with different vertical geometric irregularities with two different composite columns. The present work deals with the seismic behaviour of 15 storey building assessed through dynamic analysis (response spectrum method) as per IS 1893:2002 for seismic zone IV and soil type medium, using ETABS 2015 software package. It is also to compare and find which composite column is more effective against lateral loads. The models were analysed and results are tabulated and compared for various parameters like time period and frequency, storey displacement and storey drift.

Keywords: Concrete filled steel tube, Concrete encased I section, vertical irregular buildings, Response Spectrum analysis, Time period, Storey Displacement, Storey Drift.

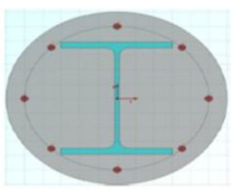
I. INTRODUCTION

The buildings in India are constructed with RCC and the adoption of steel structures is generally confined to industrial buildings, which have acquired prominence by adopting composite structural elements. The most important and most frequently encountered combination of two materials steel and concrete, with the application in multi-storey commercial buildings and factories, as well as in bridges. These materials can be used in mixed structural systems, for example, concrete cores encircled by steel tubes, as well as in composite structures where members consisting of steel and concrete act together compositely. These essentially different materials are completely compatible and complementary to each other, they have almost the same thermal expansion, they have an ideal combination of strengths with concrete efficient in compression and the steel in tension, concrete also gives corrosion protection and thermal insulation to the steel at elevated temperatures and additionally can restrain slender steel sections from local or lateral-torsional buckling. However, in recent times, the composite columns are gaining popularity for use in multi-storey buildings by virtue of their excellent static and earthquake resistant properties such as lower mass, high strength, rigidity and stiffness, significantly high toughness and ductility, large energy dissipation capacity. Due to these reasons, composite members are gaining importance for the making of sky-scrapers, infrastructure growth and especially for high rise structures of seismic regions in the world.

A steel-concrete composite column is a compression member, comprising either a concrete encased hot-rolled steel section or a concrete filled tubular section of hot-rolled steel and is generally used as a load-bearing member in a composite framed structure. The load carrying capacity of composite columns is more than that of the bare reinforced column and the structural steel column included in the system.



Concrete filled steel tube column



concrete encased I section column

Fig. 1 Composite columns

II. LITERATURE REVIEW

A. Comparative study on seismic analysis of multi-storied buildings with composite columns": Due to a large population and small per capita area, need of tall buildings becomes more essential in the society. The limitations of the available land frequently restrict the freedom of an engineer to create a perfect structure. In such situations the buildings will have to be designed in various shapes even with oblique corners so as to utilize the maximum benefits of the available land. As earthquakes are one of the greatest damaging natural hazards to the building, the design and construction of tall structures which is capable of resisting the adverse effects of earthquake forces are the most important. Concrete-filled steel tubular columns have excellent earthquake resistant properties such as high strength and ductility and large energy absorption capacity. The objective of this paper is to evaluate the comparison of composite columns with concrete filled steel tube and composite encased I section column. This paper mainly emphasizes the structural behavior of the multi-story building for different plan configurations like Rectangular, C, L and H shape with two different column properties. It is also to compare and find which building with the composite column is more effective against lateral loads. Modeling of 15- story buildings are analyzed using ETABS 2015. The results are tabulated, compared and final conclusions are framed. From the outputs of ETABS, various results are obtained. And these results are evaluated by preparing various graphs.

B. (April 2015) "Comparison of Seismic Behaviour of a Typical Multi-Storey Structure with Composite Columns and Steel Columns": The present work seeks to investigate the seismic behaviour of a typical ordinary moment resisting framed structure with composite columns and conventional Steel columns and examine the key design issues involved. The present study deals with the seismic behavior of a typical (G+12) storied framed structure assessed through the equivalent static method of analysis as per IS: 1893-2002 for moderate seismic zone III using ETABS software package. The analyses are performed on a suite of 2 types of ordinary moment resisting framed 3D space models with different column types – Steel and CFST. The analysis is carried out and the results are compared in terms of critical earthquake response parameters such as base shear, story drifts, roof displacements, and story overturning moments.

C. April 2013) "Comparison of R.C.C. And Composite Multi-storeyed Buildings": Steel-concrete composite construction means steel section encased in concrete for columns & the concrete slab or profiled deck slab is connected to the steel beam with the help of mechanical shear connectors so that they act as a single unit. In this present paper, steel-concrete composite with R.C.C. options is considered for the comparative study of G+15 story office building which is situated in earthquake zone IV & wind speed 39m/s. Equivalent Static Method of Analysis is used. For modeling of Composite & R.C.C. structures, stand-pro software is used and the results are compared and it is found that composite structure is more economical.

D. (November 2015) "Comparison of Seismic Behaviour of a Structure with Composite and Conventional Columns": An extensive study has been carried out on the behaviour of the composite column in a structure. In composite column construction, steel and concrete are united in such a manner that the advantages of the materials are employed in an efficient manner. By bonding and friction between steel and composite material, these materials will accept the external loading in composite columns. In this study comparison of the composite and conventional structure is carried out. Just varying the design of column i.e., by using composite and conventional column and keeping all other structural members same for both the structures. Composite column design is carried out according to Euro code 4 and conventional column design is by IS 456-2000. The buildings are taken to be true to be placed in III seismic zone. Seismic design is followed by IS 1893-2002. There are many different types of the composite column from those we have taken concrete encased composite column for our analysis. Concrete encasement would increase the load resistance of steel column.

E. (April 2014) "Comparative study of RCC and steel-concrete composite structures": Steel concrete composite construction has gained wide acceptance worldwide as an alternative to pure steel and pure concrete construction. The use of steel in the construction industry is very low in India compared to many developing countries. There is a great potential for increasing the volume of steel in construction, especially in the current development needs India and not using steel as an alternative construction material and not using it where it is economical is a heavy loss for the country. In this paper study of four various multi-storied commercial buildings i.e. G+12, G+16, G+20, G+24 are analyzed by using the STAAD-Pro software. Where design and cost estimation is carried out using MS-Excel programming and from obtained result comparison can be made between R.C.C and composite structure.

III.OBJECTIVES

A. To study the comparison of seismic behaviour of two types of composite columns i.e, Concrete Filled Steel Tube (CFST) and Concrete Encased steel I Section (CES).

B. To find the structural behaviour of multi-storey buildings with different vertical geometric irregularities like setback @ 4^{th} floor, setback @ 6^{th} floor, setback @ every 3 floors and setback @ every 5 floors.

C. To find out which composite column performed well in each cases by comparing the results in terms of time period, storey displacement and storey drift.

IV. METHODOLOGY

A. Building Plan Dimension Details

A 48m x 36m 15- storey structure modeled using ETABS. The height of each storey is taken as 3.5m, making total height of the structure 52.5m. The following are the Vertical geometric irregular buildings like Setback @ 4^{th} floor, Setback @ 6^{th} floor, Setback @ every 3 floors and Setback @ every 5 floors. The plan, elevation and 3d view of models are created in ETABS.

B. Modelling

Here the study is carried out for the behavior of 15 storey R.C frame buildings with regular and irregularities. Floor height provided 3.5m. And also properties are defined for the frame structure. 8 models are created in ETABS software with concrete-filled steel tube columns and concrete encased steel I section columns in vertical geometric irregular buildings. Post analysis of the structure, time period, maximum storey drift, overturning and maximum storey displacement are computed and then compared for all the analyzed cases. Modeling of RCC frames includes an RCC framed structure is basically an assembly of slabs, beams, columns, and foundation interconnected to each other as a unit. The load transfer mechanism in these structures is from slabs to beams, from beams to columns, and then ultimately from columns to the foundation, which in turn passes the load to the soil. In this structural analysis study, we have adopted cases by assuming different shapes for the same structure, as explained below.

1) Setback @ 4^{th} floor
2) Setback @ 6^{th} floor
3) Setback @ every 3 floors
4) Setback @ every 5 floors

Properties of building	Buildings with composite columns	
	CFST(Concrete Filled Steel Tube)	CES(Concrete Encased I section)
Material properties		
Grade of concrete	M_{30}	M_{30}
Grade of reinforcing steel	HYSD 500	HYSD 500
Unit weight of concrete	25 kN/m^3	25 kN/m^3
Sectional properties		
Column type	Circular	Circular
Column size	D=600mm, t=16mm	D=600mm, t=16mm (ISHB400)
Beam size	ISWB 550	ISWB 550
RC slab	150mm	150mm
Wall thickness	230mm	230mm
Building details		
No. of bays in X-direction	7	7
No. of bays in Y-direction	7	7
Width of bays in X-direction	8m	8m
Width of bays in Y-direction	6m	6m
Height of storey	3.5m	3.5m
Type of support	Fixed	Fixed
Seismic data		
Earthquake zone	IV	IV
Damping ratio	5%	5%
Importance factor	1.5	1.5
Type of soil	Medium	Medium
Response reduction factor	5(SMRF)	5(SMRF)
Poisson's ratio	0.15	0.15

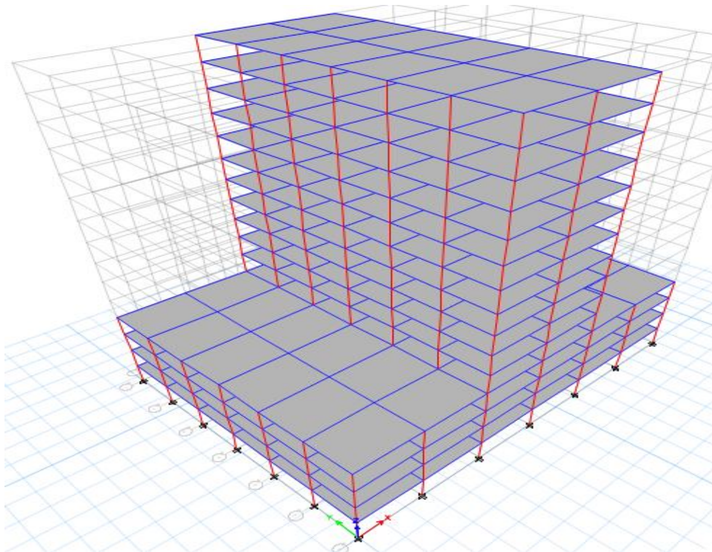


Fig. 2 3D view of setback @ 4th storey building

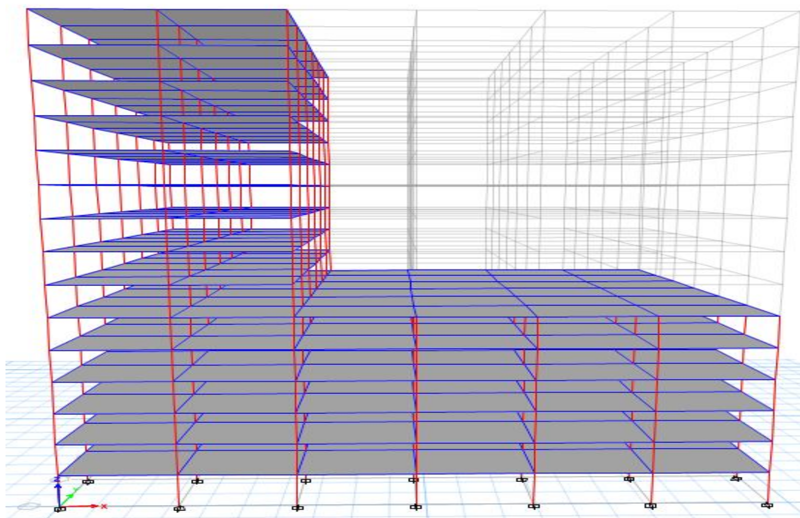


Fig. 3 3D view of setback @ 6th storey building

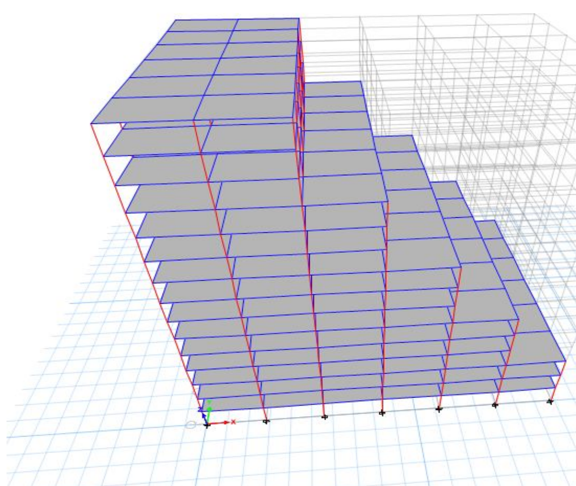


Fig. 4 3D view of setback @ every 3 floors building

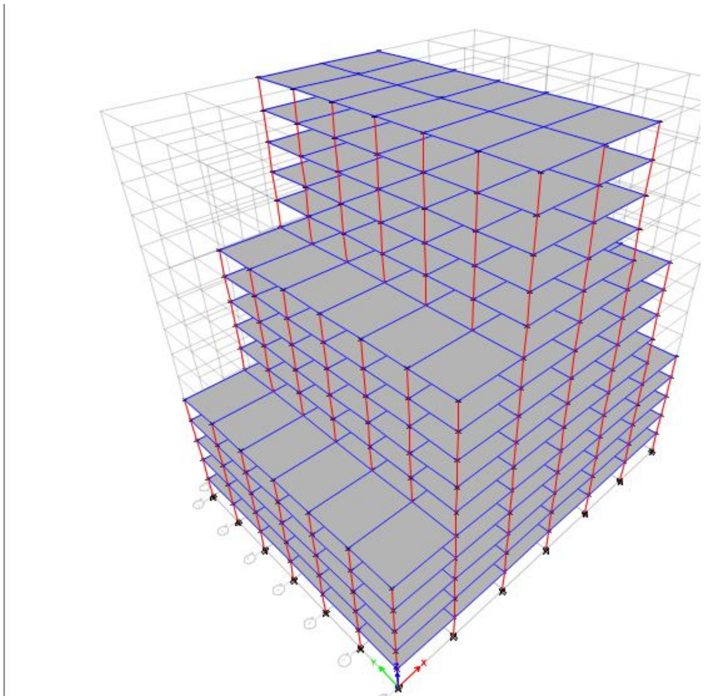


Fig. 5 3D view of setback @ every 5 floors building

C. Response Spectrum Analysis

The response spectrum represents an envelope of upper bound responses, based on several different ground motion records. For the purpose of seismic analysis, the design spectrum given in figure 1 of IS: 1893(Part 1): 2002 is used. This spectrum is based on strong motion records of eight Indian earthquakes. This method is an elastic dynamic analysis approach that relies on the assumption that dynamic response of the structure may be found by considering the independent response of each natural mode of vibration and then combining the response of each in the same way. This is advantageous in the fact that generally only a few of the lowest modes of vibration have significance while calculating moments, shear and deflections at different levels of the building.

V. COMPARISON OF RESULTS

A. Time Period

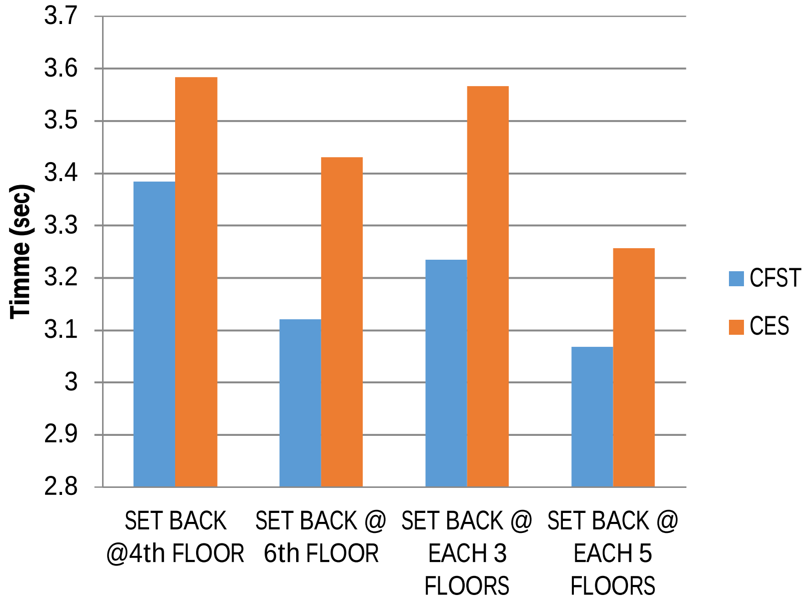


Fig. 6 Comparison of time period between CFST and CES columns

The time period reduces with the use of CFST column compared to CES column is shown in above figure for each of the buildings. As the time period reduces the stiffness of the building increases because time period is inversely proportional to the stiffness of the building.

B. Displacement

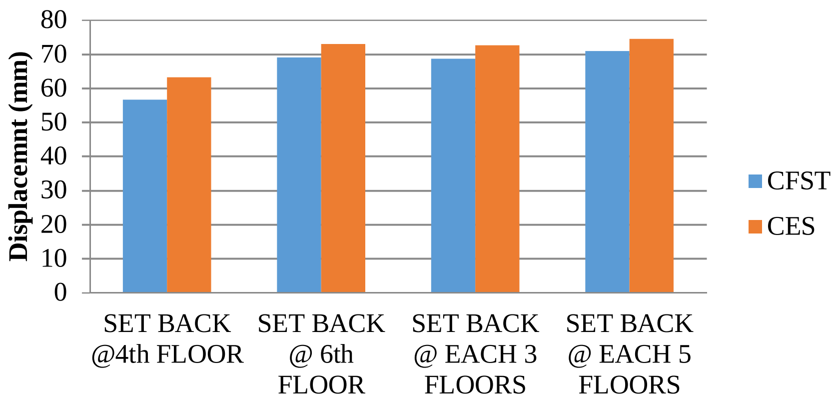


Fig. 7 Comparison of storey displacement in X-direction between CFST and CES columns

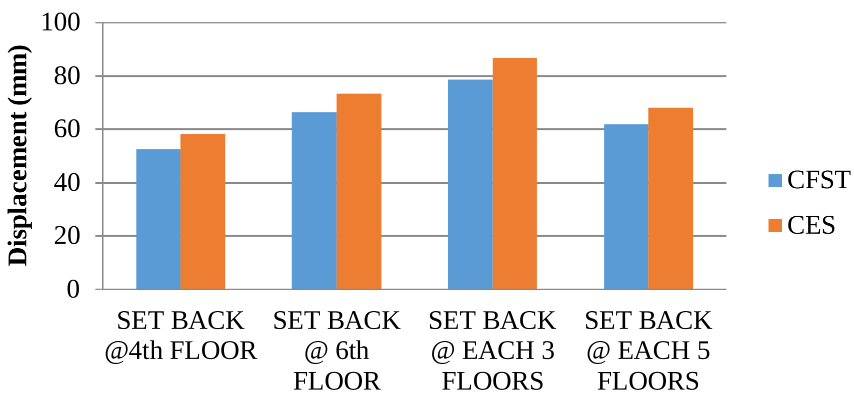


Fig. 8 Comparison of storey displacement in Y-direction between CFST and CES columns

The storey displacements were found to be lesser in case of CFST columns compared to CES columns. The setback @ each 3 floors building with CFST column performed well due to increased in the reduction percentage when compared to CES column.

C. Drift

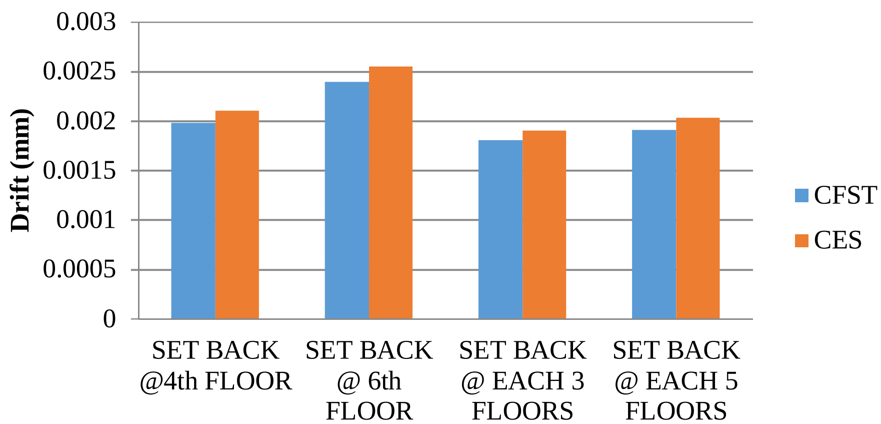


Fig. 9 Comparison of storey drift in X-direction between CFST and CES columns

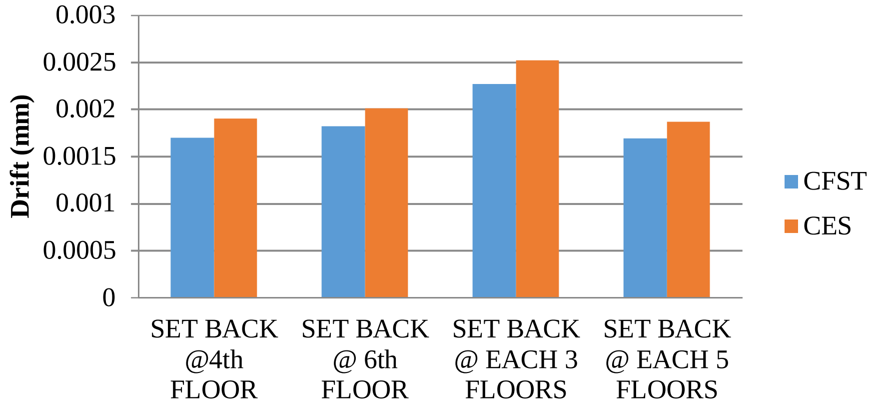


Fig. 10 Comparison of storey drift in Y-direction between CFST and CES columns

The storey drift were found to be lesser in case of CFST columns compared to CES columns. The setback @ each 5 floors building with CFST column performed well due to increased in the reduction percentage when compared to CES column

VI. CONCLUSIONS

In this present study the attempt is made to find which type of composite column is effective to resist the lateral deformation in a multi-storied building by response spectrum analysis. The time period, storey displacement and drift are plotted and compared for each of the model. The following conclusions are made based on analysis:

1) In case of setback @ 4th storey building with CFST composite column the time period reduced by 5.55%,the displacement reduced by 5.6% and 10.03 % (both in x and y direction) and the storey drift reduced by 7.6% and 13.34% (both x and y direction) compared to CES composite column.
2) In case of setback @ 6th storey building with CFST composite column the time period reduced by 9.04%,the displacement reduced by 5.5% and 9.39% (both in x and y direction) and the storey drift reduced by 6% and 4.9% (both x and y direction) compared to CES composite column.
3) In case of setback @ every 3 floors building with CFST composite column the time period reduced by 9.31%,the displacement reduced by 5.25% and 9.36% (both in x and y direction) and the storey drift reduced by 4.59% and 5.47% (both x and y direction) compared to CES composite column.
4) In case of setback @ every 5 floors building with CFST composite column the time period reduced by 5.77%,the displacement reduced by 4.97% and 9.11% (both in x and y direction) and the storey drift reduced by 5.63% and 9.51% (both x and y direction) compared to CES composite column.

From the above analysis results, it was concluded that CFST columns performed well in all the above four cases compared to CES columns; hence it is better to adopt the CFST columns for irregular buildings.

VII. ACKNOWLEDGMENT

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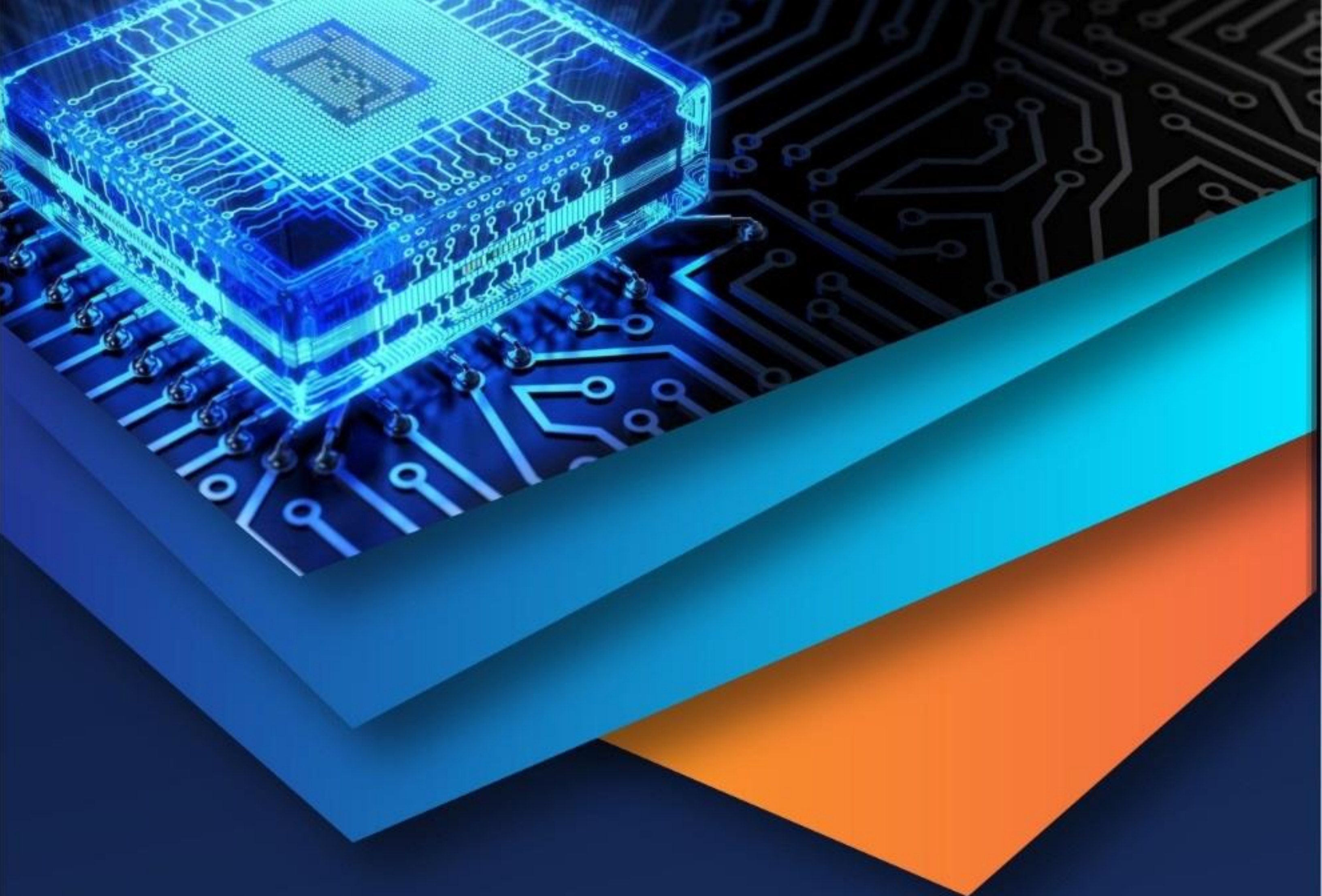

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