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Seismic Analysis of High-Rise Tube in Tube Structures with Different Bracing Conditions

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Abstract: Tall structures frequently have tubular structures. Frame tube, braced tube, tube in tube, and bundled tube constructions are examples of tubular structures. With a tubular structure, lateral loads can be resisted by designing the building to resemble a hollow cantilever that is perpendicular to the ground. Because they have less storey shear, storey displacement, and storey drift than other tubular systems, tube in tube structures are preferable. According to IS1893:2016 (Part 1), the influence of bracing type and position has been investigated in this study for a 20-story building in zone IV. Seismic metrics for braced and unbraced buildings are compared. The study at the building's corner and centre uses bracing made of angles and tubular sections. Seismic parameters are compared for unbraced and braced building. Angle and tubular section bracing are designed and used for the study at centre and corner of the building. From the study a comparative statement has been made for the use of bracing at different locations of tube in tube building. Comparative analysis will ease the designer to select the proper bracing type and location for high-rise tube in tube buildings.

Keywords: Bracing, Shear Wall, Seismic Analysis, Storey Drift, Tube in Tube Building

I. INTRODUCTION

Tall buildings frequently use tube in tube structures. It is made up of an outer tube and an inner tube. The outer tube is made up of heavy columns and deep beams that support gravity and lateral stresses, while the inner tube is a shear wall designed for lifts. Due to its substantial structural depth, the outer tube is crucial. The inner tube provides a column-free surface because it has a shear wall. These kinds of buildings are also known as hull and core constructions. Bracing is a construction method used to stabilize the building structure against lateral forces. It improves a building's capacity to withstand lateral loads imposed by wind and earthquakes. Buildings designed to withstand earthquakes must be braced in order to remain stable. In a frame structure, the bracing supports the horizontal loads while the beams and columns support the vertical loads. The main goal of bracing is to strengthen the building and prevent collapse due to an earthquake, wind gusts, or the effect of moving loads like cranes. It ensures the building's safety. Tube in tube structural form bracings provides additional resistance and stiffness in the building, making the system more effective than framed tube constructions. Tube in tube constructions with bracing models performed better than frame tube constructions. X braced framed tube structures and tube in tube structures with V bracing outperformed all other structural models that were tested [1]. The Time Period for Tubular structures reduced considerably when compared with the Tall RC Moment Resisting Frame Structure. The Base shear for Tall Tubular structures increased when compared to Tall RC Moment Resisting Frame Structure under the seismic loading. Story displacement and Storey drift got reduced in Tubular Structures compared to Tall RC Moment Resisting Structure and the value of top story displacement and storey drifts are well within the limits. Storey accelerations increased for Tubular structures over the Tall RC Moment Resisting Structure [2]. The main objectives of this study are to compare the seismic response of braced and unbraced structure against lateral loads in seismic zone IV as per IS 1893:2016.

II. METHODOLOGY

A. Model

In this study 20 storey building having 3m storey height is taken for study. The geometry of the building is rectangular. The buildings are modelled on Etabs 2018 software. The code used for designing these buildings is IS 456:2000 “Code of practice for plain and reinforced concrete”, IS 1893:2002 “Criteria for earthquake resistant design of structures”. Following models and nomenclature have been used in the model to categorise different models used in this study.

1) Regular - 20 storey rectangular tube in tube structure without bracing.
2) Bracing 1 - 20 storey rectangular tube in tube structure with angle section bracing at centre in all four faces of building.
3) Bracing 2 - 20 storey rectangular tube in tube structure with angle section bracing at corner in all four faces of building.

4) Bracing 3 - 20 storey rectangular tube in tube structure with tubular section bracing at centre in all four faces of building.
5) Bracing 4 - 20 storey rectangular tube in tube structure with tubular section bracing at corner in all four faces of building.

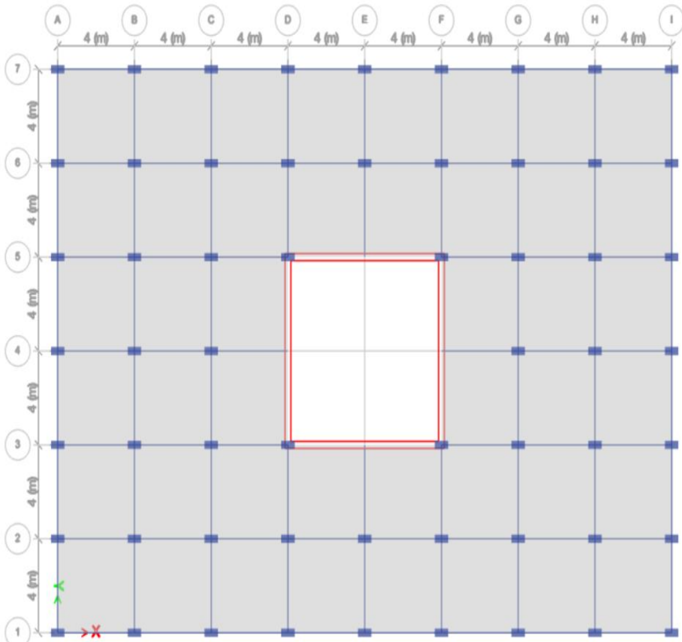

Fig. 1 Plan of 20 Storey Building

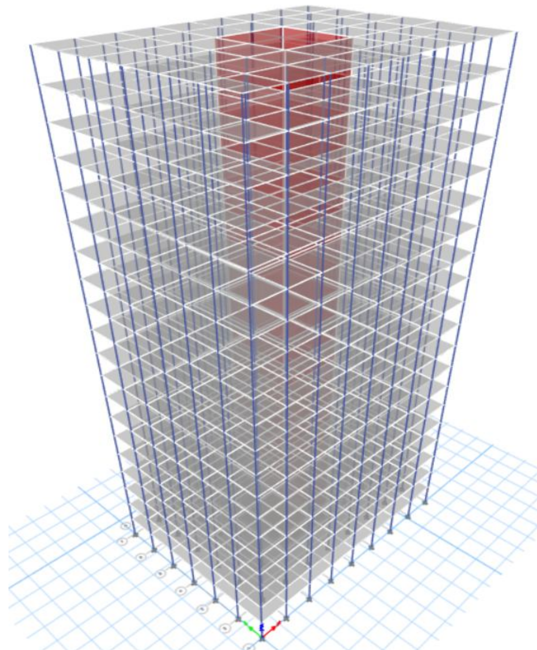
Fig. 2 3D view of unbraced tube in tube building

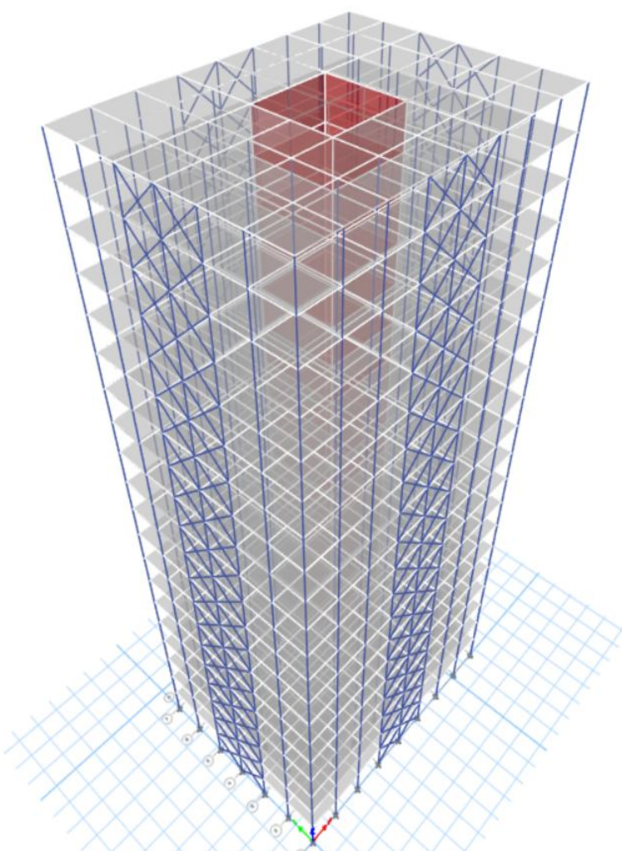
Fig. 3 3D view of braced tube in tube building

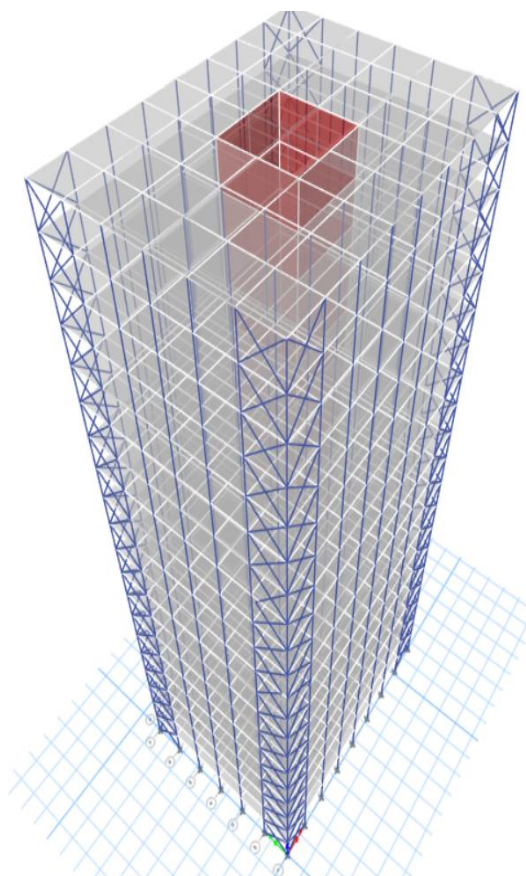
Fig. 4 3D view of braced tube in tube building at corner

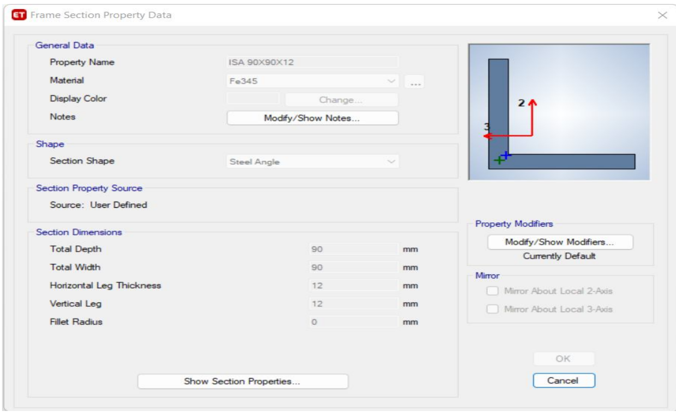

Fig. 5 Specification of Angle Bracing section

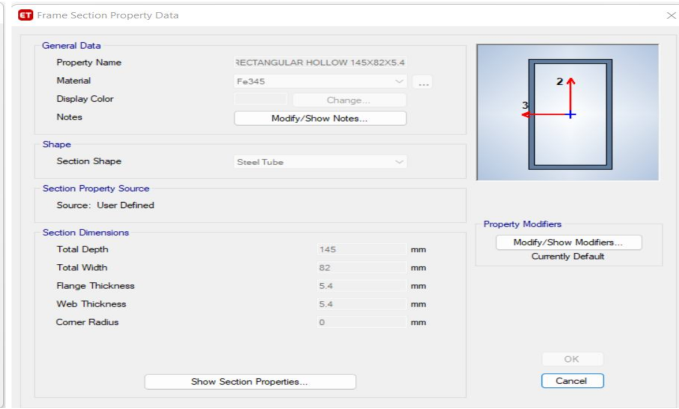

Fig. 6 Specification of Tubular Bracing section

B. *Geometrical Properties*

The geometric parameters of structures considered for study consist of the geometric plan structure height, storey height, span & floor area of structures. The geometric details are given in table 1. The beam sizes and column sizes are determined by the hit and trial method until the safe design is achieved.

Table 1. Element Properties

S.No.	Description	Specification
1	Number of stories	20
2	Story height	3 m
3	Length of the building	32 m
4	Width of the building	24 m
5	Spacing between grids	5 m
6	Grade of the concrete	M30
7	Size of beam	350 mm x 700 mm
8	Size of column	350 mm x 700 mm
9	Thickness of Slab	200 mm
10	Thickness of Shear wall	3000 mm
11	Seismic zone	IV

C. *Loading*

The designing criteria given in IS13920:2016 were followed for current work. Thus, the criteria given for selecting a grade of concrete and grade of steel has also been followed and as per clause 5.1 of IS 13920:2016 the grade of material given in table. 2. The loads applied on the structure were floor finish load and live load where live load on the roof and floor level are same.

Table 2. Loading Properties

S.No.	Parameter	Details
1	Floor Finished Load	1.2 kN/m^2
2	Exterior Periphery Wall	12.14 kN/m^2
3	Interior Wall	8 kN/m^2
4	Roof Live Load	1.5 kN/m2
6	Live Load on other levels	3 kN/m^2
7	Density of Masonry Wall	20 kN/m^2
8	Density of RCC	25 kN/m^3
9	Grade of Concrete	M30

The Indian standard code 1893:2016 (Part I) gives information of seismic parameters that are required in analysis of structures for the considered seismic zone. Zone 4 has been considered for this study.

D. Bracing Modelling

There is a design criterion for bracings in code IS 15988.2013 (seismic evolution and strengthen of existing reinforced concrete buildings-guidelines). As per clause 8.5.2.2 for circular sections the outside diameter to wall thickness ratio shall not be exceeded by 8960/fy. Tubular sections with an out-to-out width to wall thickness ratio shall not be exceeded by 288/ √fy. The width to thickness ratio of angle sections for braces shall not be exceeded by 136/√fy. Therefore, the cross section of the bracing members has been selected in such a way that the cross sections did not exceed those permissible limits (as per code).

Table 3. Bracing Parameters

Properties	Angle section	Tubular section
Nomenclature	90×90×12	145×82×5.4
Weight per unit length (kg)	15.8	17.74
Cross Sectional Area (cm^2)	20.2	22.60
Moment of inertia (cm^4)	150.3	262.6
Section modulus (cm^3)	42.9	73.7
Shear Area (cm^2)	9.9	14.9
Radius of Gyration (cm)	27.3	33.5

III. RESULTS AND DISCUSSION

The linear static analysis was carried out on tube in tube structure with and without bracing at different locations for zone IV. The sizes are obtained after number of trials of analysis and design process.

A. Time Period

Time period comparison is shown in figure7. It has been found that on incorporating bracing at centre of the building time period reduces by 5 %. Although both angle section and tubular section braced building show similar response. On using bracing at corners of the building time period reduces by narrow margin.

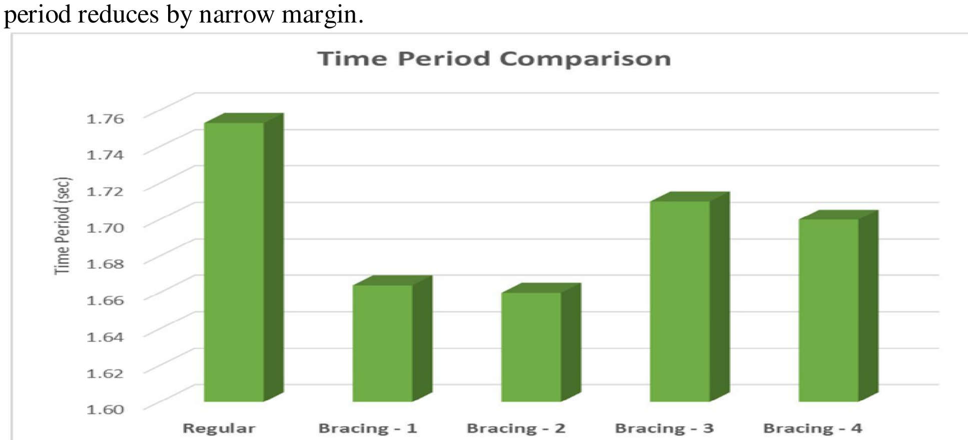

Fig. 7 Time Period Comparison

B. Storey Drift

Storey drift is shown in fig. 8. It has been found that unbraced tube in tube i.e. regular building have exceed storey drift limit at several floors. On using bracing at centre of the building storey drift reduces and falls down under permissible limit. Tubular section shows better performance. Centre bracing conditions performs well as compared to corner bracings. Similar condition occurs in Y direction also as compared for X direction. Although for Y direction building attracts more storey drift as compared to X direction.

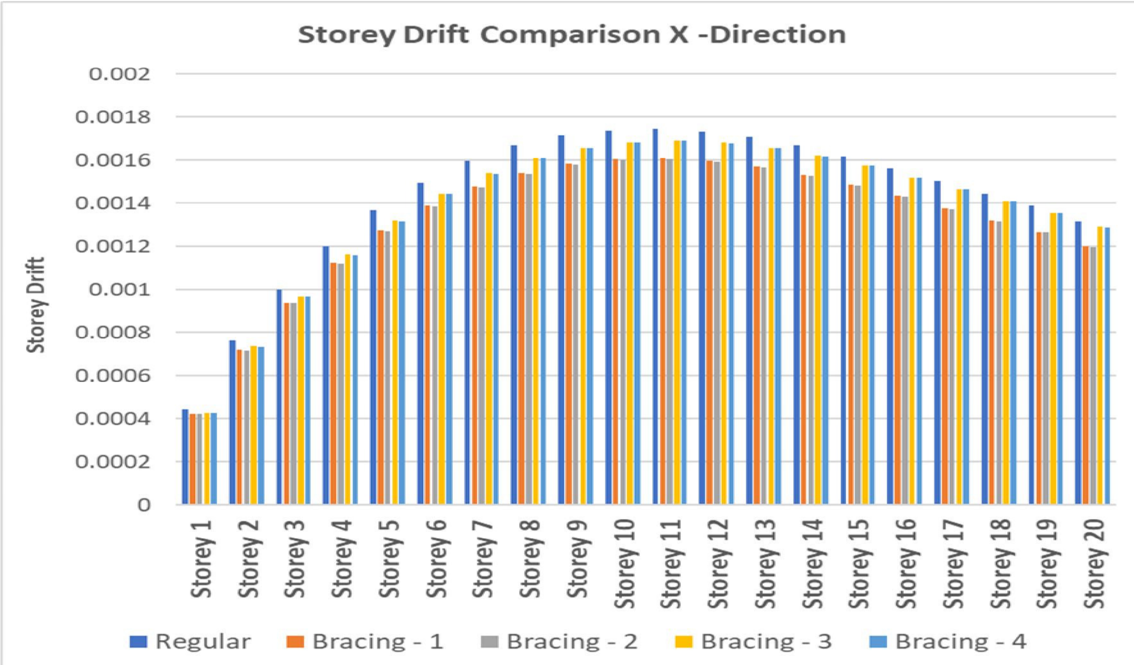

Fig. 8 Storey Drift Comparison

C. Storey Stiffness

Storey stiffness is shown in fig. 9. On incorporating bracing at different locations in regular tube in tube building, storey stiffness increases. Bracing at corner of the building provides more stiffness as compare to centre bracing system. Between angle and tubular section bracing, angle bracing system performs better.

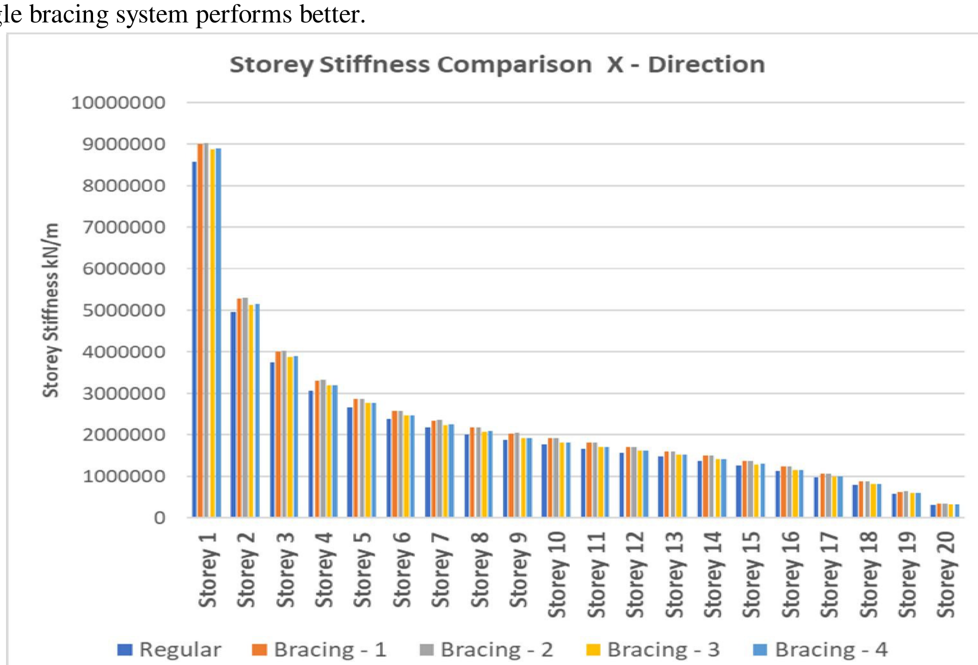

Fig. 9 Storey Stiffness Comparison

D. Maximum Storey Displacement

Maximum Storey Displacement is shown has been compared as shown in fig. 10. It has been found that on incorporating bracing at centre of the building maximum storey displacement reduces by 8%. Although both angle section and tubular section braced building show similar response. On using bracing at corners of the building time period reduces by narrow margin.

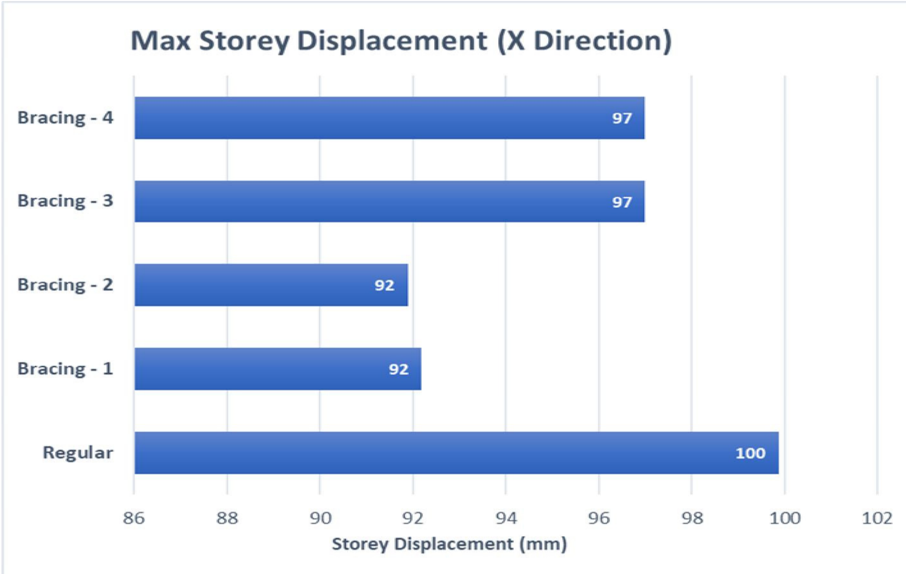

Fig. 10 Maximum Storey Displacement

IV. CONCLUSIONS

Following are the conclusions of the study –

1) It has been concluded that by selecting proper bracing section, the effect of the seismic parameters reduces significantly.
2) From the two-location decided for bracing i.e., centre and corner for the study, it has been found that centre bracing system with angle section performs well as compare to other bracing systema and location.
3) Storey drift and storey stiffness results validated that on incorporating bracing system, drift reduces, and stiffness increases.
4) It has been also concluded that bracing system in new as well as old tube in tube buildings will enhance the seismic performance of the building. Although no major change has been marked on comparing effect of angle section and tubular section.

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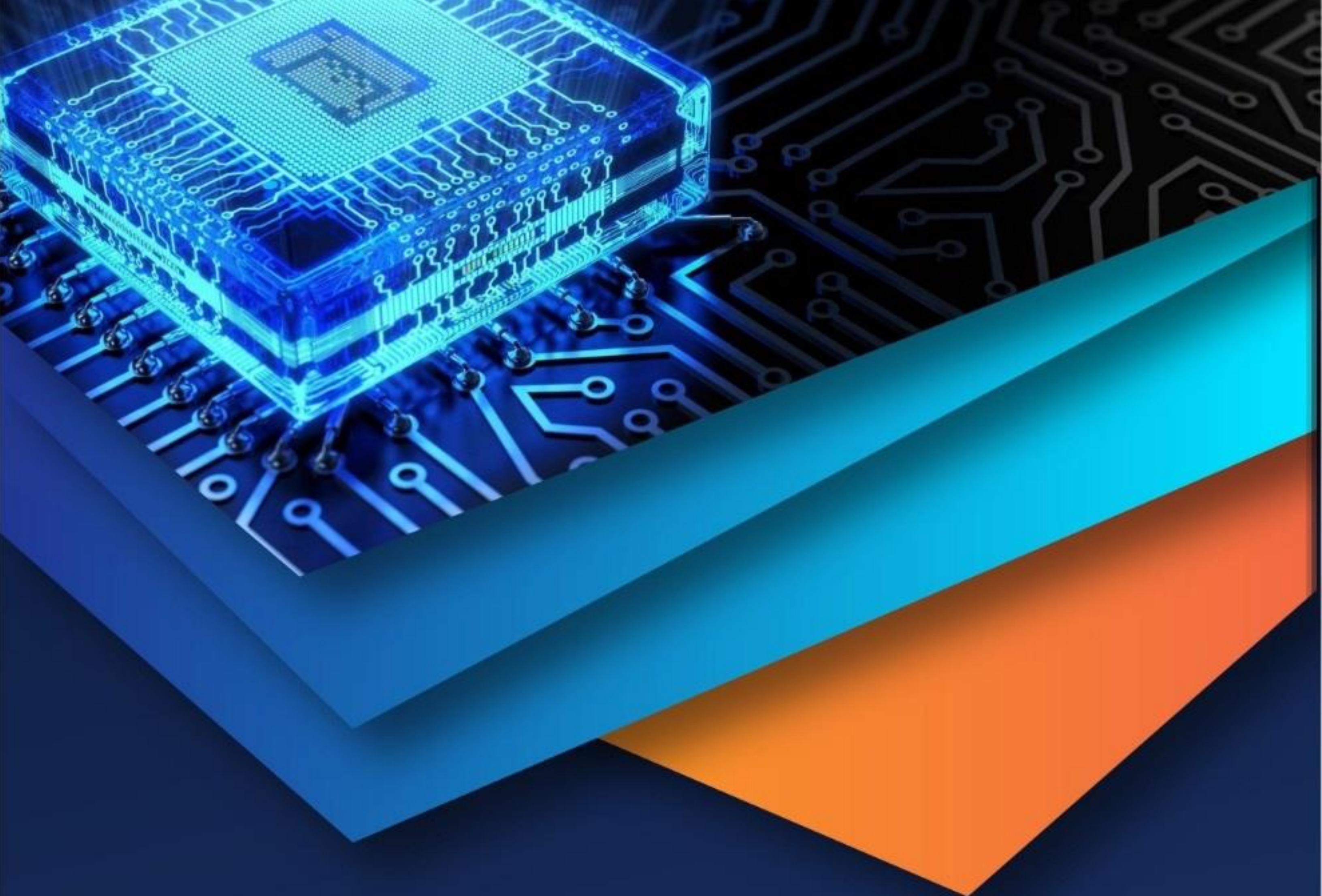

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