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Design Optimization and Analysis of Shear Wall in High Rise Buildings Using ETABS

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Abstract: The shear wall is a structural element which is used to resist earthquake forces. These wall will consumptives shear forces & will prevent changing location-position of construction & consequently destruction. On other hand, shear wall arrangement must be absolutely accurate, if not, we will find negative effect instead. For example if the shear walls make an increase distance between mass centre and hardness centre, we cannot expect a good tensional behavior from the structure. In case of mass centre and hardness centre coincide with each other, at that time the distance of shear wall from the mass centre also plays an important role in the shear contribution of the shear wall. The bending moment, shear force, torsion, axial force contribution by rest of the structural element and the ultimate design of all the structural components also affected by that.

A study has been carried out to determine the optimum Structural configuration of a multistory building by changing the shear wall locations. Three different cases of shear wall position for a 15 storey residential building with keeping zero eccentricity between mass centre and hardness centre have been analyzed and designed as a space frame system by computer application software, subjected to lateral and gravity loading in accordance with IS provisions.

Keywords: Skyscraper, exaggeration, Response spectrum, Shear wall.

I. INTRODUCTION

A. General

In modern civilization tall buildings have rapidly developed worldwide. Tall buildings are symbols of civilized, congested and populated society. It certainly resembles the economic growth, the force and the image of a civilization. A Tremendous variety of field of study shapes and complicated structural layouts are designed. The design of tall buildings essentially involves an approximate analysis, conceptual design, preliminary design and what's more, advancement, to securely convey gravity and horizontal burdens. The design criterion is strength, serviceability, stability and also human comfort. The strength is satisfies by limit stresses, while serviceability is satisfies by drift limits in the range of H/300 to H/500. Stability is satisfied by sufficient safety factor against buckling and P-Delta effects. The safety factor is around 1.67 to 1.92. The human comfort aspects are satisfied by accelerations are in the range of 10 - 25 mg, where, g -acceleration due to gravity= 981cms/sec^2.

High-rise buildings are constructed everywhere in the world. The structural design of high-rise buildings depends on dynamic analysis for winds and earthquakes. Now a day's performance of computer progresses remarkably, almost structural designers use the software of computer for the structural design of high-rise buildings. Hence, after that the structural plane and outline of high rise buildings are determined, the structural design of high-rise buildings which checks structural safety for the individual structural members is not necessary outstanding structural ability by the use of structural software on the market. However, it is not an exaggeration to say that the performance of high-rise buildings is almost determined in the preliminary design stages which work on multifaceted examinations of the structural form and outline.

The static and dynamic structural behaviors of high-rise buildings are governed by the distributions of transverse shear stiffness and bending stiffness per each storey. The deformations of high-rise buildings are composed of the axial deformation, bending deformation, transverse shear deformation, shear-lag deformation, and torsional deformation.

Today's tall buildings are becoming more and more slender, leading to the possibility of more sway in comparison with earlier high-rise buildings. Therefore, the time dependency of concrete has become another important factor that should be considered in analyses to have a more reasonable and economical design.

In this study we considering a 15 storey high rise building for shear wall design and optimization by using the software E-tabs and the shear walls are arranged in such a way to resist the lateral forces in zone III region according to Indian codes.

B. Advantages of shear wall in Skyscraper

Properly designed and detailed buildings with shear walls have very good performance in earthquakes. The shear walls are oriented in one direction, so only lateral forces in that direction can be resisted. Shear wall can be defined as structural vertical member that is able to resist combinations of shear, moment and axial load induced by lateral wind load and gravity load transferred to the wall from other structural members. The use of shear wall structure has gained popularity in high rise building construction, especially in the construction of service apartment or office/commercial tower. The overwhelming success of buildings with shear walls in resisting strong earthquakes is summarized as "we cannot afford to build concrete buildings meant to resist severe earthquakes without shear walls". Shear wall resist to the lateral forces.

C. Objectives

1) Behavior study of 15storey high rise RCC structure with shear walls for seismic & wind loads.
2) The variation of storey drifts of the models to be studied.
3) The variation of displacement has to studied
4) Both equivalent static analysis and Response spectrum analysis are to be carried out
5) Optimum location of shear wall.

D. Scope

Earthquakes are occurring frequently now a day. The seismic analysis and design of buildings has traditionally focused on reducing the risk of loss of life in the largest expected earthquake. To reduce the effects caused by these earthquakes and wind loads different lateral loading systems are introduced in the structures. Position of shear walls in unsymmetrical buildings has due considerations. It is very necessary to determine efficient and ideal location of shear wall.

II. LITERATURE REVIEW

A. General

Extensive literature study has been carried out from national and international journals. The journals like International Journal of Research in Engineering and Technology, International Journal of Innovative Research and Development, IJERA, etc., are studied.

B. Effect of shear wall location in rigid frame on earthquake response of roof structure by Koichiro, etal (2001)

The purpose of this study is to investigate the effect of shear wall location in rigid frames on the dynamic behavior of a roof structure due to vertical & horizontal earth quake motion. Large horizontal stiffness difference between the side frames is caused by the shear wall location which results in large vertical vibration of the roof & large shear at the side bearings .The study has carried out the earthquake response analysis of gabled & flat beams supported by bearing structures.

C. Structural configuration optimization of a multi storey building by optimum positioning of shear wall by Tanwer, et al (2012)

This study has been carried out to determine the optimum structural configuration of a multistory building by changing the shear wall location radially .Four different cases of shear wall position for a residential building with keeping zero eccentricity between mass centre and hardness centre have been analyzed and designed as a space frame system by computer application software .A model building is designed with design data by using STRUD software. Comparison of analysis and design data of four different cases having various radial position of shear wall generated in the STRUD.

D. Effect of shear wall location in buildings subjected to seismic loads By Lakshmi, et al (2014)

This study deals with shear wall systems which are one of the most commonly used lateral load resisting systems in high rise buildings .This study is about comparing various parameters such as storey drift, storey shear, deflection, reinforcement requirement in columns etc. of a building under lateral loads based on linear & nonlinear analysis procedures are adopted and shear wall location on various parameters are compared .The capacity spectrum is used to obtain the overall performance level of a structure by using E-TABS software .The results obtained from the study are as follows
Response spectrum analysis results provides a more realistic behavior of structure response & hence it can be seen that the displacement values in both X & Y directions are least in model with shear wall in core & corners when compared to all models.

III. METHODOLOGY

A. General

Structural analysis was carried out by means of well-known computer program E-tabs issued for the linear structural analysis of buildings subjected to static and dynamic loads, is documented. Efficient model formulation and problem solution is achieved by idealizing the building as a system of frame and shear wall substructures inter-connected by floor diaphragms.

B. Method of analysis

Design of 15 storey high rise building and optimization of shear wall is done by computer aided software E-Tabs. Plan generated in Auto cad is imported and modeled in E-Tab. This model is analyzed for axial and lateral loads and the results are studied. For optimization of shear wall location shear wall is placed in three different locations and the results obtained such as displacements, drifts, storey shears are studied and compared.

1) *Sequence of work:* The sequence of work done is represented in a flow chart form in figure 3.1.

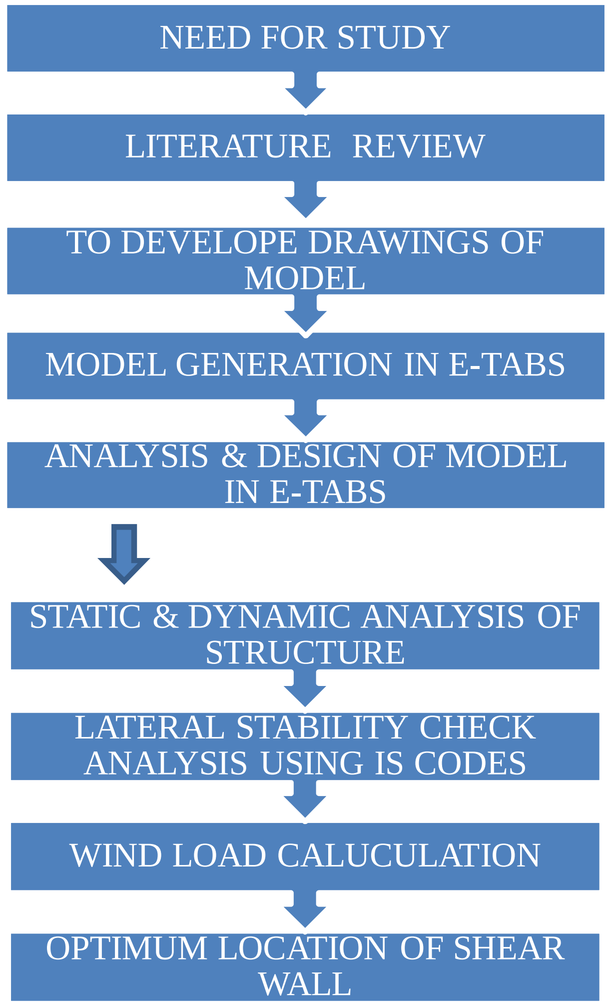

Fig3.1: Flow chart of methodology

IV. MODELING AND DESIGN

A. Building considerations

A high rise building is assumed for seismic analysis that consists of a G+14 R.C.C. residential building. The plan of the building is irregular in nature but considered as it is regular for easy analysis. The building is located in Seismic Zone III and is constructed on medium type soil. The building is 54.4m in height 18.69m in length and 18.99m in width. The important details of the structure are as follows.

B. Load considerations

Dead Load (DL) and Live load (LL) have been taken as per IS 875 (Part 1) (1987), IS 875 (Part 2) (1987) and IS 875 (Part 3)

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(1987), respectively. Seismic load calculation has been done based on the IS 1893-2000 (Part 1) approach.

C. LOADS

A building is subjected to the following loads during its service life.

1) Dead Load: The dead loads in a building shall compromise of the weight of all the walls, partition walls, floors and roofs and shall include the weight of all the other permanent constructions in the building.

2) Live Load: Live loads are also called the superimposed loads and include all the moving or variable loads, due to people or occupants, their furniture, temporary stores, machinery etc. Live loads on floors shall compromise of all loads other than the dead loads. The various live loads acting on the different floors are given in IS 875: 1998

3) Earthquake Load: EQ load acts on the structure during earthquake. It will act horizontally on the structure. It is also called as seismic force.

The following load combinations are considered as per IS codes and the model is analyzed for critical load condition.

a) 1.5(DL+LL)
b) 1.5(DL+LL+SIDL)
c) 1.2(DL+LL+SIDL+WL)
d) 1.2(DL+LL+SIDL-WL)
e) 1.5(DL+SIDL+WL)
f) 1.5(DL+SIDL-WL)
g) 0.9(DL+SIDL)+1.5WL
h) 0.9(DL+SIDL)-1.5WL
i) 1.2(DL+LL+SIDL+EQ-X)
j) 1.2(DL+LL+SIDL-EQ-X)
k) 1.2(DL+LL+SIDL+EQ-Y)
l) 1.2(DL+LL+SIDL-EQ-Y)
m) 1.5(DL+SIDL+EQ-X)
n) 1.5(DL+SIDL-EQ-X)
o) 1.5(DL+SIDL+EQ-Y)
p) 1.5(DL+SIDL-EQ-Y)
q) 0.9(DL+SIDL)+1.5EQ-X
r) 0.9(DL+SIDL)-1.5EQ-X
s) 0.9(DL+SIDL)+1.5EQ-Y
t) 0.9(DL+SIDL)-1.5EQ-Y
u) 1.5(DL+SIDL)

4) Mathematical model: The three dimensional view and plan of the building are showed in figure 4.1and 4.2 respectively.

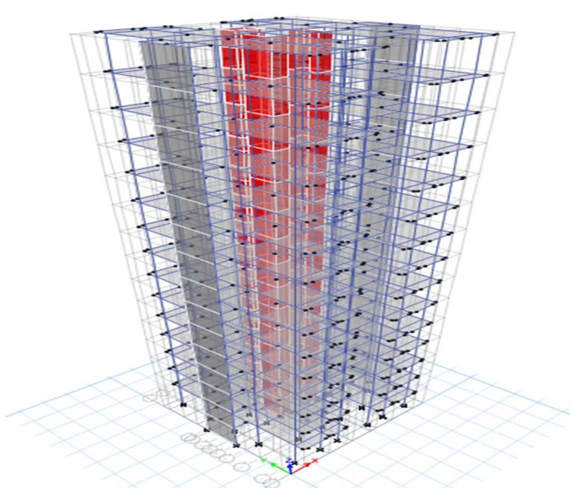

Fig 4.1.-3D view of the building

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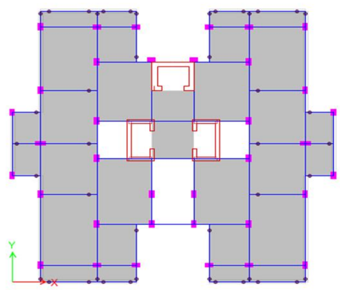

Fig 4.2: Plan of the building

Table 4.1: floor to floor height of the building

Floor ID	Floor to floor height (m)	Elevation (m)
Storey 15	3.6	54.4
Storey 14	3.6	50.8
Storey 13	3.6	47.2
Storey 12	3.6	43.6
Storey 11	3.6	40
Storey 10	3.6	36.4
Storey 9	3.6	32.8
Storey 8	3.6	29.2
Storey 7	3.6	25.6
Storey 6	3.6	22
Storey 5	3.6	18.4
Storey 4	3.6	14.8
Storey 3	3.6	11.2
Storey 2	3.6	7.6
Storey 1	3.6	4
Base	4	0

1) Optimization of shear wall: The present work deals with the study of effect of seismic and wind loading on placement of shear walls in 15 storey high rise building at different locations. The residential high rise building is analyzed for earthquake force and wind force. Shear wall is placed at different positions of building and optimization of shear wall has been studied. The optimum location for the particular case is found and compared with the rigid frame. The analysis is carried out by using standard package ETABS.

The different cases considered are:
Case A - without shear wall
Case B – shear wall at corners
Case C – shear wall parallel to X-axis
Case D – shear wall parallel to Y-axis

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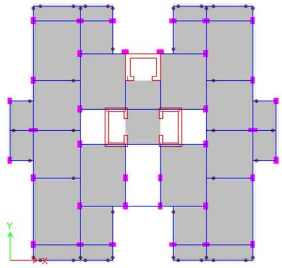

Fig 4.3: Model without shear wall

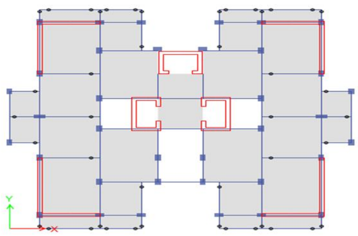

Fig 4.4:Model with shear wall at corner

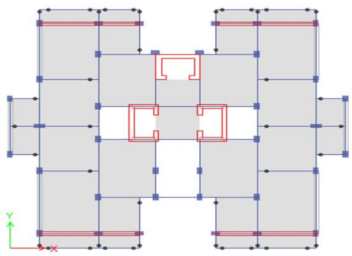

Fig 4.5:Model with shear wall parallel to x-axis

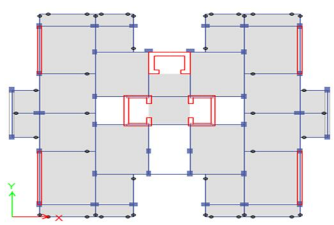

Fig 4.6: Model with shear wall parallel to y-axis

2) *Displacement:* According to IS 456:2000, the allowable displacement is 0.04H (H/250) where h is the storey height and H is the total height of the building, for a partial safety factor of 1.0.
3) *Design*

D. Seismic coefficient method (static method)

Seismic analysis of most structures is still carried out on the assumptions that the lateral (horizontal) force is equivalent to the actual (dynamic) loading. This method is usually conservation for low to medium-height buildings with a regular conformation.

Static method values:

Direction and Eccentricity

Direction = Multiple

Eccentricity Ratio = 5% for all diaphragms

Factors and Coefficients:

Seismic Zone Factor, Z [IS Table 2]
Response Reduction Factor, R [IS Table 7]
Importance Factor, I [IS Table 6]
Site Type [IS Table 1] = II
Seismic Response

Spectral Acceleration Coefficient, S_a /g [IS 6.4.5]

$$\frac{S_a}{g} = \frac{1.36}{T}$$

$$Z = 0.16$$

$$R = 5$$

$$I = 1$$

For rocky, or hard soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T; & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.40 \\ 1.00/T & 0.40 \le T \le 4.00 \end{cases}$$

$$\frac{S_a}{g} = 0.990338$$

For medium soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T; & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.55 \\ 1.36/T & 0.55 \le T \le 4.00 \end{cases}$$

For soft soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T; & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.67 \\ 1.67/T & 0.67 \le T \le 4.00 \end{cases}$$

Basic Wind Speed, V_b

$$V_b = 50 \frac{meter}{sec}$$

Windward Coefficient, $C_{p,wind}$

$$C_{p,wind} = 0.8$$

Leeward Coefficient, $C_{p,lee}$

$$C_{p,lee} = 0.5$$

E. Response spectrum analysis

According to the Indian code in the response spectrum method, the response of a structure during an earthquake is obtained directly from the earthquake response (or design) spectrum. This procedure gives an approximate peak response, but this is quite accurate for structural design applications. The responses of different modes are combined to provide an estimate of total response of the structure using modal combination methods such as complete quadratic combination (CQC), square root of sum of squares (SRSS), or absolute sum (ABS) method. Response spectrum method of analysis should be performed using the design spectrum specified or by a site.

1) *Dynamic analysis:* Dynamic analysis done by E-tabs by giving scale factor initially as 1000 and analysis is done by trial and error method. The ratio of static by dynamic will get the scale factor and the initial scale factor is replaced by obtained scale factor.

F. Wind Load Calculation

Exposure Parameters:

Structure Class = Class B

Terrain Category = Category 2

Wind Direction = 0:90 degrees

Top Story = Story15

Bottom Story = Base

Include Parapet = No

Factors and Coefficients:

Risk Coefficient, k_1 [IS 5.3.1]

$$k_1 = 1$$

Topography Factor, k_3 [IS 5.3.3]

$$k_3 = 1$$

Design Wind Speed, V_z [IS 5.3]

$$V_z = V_b k_1 k_2 k_3$$

DesignWind Pressure,p_z[IS 5.4]

Lateral Loading

$$p_z = 0.6V_z^{\,2}$$

V. RESULTS AND DISCUSSIONS

The seismic analysis of reinforced concrete frame structure is done by both static and dynamic analysis to determine and compares the base shear. Dynamic analysis done by E-tabs by giving scale factor initially as 1000 and analysis is done by trial and error method. The ratio of static by dynamic will get the scale factor and the initial scale factor is replaced by obtained scale factor. From the lateral stability of the building values obtained by E-tabs for static and dynamic analysis the scale factor assumed in dynamic analysis is satisfied.

Base shear is affected marginally with placing of shear wall. The base shear is increasing by adding shear wall due to increase in shear wall of the building. Provision of shear wall generally results in reducing the displacement because the shear walls increase the stiffness of building. The better performance for structure with shear wall has low displacement. It has been seen from Table that the top deflection has not exceeded the permissible deflection, i.e. 0.004 times the total height of the building as per IS 1893 (Part 1) (2002) clause No.7.11.

VI. CONCLUSION

A. From the study of literature review it is clear to say that due to the presents of shear walls and their location in the structure place a major role in construction of a building.

B. The results obtained from the study shows that shear wall arrangement gives best result towards the building elements like storey displacement, inter-storey drift, base shear, lateral forces compared to bare frames.

C. The model with shear wall placed at corners of the building shows less displacements and drifts and thus considered as optimum location.

D. In this present paper from the study of literature paper the structure is constructed by shear walls at different locations. It has been observed that the top deflection was reduced and reached within the permissible deflection after providing the shear walls at possible failure positions such as the shorter directions.

E. Increasing axial load level decreases R factor. So design base shear will be increased and moment of inertia of the section should be increased. In other hand, the lesser the axial load, the much more cross sectional area.

F. Confinement of concrete in shear walls is a good way to provide more level of ductility and getting more stable behavior. So, the designer would be allowed to bring up the level of axial stresses to have a reasonable design.

G. Not only main walls are assumed to carry seismic loads, but also they are going to bear a significant percentage of gravity loads.

H. The results for storey displacement, inter-storey drift and base shear are provided in this paper for 15 storey high rise building.

VII. SCOPE FOR FUTURE WORK

Today's tall buildings are becoming more and more slender, leading to the possibility of more sway in comparison with earlier high-rise buildings. We can achieved minimize displacement wind forces and seismic forces, also the structure should be stable and we need to another case study of offshore structures and consider water pressure how it will occur& also consider ETAB software.

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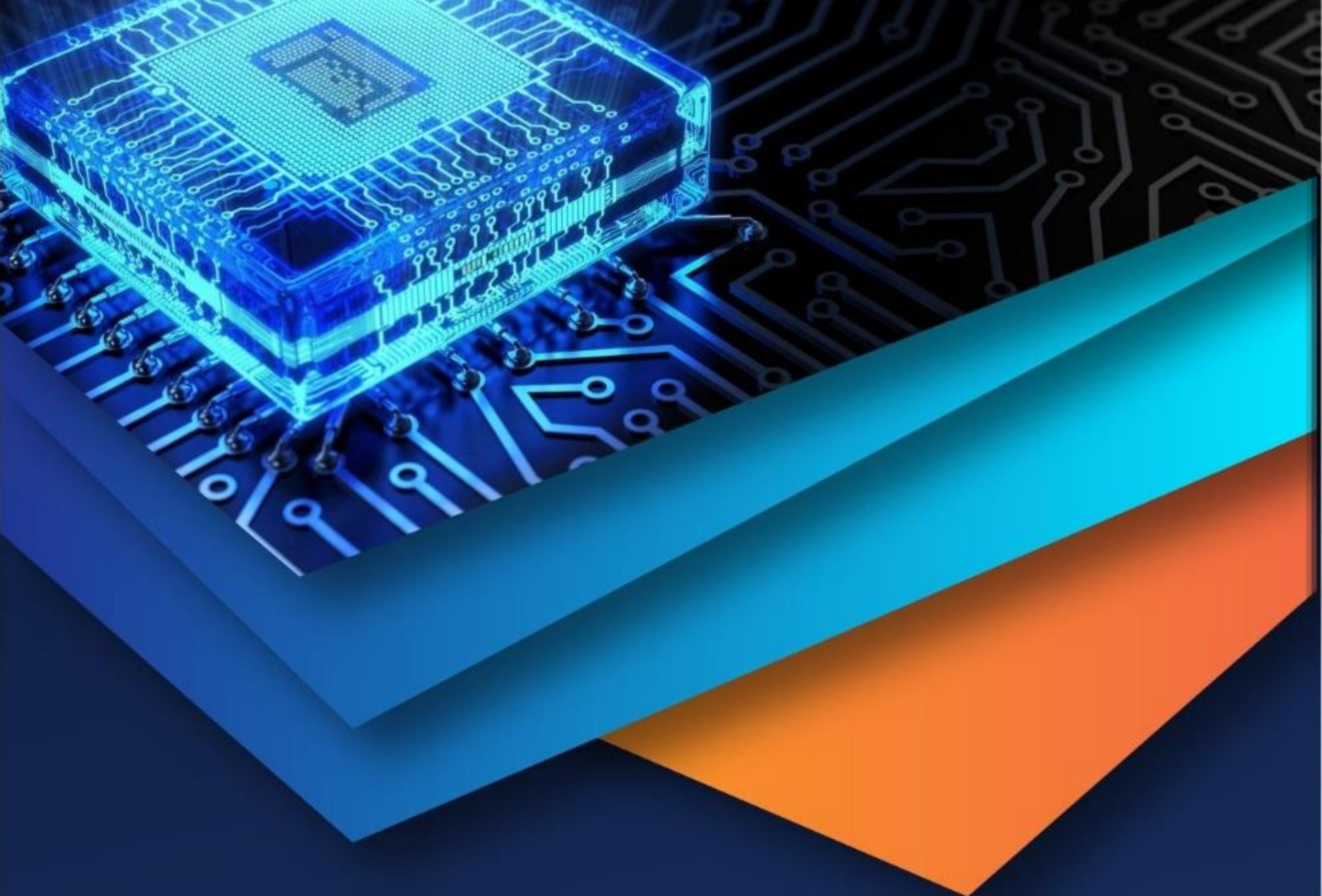

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