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Seismic Analysis of RC Frame Structure with Diagrid using ETABS

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Abstract: A 12-storey Diagrid building and a Bare-frame building are compared in this study. A 24 m x 24 m plus-shaped floor plan is taken into consideration. Structural member modelling and Response spectrum analysis are done with ETABS. Every structural member was designed in accordance with IS 456:2000, and the structure's analysis and design took into account load combinations like dead load, live load, and design earthquake loads & wind loads. A comparison was made between later RC frames with and without diagrid structural systems.

Keywords: Tall buildings, RC frame structure, RC Diagrid Structural System. Storey Displacement, Storey Drift, Storey Shear, Storey Stiffness, Response Spectrum.

I. INTRODUCTION

Taller buildings are preferred these days due to the fast urban population growth and land shortage. Therefore, lateral load consideration becomes crucial as the structure's height increases. Systems that can withstand lateral loads are more crucial than those that can withstand gravitational loads. The diagonal grid structural system has been used extensively for tall buildings in recent years because of its unique geometric configuration, which offers both structural efficiency and aesthetic potential. Thus, the diagrid's structural efficacy and aesthetic appeal have rekindled interest in tall building architecture and structural design.

An exterior structure known as a "diagrid structural system" is made up of a framework of beams made of concrete, metal, or wood that intersect diagonally in buildings. Because of its flexibility in architectural planning and structural efficiency, the diagrid structural system has recently been used in tall buildings. The diagrid structure is made up of inclined columns on the outside of the building as opposed to vertical columns that are closely spaced in a framed tube. In contrast to the bending of vertical columns in a framed tube structure, the axial action of the diagonal in inclined columns resists the current lateral loads. Since the diagonals on the building's periphery can carry lateral shear, diagrid structures typically do not require a core. The absence of traditional vertical columns distinguishes the diagrid structural pattern from the exterior-braced conventional frame structural pattern. Previous Indian earthquakes have demonstrated that both engineered and non-engineered structures must be designed to withstand seismic loading. Diagrid can be supplied to improve the structural performance under seismic loading and to increase the performance under lateral loading. In addition to increasing the natural frequency and typically decreasing lateral drift, diagrids enable the system to achieve a significant increase in lateral stiffness. An Example of Diagrid Structure is IBM Building Located in Pittsburgh was Constructed In 1960. Another Examples are Hearst Tower in New York and Cyclone Tower Asan (Korea), New World Trade Centre in New York.

Diagrid is visually appealing and conspicuous. A diagrid system's efficiency and design minimize the number of structural elements needed on a building's facade, which lessens the obstruction to the exterior view. The diagrid system's structural effectiveness also aids in avoiding corner and interior columns, giving the floor plan a great deal of flexibility. Because of their triangular shape, the diagonal members in diagrid structural systems can support both lateral and gravity loads. Nevertheless, the main drawbacks of the diagrid system are that it has not yet been fully investigated. This constructions requires skilled labours, the current crew lacks knowledge or experience in diagrid installation.

Fig.1. RC bare frame and RC diagrid structures

Fig.2. Hearst tower

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A. Response Spectrum Analysis

The response spectrum technique to earthquake evaluation is a useful tool for projecting member displacements and forces in structural systems. This method determines the highest values in relation to member forces and displacements in each vibration mode using smooth design spectra, which are averages of multiple earthquake movements. Response spectra are curves that show the maximum response of a single-degree-of-freedom (SDOF) system to the ground motion and time period (or frequency) of a particular earthquake. The area of maximum response for a given damping ratio of the SDOF system is represented by the response spectrum. It could assist in the design of earthquake-resistant structures and be used to evaluate the lateral forces produced in a structure during an earthquake.

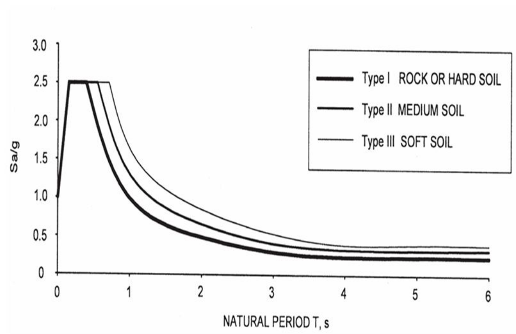

Fig.3. spectra for response spectrum analysis

II. THE OBJECTIVES OF THE PROPOSED RESEARCH

A. Introduction

This study compares a 12-story RC bare frame building with a diagrid structural system building of the same design. A straightforward 24 x 24 m floor plan was taken into consideration. A 12-story building with a 3.5-meter floor height was the subject of the analysis, and the findings are shown in terms of top storey displacement, storey drift, storey shear, and storey stiffness. Using diagrids, the current study will assess the G+11-story RC frame structure's seismic response. Response spectrum analysis (RSA) under earthquake loading is modelled using ETABS software in a straightforward computer-based manner.

B. Objectives

1) To comprehend the RC framed structure's behaviour using diagrids.
2) The purpose of this study is to determine the best configuration for effectively withstanding seismic loads and to assess how bare frame and frame with diagrid structure respond to such loads.
3) In order to assess the base shear, storey drifts, and storey displacement, storey stiffness for both RC bare frames and RC frames with diagrid structures.
4) To comprehend how RC bare frames and RC frames with diagrids behave in zone V, as well as RC frames with diagrids comparing in zones II, III, IV, and V.

C. Methodology

The project investigation was divided into two stages. A literature review that included online searches, eBooks, guides, passwords, and journal articles was used to gather the primary data. The issue statement is created after the evaluation, and the model is ready for in-depth investigation and analysis. The following guidelines will guide the conduct of this study:

1) Evaluation of building structure and response spectrum analysis applications through a comprehensive review of the literature.
2) Research on the RC diagrid frame.
3) System creation and material specification.
4) RC bare frame and RC diagrid frame modelling using ETABS software.
5) Analyse the models using response spectrum.
6) Findings and discussions.
7) Conclusion.

III. ANALYSIS & MODELLING OF A G+11 STOREY STRUCTURE

A. *Building Configuration*

The 12-storey structure has a plan dimension of 24 x 24 m and a total height of 42 m. The height of the storeys is 3.5 m between each floor. The two models used for the comparative study are a diagrid structure and a RC bare frame building. The building is identical for both models, with M40 grade concrete, HYSD550 bars for reinforcement, and beam and column sizes of 230 x 450mm and 450 x 450mm, respectively. The slab thickness is 150 mm. The diagonal member, or diagonal, measures 450 x 450 mm. On terrace level, the applied dead load and live load are 0.22 kN/m^2 and 0.75 kN/m^2, respectively. For a typical floor slab, the applied dead and live loads are 1 kN/m^{2}and 2.5 kN/m^2, respectively, and the wall load is 14 kN/m. According to IS 875(part-III): 2015, the wind load applied to the buildings is 44 m/s. The category of terrain is IV. According to IS-1893-2016 (Part I), the zone factor, importance factor, and response reduction are used to calculate the design earthquake load for soil type II. According to IS-1893-2016(Part I), the design earthquake load is taken into account in seismic analysis, which means that 25% of the live load is taken into account. The building's a/l ratio was taken into account and is significantly higher than the allowed limits. ETABS 2022 software was used for the modelling, analysis, and design of the diagrid structure. It is assumed that the diagrid's end condition is hinged, its support conditions are fixed, and its member design complies with IS-456 2000.

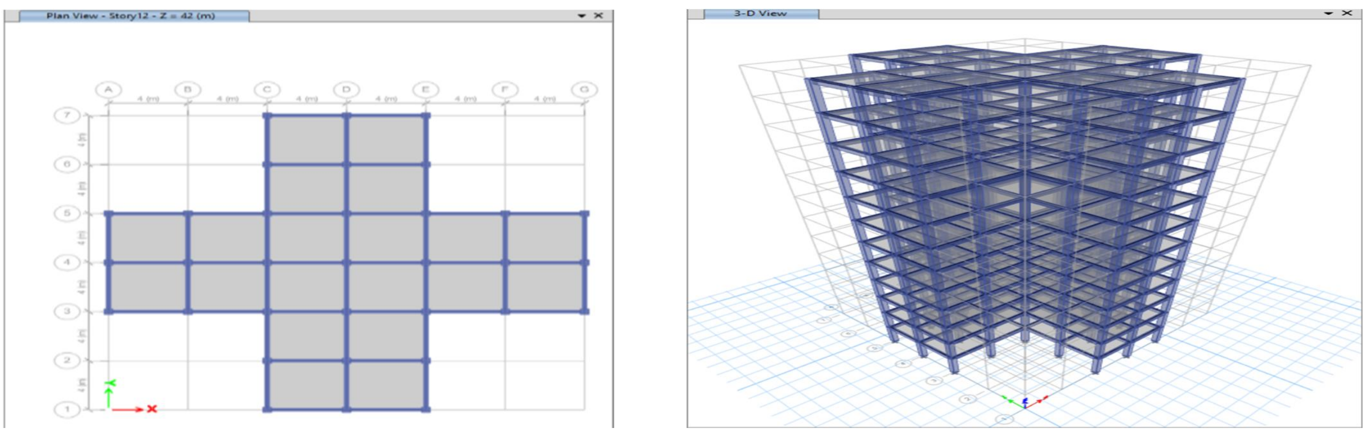

Fig 4. Plan & 3D-view of RC bare frame

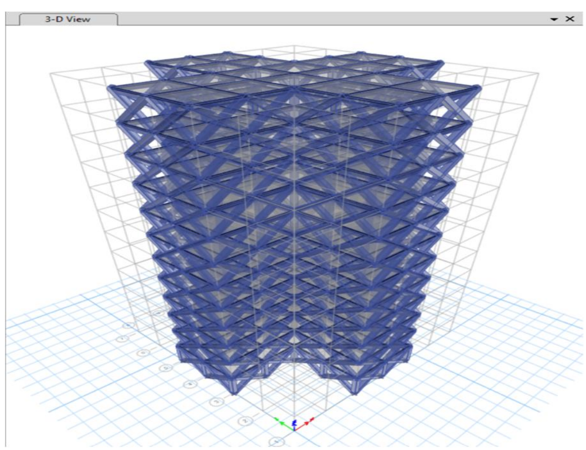

Fig 5. 3D-view of RC Diagrid frame

IV. RESULTS & DISCUSSIONS

In the zone V, the deformed shapes of the structures are compared between the RC diagrid frame and the RC bare frame in the outer periphery.

1) *Storey Displacement:* Taking into consideration a G+11-story reinforced concrete building, the dynamic analysis yielded the storey displacement value. The following lists the storey displacement of G+11 storey building models that are subjected to earthquake loads in the direction of RSX (response spectrum in X- direction).

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Table 1. storey displacement of plus-shaped RC frame & diagrid frame building models in zone-V at each floor level subjected to RSX.

Storey Displacement Along RSX, (mm)		
Storey No.	RC Bare Frame	Diagrid Frame
12	23.843	9.879
11	23.208	8.904
10	22.227	7.899
9	20. 904	6.877
8	19.277	5.848
7	17.379	4.829
6	15.236	3.839
5	12.864	2.9
4	10.278	2.033
3	7.501	1.271
2	4.591	0.668
1	1.759	0.255

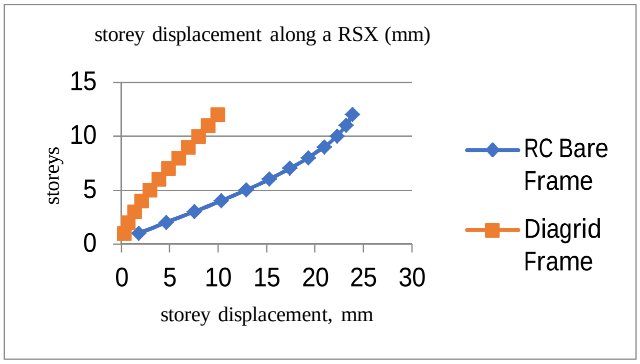

Fig 6 storey displacement of plus-shaped RC frame & RC diagrid building models in zone-V at each floor level subjected to RSX.

The findings show that the RC bare frame has the largest storey displacement, while the RC diagrid frame has the smallest. Additionally, it is evident that the top storey of an RC bare frame experiences the greatest storey displacement, while the base experiences the minimum storey displacement.
Compared to RC frames with diagrid, storey displacement is reduced by 58.56%. As a result, RC frames with diagrids work better than bare frames.

2) Storey Drift:

The difference between the displacement in the lower and higher storeys is known as storey drift. The ratio of storey drift to the structure's overall height is known as the drift ratio.

Table 2: storey drift of plus-shaped RC frame & RC diagrid building models in zone-V at each floor level subjected to RSX

Storey Drift Along RSX		
Storey No.	RC Bare Frame	Diagrid Frame
12	0.000218	0.000301
11	0.000341	0.00031
10	0.00045	0.000316
9	0.000538	0.000319
8	0.000608	0.000316
7	0.000665	0.000306
6	0.000714	0.000287
5	0.000761	0.000266
4	0.000804	0.000236
3	0.000835	0.000194
2	0.000811	0.000135
1	0.000503	7.3E-05

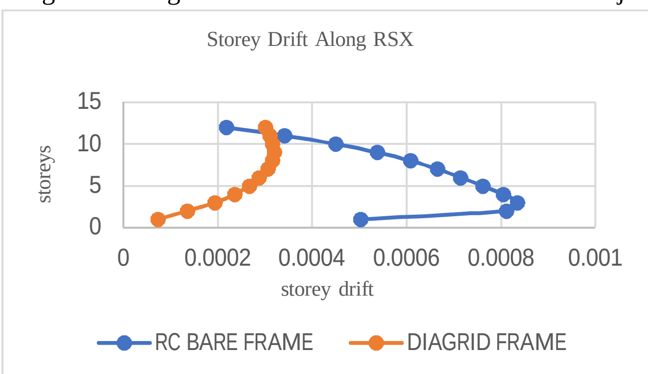

Fig 7: storey drift of plus-shaped RC frame & RC diagrid building models in zone-V at each floor level subjected to RSX.

According to the findings, storey drift is lowest for RC frames with diagrid and highest for RC frames without. Furthermore, it is evident that the storey-3 is where the RC bare frame experiences the greatest storey drift. Compared to RC frames without diagrid, the maximum storey drift is reduced by 61.7%. As a result, RC frames with diagrids work better than bare frames.

3) *Base Shear*

The maximum anticipated lateral force that will result from seismic ground motion at a structure's base is estimated by base shear. Base shear (V) calculations are dependent on the site's soil conditions and the distance from possible seismic activity sources.

Table 3: storey shear of plus-shaped RC frame & RC diagrid building models in zone-V at each floor level subjected to RSX.

Storey Shear Along RSX, (kN)		
Storey No.	RC Bare Frame	Diagrid Frame
12	128.8248	365.525
11	251.9065	767.0387
10	346.8311	1098.2747
9	420.9485	1373.7728
8	480.7351	1603.9613
7	530.2843	1797.3555
6	575.7702	1960.647
5	621.1596	2096.4454
4	665.8115	2203.9441
3	708.4162	2281.4112
2	743.635	2327.3332
1	760.3579	2346.9478

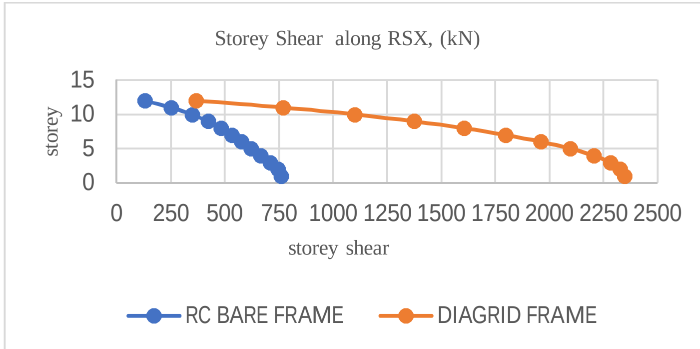

Fig 8: storey shear of plus-shaped RC frame & RC diagrid building models in zone-V at each floor level subjected to RSX.

It can be seen from the results that a storey shear decreases as the building's height increases. The RC bare frame has the least storey shear, while the RC frame with diagrid has the most. It is evident that the storey-1 experiences the highest storey shear for both models. From RC bare frame to RC frame with diagrid, it is evident that the storey shear is increased by 67.6%. Thus, RC frames with diagrids are more effective during an earthquake based on serviceability criteria.

4) *Storey Stiffness*

Table 4: storey stiffness of plus-shaped RC frame & RC diagrid building models in zone-V at each floor level subjected to RSX.

Storey Stiffness Along RSX, (kN/m)		
Storey No.	RC Bare Frame	Diagrid Frame
12	169784.726	376844.472
11	211475.554	758919.537
10	220025.453	1061012.823
9	223494.903	1315468.512
8	225949.11	1549640.266
7	227970.74	1787292.75
6	230283.519	2055900.003
5	233176.796	2410724.519
4	236596.919	2922008.792
3	242460.94	3812803.323
2	262192.348	5961945.77
1	433292.62	11453832.83

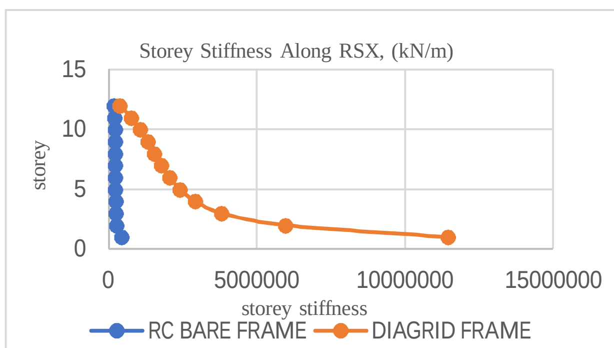

Fig 9: storey stiffness of plus-shaped RC frame & RC diagrid building models in zone-V at each floor level subjected to RSX.

The findings indicate that a storey's stiffness decreases as the building's height increases. A bare RC frame has the least amount of storey stiffness, while a diagrid RC frame has the most. It is also evident that the storey-1 is where the two models' maximum storey stiffness is found. Compared to RC bare frames, storey stiffness is shown to have increased by 96.21% when using RC frames with diagrid. In contrast to RC bare, which has a stiffness of only 3.79%, RC frames with diagrid have the highest storey stiffness at the base. Accordingly, RC frames with diagrids are more effective during an earthquake based on serviceability ratings.

V. CONCLUSION

Diagrid structures are well-known for being effective structural systems for buildings subjected to high lateral loads, like wind or seismic loads. It is possible to greatly increase the frame's lateral resistance by adding a diagrid system. Diagrid systems have the potential benefits of a relatively small mass increase and faster execution of application.

A. Results on Comparison of RC Bare Frame and RC Diagrid Frame in Zone- V.

1) The storey displacement and storey drift is maximum for RC bare frame and minimum for RC diagrid frame.
2) Storey displacement is decreased by 58.56% from RC bare frame to RC diagrid frame system.
3) Storey drift is decreased by 61.7% from RC bare frame to RC diagrid frame.
4) Maximum storey shear is observed at the base in the two models, storey shear is increased by 67.6% from RC bare frame to RC diagrid frame.
5) Storey stiffness is minimum for RC bare frame and maximum for RC diagrid frame.
6) Stiffness is increased by 96.21% from RC bare frame to RC diagrid frame.

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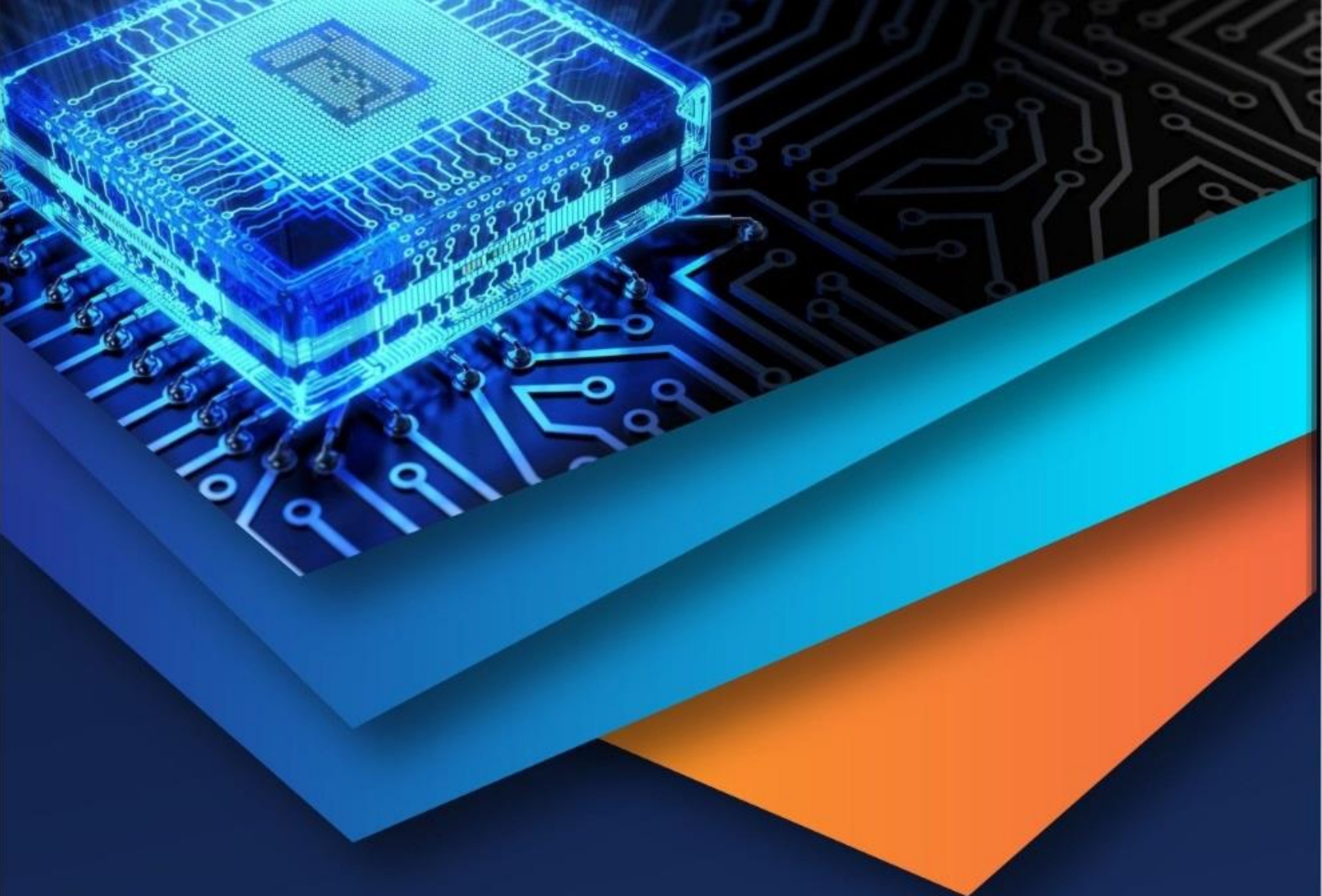

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