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Comparison of Substructure's Seismic Stability with the Change in Underlying Soil Parameters

Dr. A. R. Gupta[1], Ms. Poonam V. Sarode[2]
[1, 2]Department of Civil Engineering M.E Struct. Engg. COET, Akola.

Abstract: There are different types of soil are found on the earth (i.e. Sand, Silt, Clay, Loamy). In Civil Engineering aspects, each type of soil have some trouble due to which the foundation may get failed or damaged. This study discussed the properties of various soils (Sand, Silt, Clay), effect of these soils on structures and covers the guidelines to construct the structure in these types of soils. The main objective of this study is to understand the effect of seismic forces on footing with the change in underlying soil. Also from various literature reviews, study shows the points which are helpful to overcome the damages in footing construction by showing different methods, loading combinations, seismic effect, footing stability, etc. This project is to analysis of RC Isolated footing on different types of soil for seismic forces and analyzed isolated footing manually and using STAAD FOUNDATION. The aim of this study is to analyze the changes in footing design with the changes in the properties of soils. The footing having some external loading (Seismic Loading) is analyzed and designed for various types of soil i.e. Sand, Silt and Clay. The changes in the pressures for various soil types are determined and studied.
Keywords: Various Soils, Properties, Isolated Footing, Stability.

I. INTRODUCTION

A. Aim

To study about Substructure's Seismic Stability with the Change in Underlying Soil Parameters.

B. Objective

The study aims at removing the possibility of failure of foundation by tilting, overturning and sliding due to pressure imposed on soil by foundation being in excess of the ultimate capacity of the soil. The purpose to carry the above mentioned project is:

1) To study the soil construction property.
2) To study the types and function of footing.
3) Analyzing the examples on RC isolated footing
4) Comparing results of different soil conditions and their effect on foundation during seismicity.

C. Need

Superstructure loads are transmitted to the underlying soil strata through a suitably designed foundation. Therefore, the foundation of a structure is considered the most crucial structural element in a building. Each type of soil such as silt, sand, clay, loamy, black cotton having the effects on foundation like porosity, swell and shrink, lack of drainage, water holding capacity, etc. Thus because of these effects, foundation may get fail or having some major or minor defects and it also create a different problem in construction of foundation. Hence, to overcome or to reduce these effects, it is very necessary to analyze the safety and stability of the foundation.

II. LITERATURE REVIEW

B. Ravi Sankar, et. al (1) Design the isolated footing for cohesive & non-cohesive types of soil for same type of building and try to find which soil is economical & reduced the cost of construction of building by using standard penetration test and finally concluded that, size of isolated footing in cohesive soil is nearly two times more than in non-cohesive soil. Also in cohesive soil the isolated footing is not advisable & more costlier than that of non-cohesive soil. So in cohesive soil pile grouping, well foundation are more suitable than other types of foundation.

Tarun Tiwari, (2) Studied on the effect of soil type for evaluating the seismic performance of footing. By using software STAAD PRO, finding the better technique to make the sensitivity of footing rested on different soil type and finally stated that, soil type which are available at foundation site effects the stability of foundation when subjected to earthquake waves.

Prof. A. R. Gupta, et. al (3) Stated that, it is difficult to construct the structure in black cotton soil because of their poor strength and deformation characteristics.
Thus, after discussing on the properties and effect of black cotton soil it is concluded that, under-reamed pile foundation & mat foundation is the safest and economical option to construct the foundation in black cotton soil.
Samridhi Singh, et. al (4) Studied the effect of earthquake on different types of foundation such as shallow, mat/raft, pile & structure like gravity dam, arch dam, etc. and provide few ways to overcome the losses during earthquake. The main aim is that, to protect the life of common man from dangerous effect of earthquake.
Komal Bedi, et. al (5) Studied on bearing capacity & settlement of isolated footing for various shape(i.e. square, rectangular, triangular, circular, octagonal, hexagonal, etc.) and stated that, square footing shows the better load settlement behavior for a given settlement indicating higher load carrying capacity.

III. LOADING COMBINATIONS

It's our duty to design a safe and serviceable structure and in order to do so we must predict the magnitudes of various loads that are likely to be applied to the substructure or superstructure over its lifetime.

Load combinations provide the basic set of building load conditions that should be considered by the designer.

A. 1.5(DL+LL)
B. 1.2(DL+LL+EQX)
C. 1.2(DL+LL-EQX)
D. 1.2(DL+LL+EQZ)
E. 1.2(DL+LL-EQZ)
F. 1.5(DL+EQX)
G. 1.5(DL-EQX)
H. 1.5(DL+EQZ)
I. 1.5(DL-EQZ)
J. 0.9DL+1.5EQX
K. 0.9DL-1.5EQX
L. 0.9DL+1.5EQZ
M. 0.9DL-1.5EQZ

IV. CASE CONSIDERATION MODELLING AND ANALYSIS

A. Computational Building Analysis

The details of a structure considered for the analysis is as follows:
It is six storied RCC frame structure comprising of rooms. The dimensions of respective 5 rooms are;
Living Room = 3.89 x 3.53 m
Bed Room(1) = 2.81 x 3.54 m   Bed Room(2) = 3.47 x 3.84 m
Kitchen = 3.55 x 3.54 m
Study Room = 3.23 x 3.84 m
Store Room = 5.17 x 2.58 m
Wc = 1.53 x 1.14 m   Bath = 1.53 x 1.44 m
Puja = 2.81 x 1.23 m   Porch = 2.81 x 2.3 m
Height of each floor = 3 m
Depth of footing = 3.1 m
Size of Beam = 0.50 x 0.30 m
Size of Column = 0.45 x 0.45 m
Total Height of Building = 21.1 m

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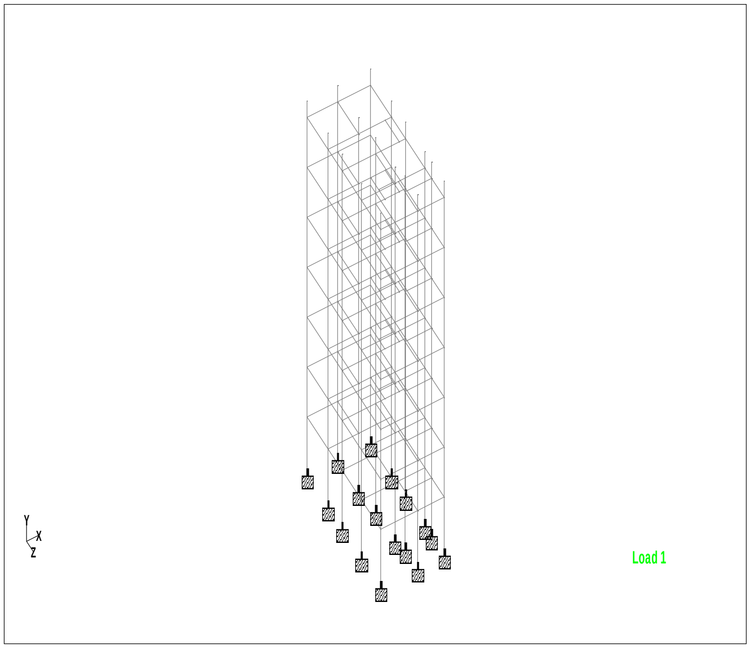

Fig. 1 STAAD-PRO Structure

Table 1: Support Reactions on Isolated Footing

Footing No.	Horizontal Fx (kN)	Vertical Fy (kN)	Horizontal Fz (kN)	Moments Mx (kNm)	My (kNm)	Mz (kNm)
1	63.474	1195.14	56.955	120.694	1.073	130.186
2	62.486	1348.620	75.979	139.905	0.970	128.735
3	60.555	1338.231	76.561	140.511	0.789	124.935
4	58.331	1377.985	73.933	137.722	0.766	120.189
5	59.136	1173.519	56.121	119.412	0.737	112.655
6	82.937	1267.25	53.449	119.412	0.725	150.350
7	81.112	1219.911	50.162	109.170	0.709	149.576
8	79.080	1214.539	58.113	118.958	0.667	147.654
9	74.878	1214.761	63.972	124.832	0.771	141.999
10	64.206	1105.202	75.837	136.602	0.709	125.053
11	71.870	1362.995	58.301	118.958	0.620	138.841
12	60.604	1161.667	53.954	113.696	0.357	130.525
13	59.275	1236.652	71.209	131.157	0.434	129.752
14	59.558	1222.339	71.825	131.856	0.661	128.476
15	56.667	1164.415	73.537	133.526	0.769	123.723
16	56.990	1180.105	76.695	136.626	0.678	126.003
17	55.546	1178.769	57.951	117.741	0.530	122.415

From above table, we can consider one exterior footing and one interior footing. So that, to observe the variations in result due to seismic forces, footing no.3 and footing no.13 is considered for further studies. The output of STAAD design for various cases are:

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1) Case 1: For Sand (External Footing)

Isolated Footing 3

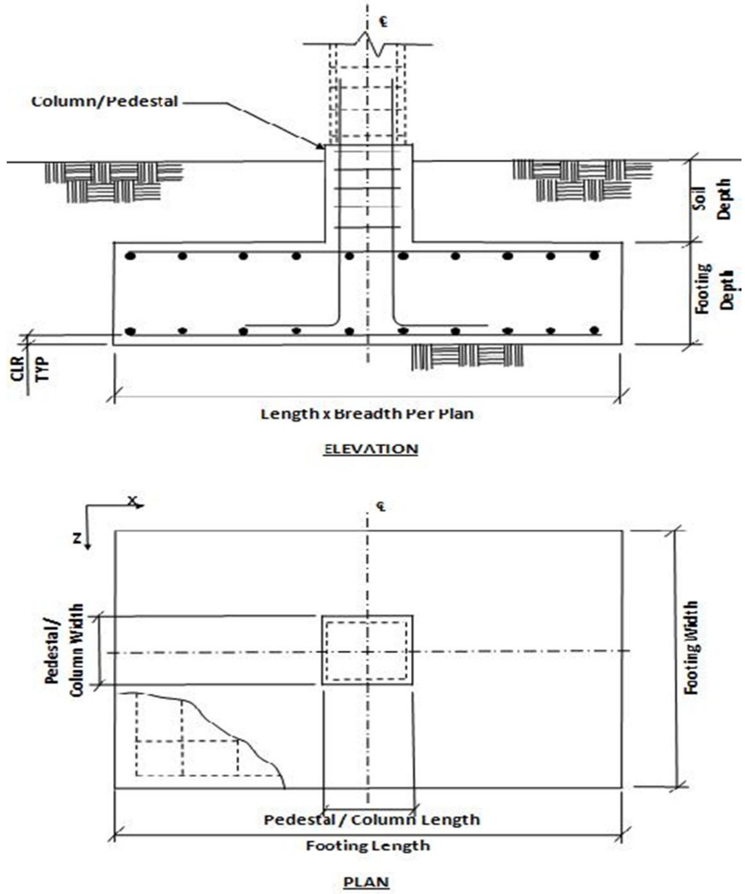

Fig. 1.1 Isolated footing for Case 1

B. Input Values

1) Footing Geometry

Design Type: Calculate Dimension
Footing Thickness (Ft): 550.000 mm
Footing Length – X (Fl): 3400.000 mm
Footing Width – Z (Fw): 2300.000 mm
Eccentricity along X (Oxd): 0.000 mm
Eccentricity along Z (Ozd): 0.000mm

2) Column Dimensions

Column Shape: Rectangular
Column Length –X (Pl): 0.450 m
Column Width – Z (Pw): 0.450 m

3) Pedestal

Include Pedestal: No
Pedestal Shape: N/A
Pedestal Height: N/A
Pedestal Length – X (Pl): N/A
Pedestal Width – Z (Pw): N/A

C. Design Parameters

1) Concrete and Rebar Properties

Unit Weight of Concrete: 25.0KN/m^3
Strength of Concrete: 25.000 N/mm^2
Yield Strength of Steel: 415.0 N/mm^2
Minimum Bar Size: Ø10
Maximum Bar Size: Ø32
Minimum Bar Spacing: 110.00 mm
Maximum Bar Spacing: 500.00 mm
Pedestal Clear Cover (P,CL): 50 mm
Footing Clear Cover (F,CL): 50 mm

2) Soil Properties

Soil Type: Drained
Unit Weight: 16.000 KN/m^3
Soil Bearing Capacity: 100.0 KN/m^2
Soil Surcharge: 13.39 KN/m^2
Soil Depth above Footing: 1200 mm
Cohesion: 2.000 KN/m^2
Min Percentage of Slab: 0.000

3) Sliding and Overturning

Coefficient of Friction: 0.450
F.O.S Against Sliding: 1.500
F.O.S Against Overturning: 1.500

V. OBSERVATION AND REMARK

For the study undertaken, the super structure was analyzed and the footing design is done for exterior and interior footing resting on different types of soil. Case-1 is the modeling analysis and design of footing for sand. Case-2 is for silt type of soil and Case-3 is for clay type of soil.

Table 2: Input soil properties of different types of soil

	Case 1	Case 2	Case 3
Soil Type	Sand (Drained)	Silt (Drained)	Clay (Un drained)
Unit Weight	16.000 KN/m^3	18.000 KN/m^3	21.000 KN/m^3
Soil Bearing Capacity	100-300 KN/m^2	Up to 75 KN/m^2	75-180 KN/m^2
Soil Surcharge	13.39 KN/m^2	-	17.580 KN/m^2
Depth of Soil above Footing	1.2000 m	1.200 m	1.200m
Cohesion	0.5-2 KN/m^2	75 KN/m^2	10-100 KN/m^2
Un drained Shear Strength	0	0	0
Min Percentage of Slab	0	0	0
Coefficient of Friction	0.450	0.500	0.300

1) *Remark:* From the above table it can be seen that the Bearing capacity of the silt soil is minimum and is more for sand type. While the cohesion is maximum for clay type of soil. The density is minimum for sand while maximum for clay.

Table 3: Load Combination, Applied loads-Service Stress Level for Footing 3

		Axial (KN)	Shear X (KN)	Shear Z (KN)	Moment X (KN)	Moment Z (KN)
Case 1		266.608	40.630	0.670	1.375	-87.019
Case 2	EQX	-	-	-	-	-
Case 3		266.608	40.630	0.670	1.375	-87.019
Case1		-204.685	-2.479	35.372	75.111	5.226
Case 2	EQZ	-	-	-	-	-
Case 3		-204.685	-2.479	35.372	75.111	5.226
Case 1		9323.851	61.513	53.954	-113.692	-130.542
Case 2	Max. Value	-	-	-	-	-
Case 3		9323.851	61.513	53.954	-113.692	-130.542

A. For footing 13

Table 4: Load Combination, Applied loads-Service Stress Level for Footing 13

		Axial (KN)	Shear X (KN)	Shear Z (KN)	Moment X (KN)	Moment Z (KN)
Case 1		-160.771	41.544	1.977	2.038	-84.218
Case 2	EQX	-	-	-	-	-
Case 3		-160.771	41.544	1.977	2.038	-84.218
Case1		47.271	1.368	50.484	91.031	-2.633
Case 2	EQZ	-	-	-	-	-
Case 3		47.271	1.368	50.484	91.031	-2.633
Case 1		10566.389	-64.206	-75.837	-136.596	128.460
Case 2	Max. Value	-	-	-	-	-
Case 3		10566.389	-64.206	-75.837	-136.596	128.460

1) *Remark:* From the above tables (i.e. 3 & 4) it can be seen that the values for sand and clay are coming same while the values for case 2 that is silt is absent, which reflects failure of footing.

Table 5: Load Combination, Applied loads-Strength Level for Footing 3

		Axial (KN)	Shear X (KN)	Shear Z (KN)	Moment X (KN)	Moment Z (KN)
Case 1		266.608	40.630	0.670	1.375	-87.019
Case 2	EQX	-	-	-	-	-
Case 3		266.608	40.630	0.670	1.375	-87.019
Case1		-204.685	-2.479	35.372	75.111	5.226
Case 2	EQZ	-	-	-	-	-
Case 3		-204.685	-2.479	35.372	75.111	5.226
Case 1		13985.777	75.154	-53.954	-113.692	-130.542
Case 2	Max. Value	-	-	-	-	-
Case 3		13985.777	75.154	-53.954	-113.692	-130.542

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Table 6: Load Combination, Applied loads-Strength Level for Footing 13

		Axial (KN)	Shear X (KN)	Shear Z (KN)	Moment X (KN)	Moment Z (KN)
Case 1		-160.771	41.544	1.977	2.038	-84.218
Case 2	EQX	-	-	-	-	-
Case 3		-160.771	41.544	1.977	2.038	-84.218
Case1		47.271	1.368	50.484	91.031	-2.633
Case 2	EQZ	-	-	-	-	-
Case 3		47.271	1.368	50.484	91.031	-2.633
Case 1		15849.584	-64.206	80.050	143.014	128.460
Case 2	Max. Value	-	-	-	-	-
Case 3		15849.584	-64.206	80.050	143.014	128.460

1) *Remark:* The table (5 & 6) shows the values of Earthquake load and maximum load for the 3 cases in which for both sand and clay results are similar while for the silt is it absent showing failure of the footings.

Table 7: Pressure at Corner of Footing for footing 3

	Pressure at Corner 1 (q1) (KN/m^2)	Pressure at Corner 2 (q2) (KN/m^2)	Pressure at Corner 3 (q3) (KN/m^2)	Pressure at Corner 4 (q4) (KN/m^2)	Area of Footing in Uplift (Au) (m^2)
Case 1	96.7092	97.7130	98.2990	97.2651	0
Case 2	-	-	-	-	0
Case 3	174.3920	176.8370	178.2642	175.8191	0

Table 8: Pressure at Corner of Footing for footing 13

	Pressure at Corner 1 (q1) (KN/m^2)	Pressure at Corner 2 (q2) (KN/m^2)	Pressure at Corner 3 (q3) (KN/m^2)	Pressure at Corner 4 (q4) (KN/m^2)	Area of Footing in Uplift (Au) (m^2)
Case 1	97.2688	97.7998	98.7141	98.1831	0
Case 2	-	-	-	-	0
Case 3	174.5163	175.7858	177.9716	176.7021	0

1) *Remark:* Here it is shown that (in table 7 & 8) the pressure is more developed for clay type soil that is case 3 and it is minimum for the case number 1 that is for sandy soil. It can also be seen that the density of clay is maximum and that of sandy soil is minimum.

Table 9: Stability against Overturning and Sliding for footing 3

	Against Sliding	Against Sliding	Against Overturning	Against Overturning
	Along X Direction	Along Z Direction	Along X Direction	Along Z Direction
Case 1	3798.982	15740.636	19463.591	81712.456
Case 2	-	-	-	-
Case 3	2523.033	10460.660	14420.556	60501.510

Table 10: Stability against Overturning and Sliding for footing 13

	Against Sliding Along X Direction	Against Sliding Along Z Direction	Against Overturning Along X Direction	Against Overturning Along Z Direction
Case 1	10470.775	20750.995	284165.397	45857.835
Case 2	-	-	-	-
Case 3	7127.459	14155.737	217459.40	35212.654

1) *Remark:* Here, case number 3 that is for clay soil shows the stability value for sliding and overturning is comparatively low to that of sandy solid.

VI. CONCLUSION

The study done over here is to analyze the effect of soil type on the stability of substructure that is subjected to seismic forces. For this the superstructure is modeled and analyzed for the reaction values. This reaction values are inserted as the force values that are acting on the rectangular RCC footing. Thus, the overlying forces are same for all the cases. Now with the change in underlying soil condition, three times the footing is analyzed and designed. Case for sandy soil, Case 2 for silt and case 3 for clay soil. The effect of Seismic forces and maximum forces are studied. The values of pressure on corners, centers, stresses on footing and stability against overturning and sliding is studied. The comparison of the three cases shows that for same overlying superstructure loads and reactions the footing fails if it is silt soil which is having density (<75 N/mm^2) in mid as compared to sand and clay soil. Further it can be seen that the values for pressure is more for clay soil and the safety values against sliding and overturning is less as that compared to sandy soil. Thus, the study shows over here that even if the seismic forces are considered the footing fails for silt, is good enough for clay and is more stable and sound for sandy soil. Thus the preliminary subsoil study becomes necessary for stability of structure against seismic forces.

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At this moment I feel grateful and loyal to my supervisor, **Dr. A. R. Gupta** for his Enthusiastic suggestions and kind help towards me in achieving success of my project. His constant encouragement and in valuable share of his valuable time with me made such a difficult task so easy. I take this opportunity to express our heartfelt gratitude to all those who helped me in various ways during the project at COET, Akola.
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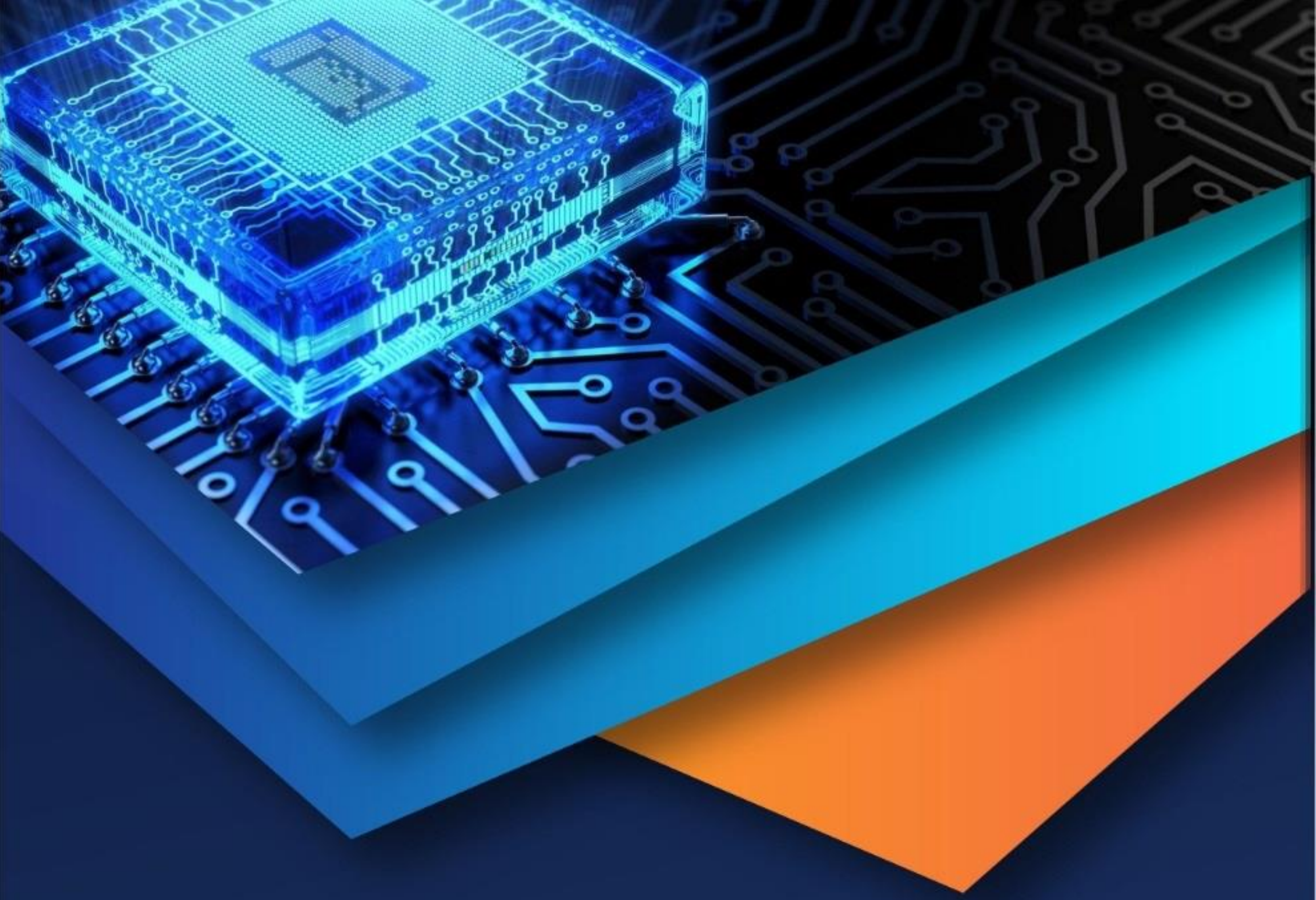

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