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Comparative Study of Soil Structure Interaction Analysis of Building on Clayey and Sandy Soil

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Abstract: ***Present days the analysis of structure with seismic design is more popular. because the first priority of the engineer is effective and durable structure. There are two type of base system first is rigid and second is flexible. In case of flexible base structure, only seismic analysis is not give very effective results. In this condition the SSI effect is more significant and give effective results for flexible base system. The term Soil Structure Interaction (SSI) means interaction between soil to the sub-structure. This effect give more accurate results after consider in the seismic analysis. If a structure is design according to the seismic analysis with SSI effect than structure could get more durability and safety against earthquake as compare to seismic analysis without SSI effect condition. So the SSI effect can change response of the seismic very significantly.***
The present study aim is based on seismic analysis of building with Soil Structure Interaction effect on two different soil. A frame rectangular building of G+6 storey has analyzed for flexible base simulating sand and clay soil conditions The software is used SAP2000. Raft foundation has been modeled also. Analysis is made with the response spectrum of IS 1893 2016 code. Seismic response of SSI analysis results are compare in terms of lateral storey displacement, base shear and modal behavior of natural time period on different type of soil (clay and sand). and conclude that the lateral storey displacement, base shear and natural time period values in SSI analysis with sand soil is maximum as compare to clay soil.

I. INTRODUCTION

Earthquake is becoming major natural disaster in present days so in this condition seismic analysis of every structure in earthquake prone zone is necessary but some condition only seismic analysis not enough for structure safety and this is the reason that structure was designed according to seismic criteria than also it fails during earthquake disaster. In such case the importance of soil structure interaction (SSI) effect is increase. Because during seismic disaster soil have their own importance to safe the structure. the earthquake response is also depends on interaction between soil and structure so the effect of SSI with seismic analysis should be consider to provide better safety and durability to structure. On flexible base system is more effective as compare to fixed base system. So that the SSI effect consider mostly is flexible base light weight structure.

II. SOIL STRUCTURE INTERACTION

SSI means the interaction between soil (ground) and a structure build upon it. it's an exchange of mutual stress, whereby the motion of the ground-structure system is influenced by each kind of soil and also the kind of structure. this is often particularly applicable to areas of seismic activity. if a flexible structure is on the rigid rock soil foundation than the movement of the base of the structure similar as free field motion but if rigid and massive structure construct on soft base foundation than the movement of the base of the structure is different. In this condition it is important to consider the effects of SSI. These impacts are more critical for hardened and additionally weighty constructions upheld on moderately soft soils. For soft and/or light designs established on hardened soil these impacts are by and large little. It is additionally critical for firmly separated construction that may expose to beating, when the general relocation is huge.

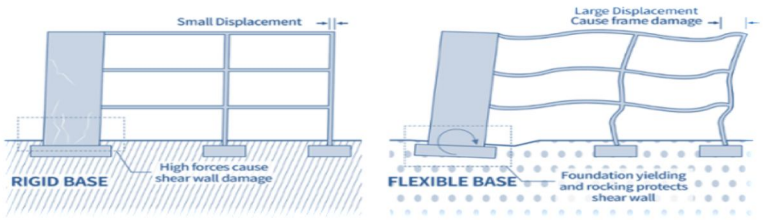

Figure 1 Behavior of soil structure interaction effect

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III. RAFT FOUNDATION

Raft foundation is genuinely a thick concrete slab resting on a huge vicinity of soil strengthened with steel, assisting columns or partitions and transfer loads from the structure to the soil. Generally, mat foundation is unfold over the entire region of the structure it's far assisting. Raft foundation is also known as mat foundation is consider in this thesis work. And analyze the effect of SSI. After analysis, from the analyzed result raft foundation is designed.

A. Maximum Load from Analysis Results

DL + LL = 18137 + 3780
= 21917 KN
Design load = 1.5 x 21917
= 32875.5 KN

B. SBC = 150 KN/m2

Now, from the available values (maximum load and SBC), calculation of the area of raft foundation is done from the following formula-

$$\text{Area of Footing} = \frac{\text{Design load}}{\text{SBC}}$$

$$= \frac{32875.5}{150}$$

Area = 219.17 m2

IV. MODELING

In present study, The three dimensional RC frame building of G+6 storey with raft foundation is consider. In current study various codes are used- IS 456-2000 for RC frame design and IS 1893-2016 for seismic analysis. SAP 2000 software is used for analysis building and response spectrum analysis is done for these model. Here, the main concern of this study is the SSI analysis is perform for two type of soil, first is clay and other is sand. Foundation design is necessary because the role of foundation is very important in SSI effect analysis, since soil is interact directly to the foundation of the structure. the frame model building with flexile base are consider and analyze with SSI effect on different soft soil (clay, sand). Then compare their results in term of maximum displacement, maximum base shear and natural time period. In analysis following assumptions are considered-

1) Frame structure is consider symmetrical
2) Equivalent static analysis are perform.
3) Response spectrum analysis are perform.
4) Soil is consider as non-linear isotropic in SSI analysis

A. Structural modeling

Table 1 Geometric properties of model

SPECIFICATION	DATA
Building type	RC frame building
Number of Storey	G+6
Storey Height	3m
Number of Bays	3 x 3 bays
Concrete grade	M-30
Steel grade of rebar	HYSD 415
Beam Size	250mm x 500mm
Column Size	500mm x 500mm
Slab Thickness	150mm

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Floor Finishing Load (Dead Load)	1.25 KN/m^2
Wall Load	10.8 KN/m^2
Live load	3 KN/m^2
Zone of Seismic	IV
Zone Factor (Z)	0.24
Importance Factor (I)	1
Response Reduction Factor (R)	5
Type of Soil	III
Damping Ratio	0.05
Soil Bearing Capacity	150 KN/m^2
Depth of Foundation	1m

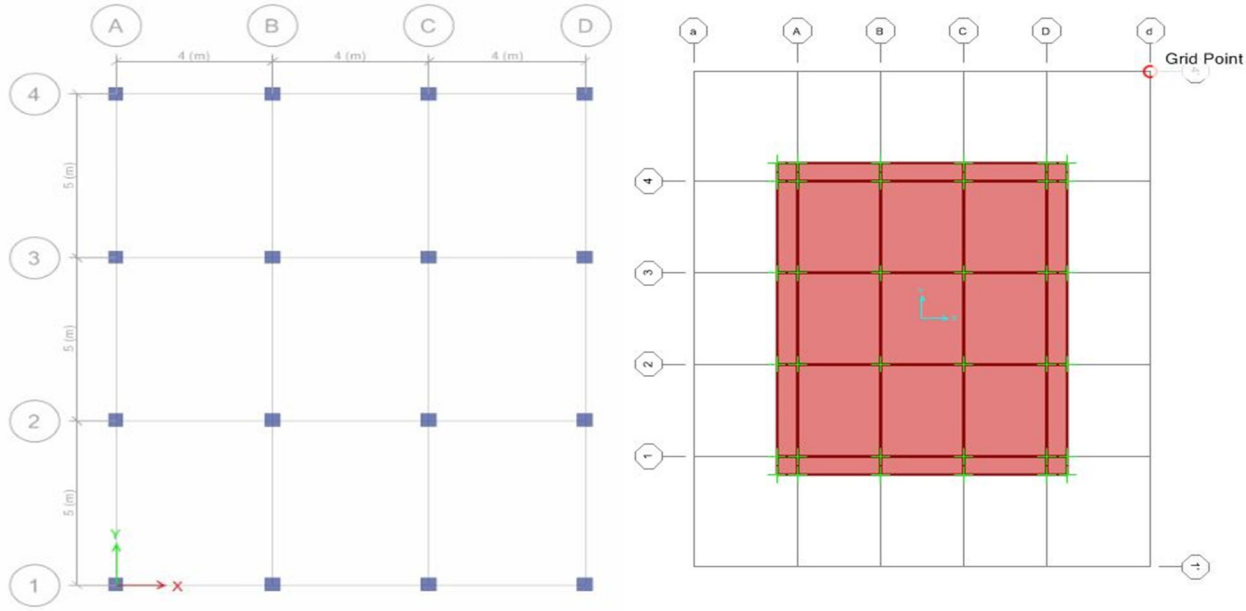

Figure 2 2D plan of frame building with foundation and soil design

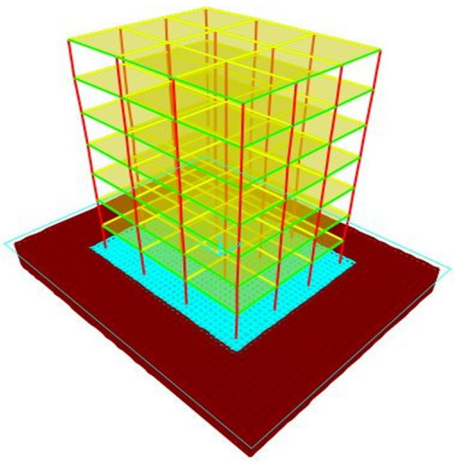

Figure 3- 3D view of RC building with SSI effect

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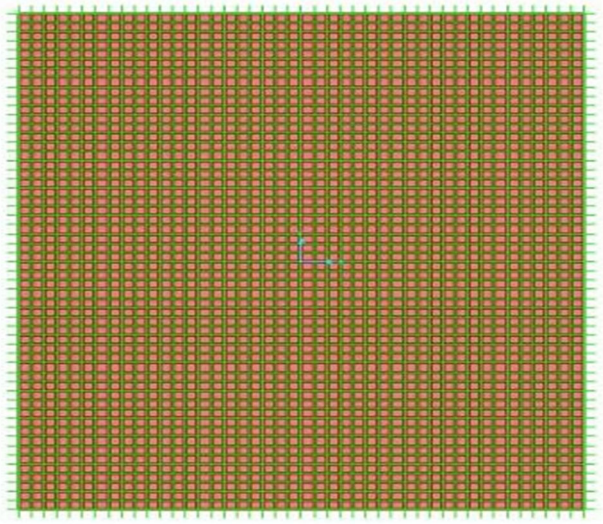

Figure 4- plan view of soil design

B. Raft Foundation Properties

Properties which consider for raft foundation design are shown below in table 2-

Table 2 Properties of raft foundation

Raft foundation Parameters	For clay soil	For sandy soil
Concrete Grade	M-30	M-30
Modulus of elasticity (KN/m^2)	50000	20000
Depth of foundation in m	1	1
Soil bearing capacity (KN/m^2)	150	150

C. Soil properties

In this study, two types of soil is consider medium clay soil and loose sand soil, these soil act as a flexible base for the structure in SSI analysis. Properties which consider for soil design are shown below in table 3-

Table 3 Properties of soil

CHARACTERISTICS	TYPE OF SOIL	
	CLAY	SAND
Weight per unit volume (KN/m^3)	17 KN/m^3	14 KN/m^3
Modulus of elasticity (KN/m^2)	50000	20000
Poisson's ratio	0.4	0.3
Friction Angle (deg)	20^0	30^0
Thickness of soil layer (m)	3.048m	3.048m
Symmetry type	Isotropic	Isotropic
Sub Type	Medium clay	Loose sand

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V. RESULT AND DISCUSSION

In current study seismic and response spectrum analysis with SSI effect, is conducted for building frame model with raft foundation on SAP 2000 software. The results are obtained after analysis are discussed. Compare the results in terms of lateral storey displacement, base shear and natural time period of frame building analyze seismic with SSI effect on clay soil and on sand soil.

A. Base Shear Comparison

Here the comparison of base shear results for clay and sand soil is discussed for building with SSI analysis on flexible base. The base shear values are shown table 4

Table 4 Base shear comparison

With SSI (Flexible Base)	Base Shear in X Direction (KN)	Base Shear in Y Direction (KN)
Clay Soil	1298.58	1298.58
Sand Soil	1484.70	1484.70

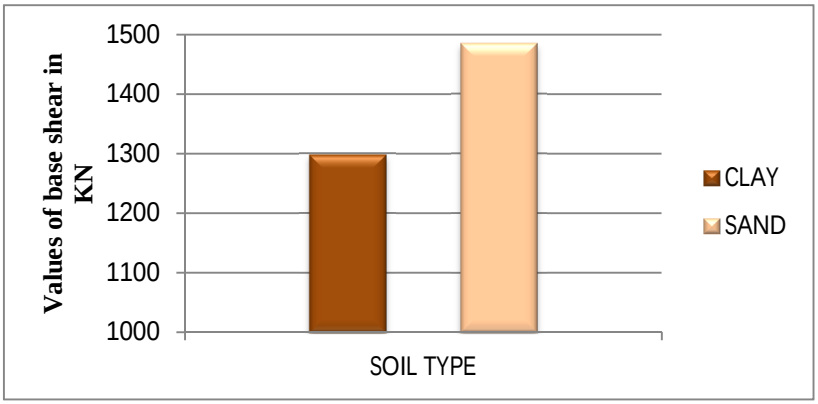

Figure 5- Base shear comparison

In the above table it is notice that the base shear values of sand soil is greater than base shear value of clay soil

B. Natural time period

Natural Time period of with SSI building for clay and sand soil in modal form is given below in table 5 which says that the natural time period of sand soil SSI analysis is more than clay soil.

Table 5 Natural time period comparison

Output case	Clay soil	Sand soil
	period sec	period sec
MODAL 1	1.403	1.449
MODAL 2	1.324	1.388
MODAL 3	1.176	1.188
MODAL 4	0.420	0.426
MODAL 5	0.398	0.406
MODAL 6	0.355	0.358
MODAL 7	0.218	0.221
MODAL 8	0.208	0.211
MODAL 9	0.188	0.193
MODAL 10	0.137	0.191
MODAL 11	0.133	0.173
MODAL 12	0.127	0.165

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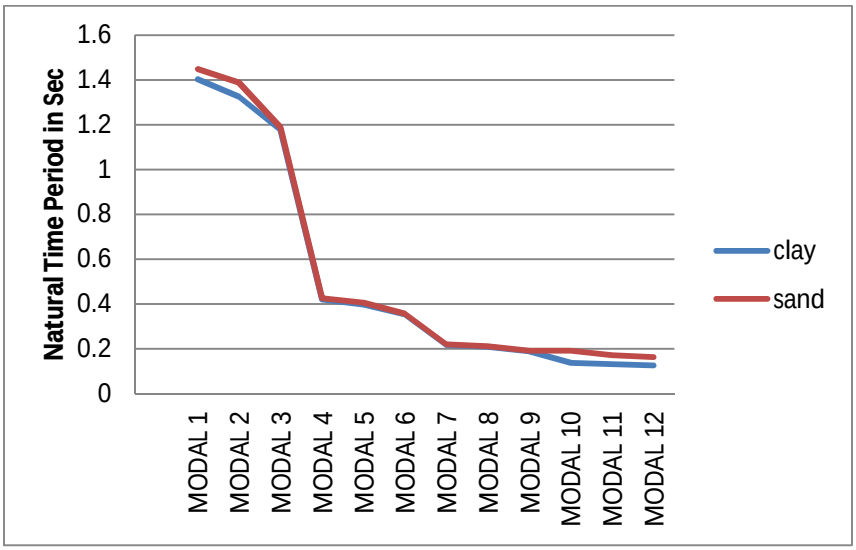

Figure 6- Natural time period comparison

C. Lateral storey displacement

The comparison of displacement (in meter) of building (with SSI) for clay and sand soil is discussed below in table 6 and table 7 in X and Y direction respectively. Results shows that displacement of sand soil is maximum as compare to clay soil.

Table 6 Lateral storey displacement (in meter) comparison in X direction

storey	Clay soil	Sand soil
storey 7	0.036273	0.040949
storey 6	0.03426	0.039012
storey 5	0.031407	0.036015
storey 4	0.027728	0.03196
storey 3	0.023288	0.026931
storey 2	0.018073	0.02091
storey 1	0.011545	0.013249
base	0.000886	0.000401

Table 7 Lateral storey displacement (in meter) comparison in Y direction

storey	Clay soil	Sand soil
storey 7	0.037711	0.043042
storey 6	0.035809	0.041105
storey 5	0.032983	0.038027
storey 4	0.029224	0.033787
storey 3	0.024585	0.028454
storey 2	0.01903	0.021982
storey 1	0.011989	0.0137
base	0.000839	0.000401

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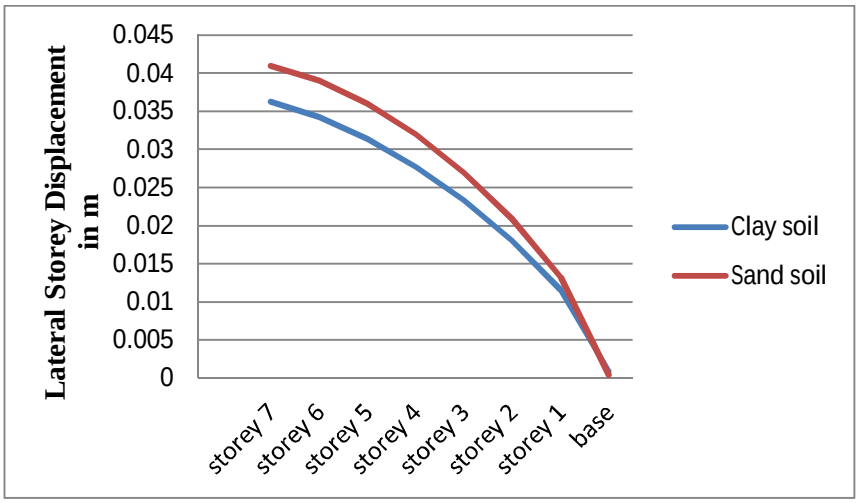

Figure 7- Lateral storey displacement comparison in X direction

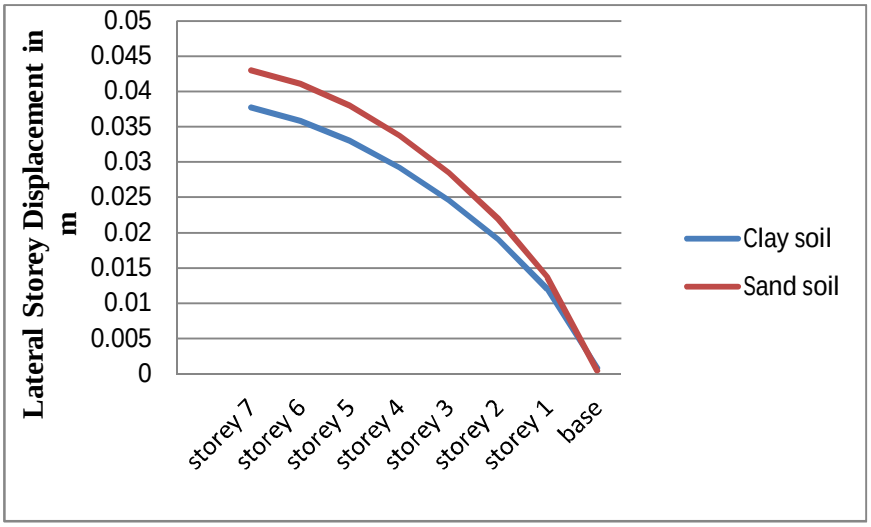

Figure 8- Lateral storey displacement comparison in Y direction

VI. CONCLUSION

The frame building is evaluate for flexible base simulating sand and clay soil conditions. Raft foundation has been modeled also. The software is used SAP2000. Analysis is made with the response spectrum of IS 1893 2016 code. Seismic response results are compared in terms of lateral storey displacement, base shear and modal behavior of natural time period. Now come to the conclusion points, the conclusions are drawn in comparison between clay soil SSI
analysis and sandy soil SSI analysis. following conclusions are made from this research work-

1) The base shear of flexible base with SSI effect on sand soil is more as compare to SSI effect on clay soil. The base shear value of sand soil is increased by 14% from the clay soil. Because the clayey soil has more shear strength as compare to sandy soil.

2) The natural time period of sand soil condition in SSI analysis is more as compare to clay soil condition. Because the base shear of sandy soil is maximum.

3) The lateral storey displacement of flexible base (with SSI) case on sand soil is more as compare to clay soil case, in both analysis (equivalent static and response spectrum analysis). The maximum displacement due to equivalent static analysis with SSI effect on sand soil is increased by 4% and due to response spectrum analysis is increased by 16% as compare to clay soil case in SSI effect analysis.

The overall conclusions says after consideration of soil structure interaction effect, the values of base shear, natural time period and Lateral storey displacement are increased and the sand soil condition all these factor's values are maximum as compare to clay soil.

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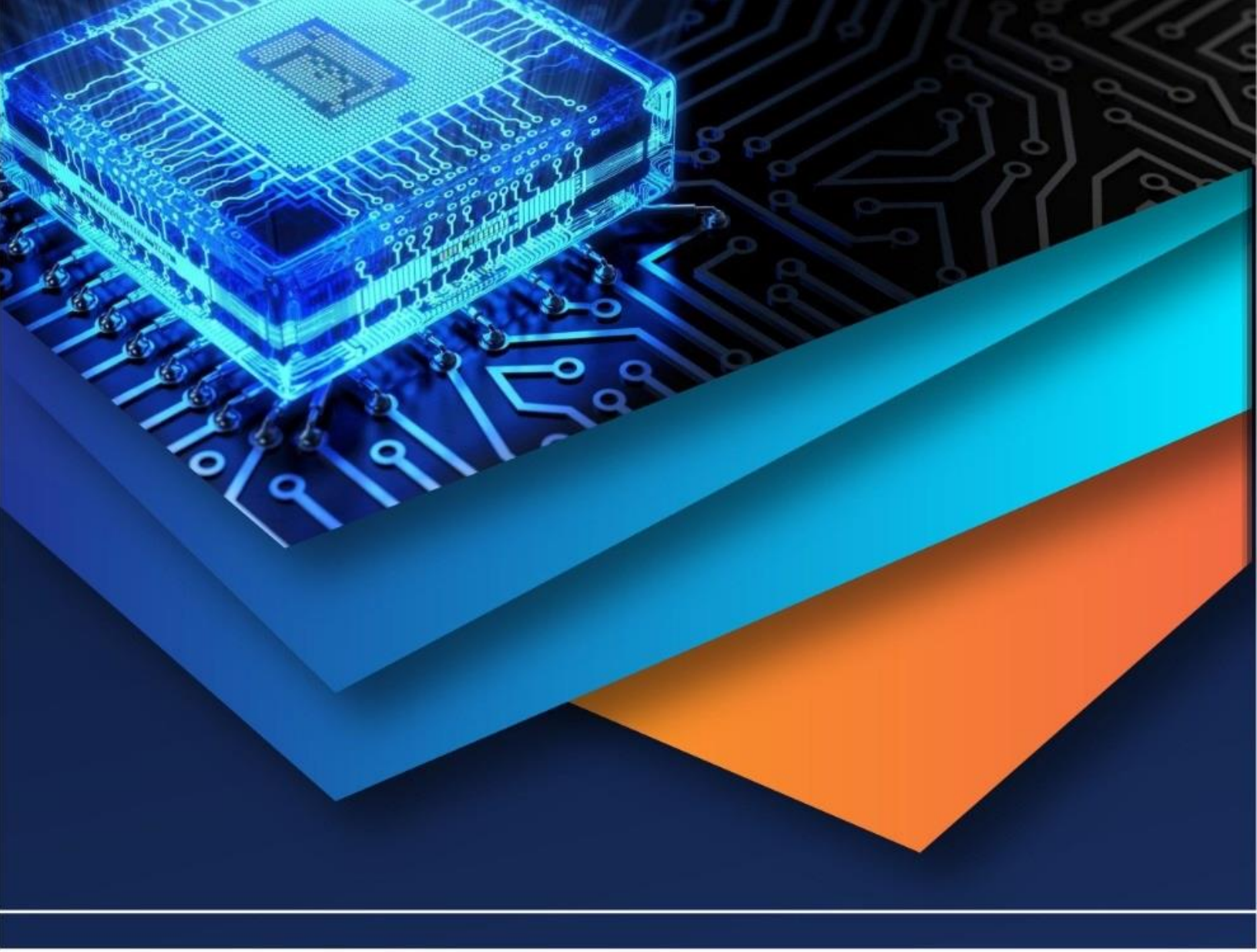

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