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Comparative Analysis of Annular Raft and Solid Raft

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Abstract: The goal of the study is annular mat foundation in various modern structures: Circular tower-shaped structures, like, microwave towers,TV tower, cooling towers, overhead water tanks, etc For this purpose, three raft cases are considered, which are mentioned below.
(1) Intze overhead tank Annular raft with net SBC 24Kn/m2
(2)Intze overhead tank Circular Solid raft
This study aims to evaluate these foundation systems' structural behavior and performance aft's outer radius is also taken as a variable for obtaining different results in our thesis work. An F.E.M.-based analysis is done to determine critical moments and deflections in both annular and circular rafts. Comparison of this base pressure critical moments, shear force, bending stress, and deflections are made based on the above-mentioned case, including the cost comparison foundation. The concrete grade is M-30, and HYSD FE 500 steel reinforcement is used in design calculation. The load combination is followed as IS 1893-2016 and IS 456-2000—seismic zone 3. The software package staad pro v8i and connect edition is used. To provide relevant calculations, Microsoft Excel is used.
Keywords: Staad pro v8i, FEM, Solid Raft, SBC

I. INTRODUCTION

The foundation is a mediator to effectively transfer the load from the superstructure to the soil, without any failure for both the structure and the soil. Annular Mat foundation is one of the effective types of shallow foundations, which carries the load to the soil without any differential settlement in the soil. Annular foundation may be used where the base soil has a low bearing capacity and/or the column loads are so large that more than 50 percent of the area is covered by conventional spread footings.

In the present era, factors like rapid urbanization and massive developments taking place at one place or the other have also given rise to instances of failure of the structures, which in turn, sometimes lead to colossal destruction and loss of lives. For this reason, the study of the bearing capacity of soil has attained paramount significance. On one hand, overestimation of the bearing capacity results in structures potentially prone to disastrous collapse, while its underestimation can make the foundation uneconomic.

There are various theories for the design of the Annular foundation. Those vary from conventional manual calculation methods to most modern computer-based methods. The finite element method is one of the effective and economical numerical methods for analyzing these foundations. For the Annular Mat foundation, advanced numerical modeling techniques are utilized by dividing the MAT into grid elements and predicting the behavior of the structure under loading for critical elements projects.

II. TYPE FOUNDATION

Following are the different types of Foundation.

1. Shallow Foundation
   - Isolated footing
   - Combined Footing
   - Strip Foundation
   - Raft Foundation
2. Deep Foundations
   Pile Foundation

III. ANNULAR AND SOLID RAFT

The raft foundation is generally recommended in underground structure, or when the footing area exceeds 50% of the building than raft foundation is provided.

The Annular or raft foundation also supports the control the differential settlement.

Annular raft foundation in various modern structures: Circular tower-shaped structures, like TV towers, microwave towers, chimneys, cooling towers, overhead water tanks, etc.

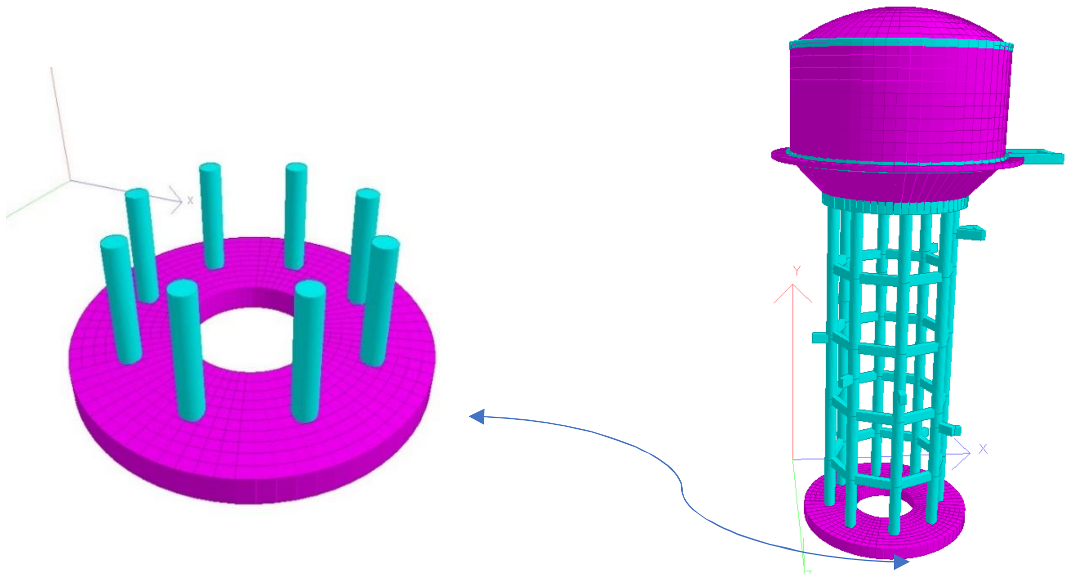

Fig:- Annular Mat Foundation

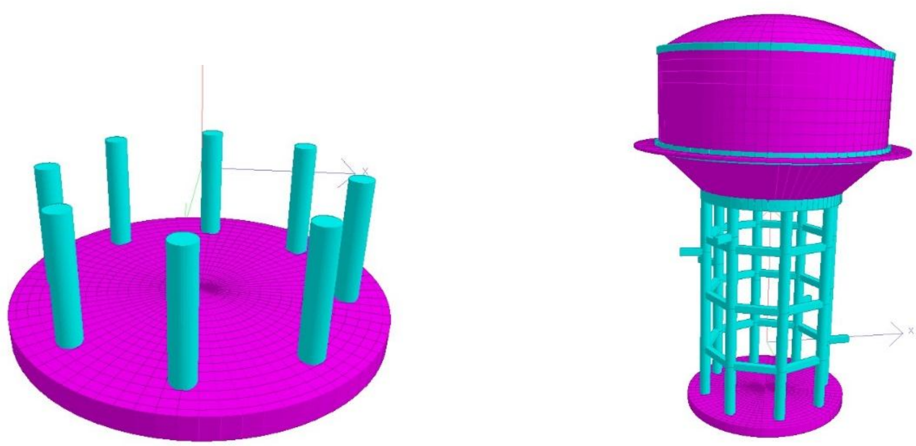

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Fig:- Solid Raft foundation

IV. NECESSARY INFORMATION REQUIRED FOR DESIGN A FOUNDATION

For satisfactory design and construction of the annular foundation, the following information a neighbouring structure.

1) Site plan- a site plan showing the location of the proposed as well neighboring structures.
2) Building plan- showing the detail of height, staging column, etc.
3) Loading condition- dead load, wind or earthquake loads, shown on the schematic plan indicating the design combination of the load transmitted to the foundation.

4) Environmental factor information relating to the geologic history of the area, seismicity of the region, hydrological, information indicating groundwater condition and its seasonal variation, climatic factor like the vulnerability of the site to sudden flooding by surface runoff, erosion, etc.
5) Geotechnical information – subsurface profile with stratification details engineering properties of the founding, strata, index properties, effective shear parameters determined under appropriate drainage conditions, compressibility characteristics, swelling properties, results of field tests like static and dynamic penetration tests, pressure meter tests, etc.
6) Modulus of elasticity and modulus of subgrade reaction.
7) Limiting values of the angular distortion and differential settlement, the superstructure can withstand.

TABLE 01 – PROPERTIES OF ANNULAR RAFT AND SOLID RAFT FOUNDATION

Annular Raft					
Inner Dia	outer Dia	Thickness	Sbc	Conc.Grade	Steel
3200	8700	600	240kn/m2	M-25	Fe-500

Solid Raft					
Inner Dia	outer Dia	Thickness	Sbc	Conc.Grade	Steel
-	8700	600	240kn/m2	M-25	Fe-500

Density of Water (γw) =	10	kN/m3
Elastic Modulus of Steel (Es) =	200000	N/mm2
For calculations related to Strength Calculations (IS:456)		
Per. Stress in Concrete due to Bending, (σcbc) =	10	N/mm2
Per. Stress in Steel due to Direct tension, (σst) =	130	N/mm2
Per. Stress in Concrete due to Direct tension (σcc) =	8	N/mm2
For calculations related to resistance to cracking (IS:3370)		
Per. Stress in Concrete due to Direct tension(σcbt) =	1.5	N/mm2
Per. Stress in Concrete due to Bending =	2	N/mm2
Elastic Modulus of Concrete, Tank (Ec) =	27386.1279	N/mm2
Elastic Modulus of Concrete, Staging (Ec) =	25000	N/mm2
Modular Ratio (m) =	9.33333333	
Earthquake Zone =	III	
Soil type =	Hard	Soil
Wind Speed =	50	m/sec

V. METHODOLOGY

The finite element analysis carried out staad pro connect edition, of solid and annular raft foundation, The sub grade modulus value is considering differential settlement 50mm.

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The comparative analysis of both case has been carried out.The different case study is carried it has been observed that if annular beam is provided the shear force and bending can be reduced. The oneway shear force is calculated at D distance. The punching shear force is calculated at D/2 distance. If the sbc is increased the raft inner /outer projection forces are reduced. Thus, the section can be economized.

To reach a certain conclusion, one of the variables should be taken as unknown, and the rest of the others should be made constant; therefore, in our research work, Dia of the raft and sbc variable. Other boundary conditions such as backfill soil characteristics, Grade of concrete and reinforcement, and designing methodology (Limit state method as per IS 456:2000) were kept constant during analysis and design work.

VI. RESULT

Load Combination

The structure shall be analysed for the following load combination and each structure element (wall, beam, column,etc.) shall be designed for the load combination producing most unfavourable effect on it.

- DL + LL
- DL + WL(+X)
- DL + WL(-X)
- DL + WL(+Z)
- DL + WL(-Z)
- DL + EQ(+X)
- DL + EQ(-X)
- DL + EQ(+Z)
- DL + EQ(-Z)
- DL + LL + WL(+X)
- DL + LL + WL(-X)
- DL + LL + WL(+Z)
- DL + LL + WL(-Z)
- DL + LL + EQ(+X)
- DL + LL + EQ(-X)
- DL + LL + EQ(+Z)
- DL + LL + EQ(-Z)A

Limit State of Serviceability :

LC	DL	LL	WL	EQ
1	1.0	1.0	-	-
2	1.0	-	1.0	-
3	1.0	-		1.0
4	1.0	1.0	1.0	-
5	1.0	1.0	-	1.0

Limit State of Collapse:

LC	DL	LL	WL	EQ
6	1.5	1.5	-	-
7	1.5	-	1.5	-
8	1.5	-	-	1.5
9	1.2	1.2	1.2	-
10	1.2	1.2	-	1.2
11	0.9	-	1.5	-
12	0.9	-	-	1.5

Note :

DL Dead Load
LL Live Load

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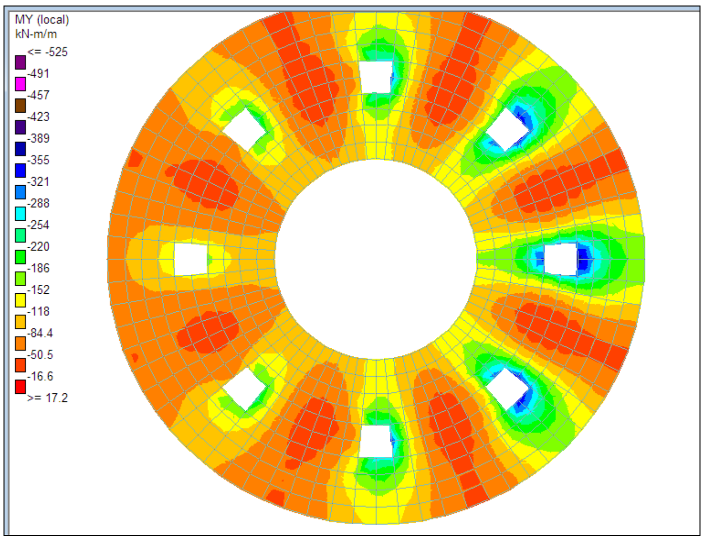
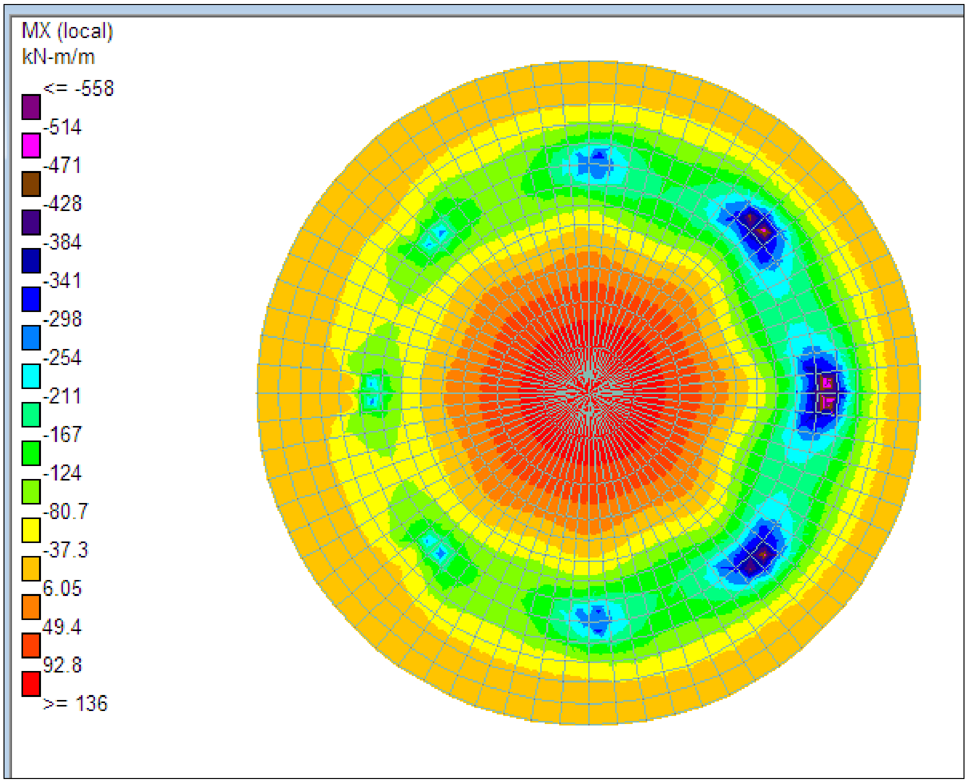
VII. RESULTS AND COMPARISON

Annular Raft shear force and bending moment as per Staad result

			Shear		Membrane			Bending Moment		
	Plate	L/C	SQX (local) kN/m2	SQY (local) kN/m2	SX (local) kN/m2	SY (local) kN/m2	SXY (local) kN/m2	Mx kN-m/m	My kN-m/m	Mxy kN-m/m
Max Qx	4431	102 TANK_FULL_ULS_1.5DL+1.5WRL+1.5WDL (+) X	**1528.888**	-251.597	0.000	0.000	0.000	-236.906	-331.664	-15.314
Min Qx	3718	102 TANK_FULL_ULS_1.5DL+1.5WRL+1.5WDL (+) X	**-924.949**	38.142	0.000	0.000	0.000	-119.308	-295.151	-40.522
Max Qy	3820	105 TANK_FULL_ULS_1.5DL+1.5WRL+1.5WDL (-) Z	274.389	**1324.142**	0.000	0.000	0.000	-279.346	-226.625	-2.003
Min Qy	3790	102 TANK_FULL_ULS_1.5DL+1.5WRL+1.5WDL (+) X	388.543	**-1287.138**	0.000	0.000	0.000	-280.413	-225.186	1.724
Max Sx	4434	101 TANK_FULL_ULS_1.5DL+1.5HT+1.5LL	89.688	-30.295	**0.000**	0.000	0.000	-0.514	-145.731	3.855
Min Sx	4434	101 TANK_FULL_ULS_1.5DL+1.5HT+1.5LL	89.688	-30.295	**0.000**	0.000	0.000	-0.514	-145.731	3.855
Max Sy	4434	101 TANK_FULL_ULS_1.5DL+1.5HT+1.5LL	89.688	-30.295	0.000	**0.000**	0.000	-0.514	-145.731	3.855
Min Sy	4434	101 TANK_FULL_ULS_1.5DL+1.5HT+1.5LL	89.688	-30.295	0.000	**0.000**	0.000	-0.514	-145.731	3.855
Max Sx	4434	101 TANK_FULL_ULS_1.5DL+1.5HT+1.5LL	89.688	-30.295	0.000	0.000	**0.000**	-0.514	-145.731	3.855
Min Sxy	4434	101 TANK_FULL_ULS_1.5DL+1.5HT+1.5LL	89.688	-30.295	0.000	0.000	**0.000**	-0.514	-145.731	3.855
Max Mx	4071	135 TANK_EMPTY_ULS_0.9DL+1.5WDL (+) X	-322.415	76.782	0.000	0.000	0.000	**66.015**	23.405	-0.589
Min Mx	4419	102 TANK_FULL_ULS_1.5DL+1.5WRL+1.5WDL (+) X	-231.237	-1179.054	0.000	0.000	0.000	**-336.201**	-167.019	42.830
Max My	4000	135 TANK_EMPTY_ULS_0.9DL+1.5WDL (+) X	-32.953	-227.575	0.000	0.000	0.000	16.380	**34.286**	25.760
Min My	4431	102 TANK_FULL_ULS_1.5DL+1.5WRL+1.5WDL (+) X	1528.888	-251.597	0.000	0.000	0.000	-236.906	**-331.664**	-15.314
Max Mx	3878	105 TANK_FULL_ULS_1.5DL+1.5WRL+1.5WDL (-) Z	-573.270	-521.499	0.000	0.000	0.000	-168.003	-141.337	**95.727**
Min Mxy	4268	104 TANK_FULL_ULS_1.5DL+1.5WRL+1.5WDL (+) Z	-613.821	468.305	0.000	0.000	0.000	-149.172	-158.095	**-96.778**



			Shear		Membrane			Bending Moment		
	Plate	L/C	SQX (local) kN/m2	SQY (local) kN/m2	SX (local) kN/m2	SY (local) kN/m2	SXY (local) kN/m2	Mx kN-m/m	My kN-m/m	Mxy kN-m/m
Max Qx	4431	102 TANK_FULL_ULS_1.5DL+1.5WRL+1.5WDL (+) X	**1412.011**	-226.831	0.000	0.000	0.000	-228.233	-242.114	-21.671
Min Qx	3718	102 TANK_FULL_ULS_1.5DL+1.5WRL+1.5WDL (+) X	**-1126.439**	54.741	0.000	0.000	0.000	-149.576	-172.183	-43.895
Max Qy	3820	105 TANK_FULL_ULS_1.5DL+1.5WRL+1.5WDL (-) Z	246.878	**1302.889**	0.000	0.000	0.000	-293.261	-131.103	-1.835
Min Qy	3789	102 TANK_FULL_ULS_1.5DL+1.5WRL+1.5WDL (+) X	-306.684	**-1279.846**	0.000	0.000	0.000	-324.768	-102.252	34.675
Max Sx	4724	101 TANK_FULL_ULS_1.5DL+1.5HT+1.5LL	-73.572	-5.116	**0.000**	0.000	0.000	146.184	144.949	0.443
Min Sx	4724	101 TANK_FULL_ULS_1.5DL+1.5HT+1.5LL	-73.572	-5.116	**0.000**	0.000	0.000	146.184	144.949	0.443
Max Sy	4724	101 TANK_FULL_ULS_1.5DL+1.5HT+1.5LL	-73.572	-5.116	0.000	**0.000**	0.000	146.184	144.949	0.443
Min Sy	4724	101 TANK_FULL_ULS_1.5DL+1.5HT+1.5LL	-73.572	-5.116	0.000	**0.000**	0.000	146.184	144.949	0.443
Max Sx	4724	101 TANK_FULL_ULS_1.5DL+1.5HT+1.5LL	-73.572	-5.116	0.000	0.000	**0.000**	146.184	144.949	0.443
Min Sxy	4724	101 TANK_FULL_ULS_1.5DL+1.5HT+1.5LL	-73.572	-5.116	0.000	0.000	**0.000**	146.184	144.949	0.443
Max Mx	4517	101 TANK_FULL_ULS_1.5DL+1.5HT+1.5LL	-73.601	-5.675	0.000	0.000	0.000	**146.296**	144.674	0.005
Min Mx	4419	102 TANK_FULL_ULS_1.5DL+1.5WRL+1.5WDL (+) X	-285.028	-1208.096	0.000	0.000	0.000	**-346.529**	-62.752	35.433
Max My	4688	101 TANK_FULL_ULS_1.5DL+1.5HT+1.5LL	-74.395	-2.734	0.000	0.000	0.000	144.735	**146.108**	0.408
Min My	4431	102 TANK_FULL_ULS_1.5DL+1.5WRL+1.5WDL (+) X	1412.011	-226.831	0.000	0.000	0.000	-228.233	**-242.114**	-21.671
Max Mx	4418	102 TANK_FULL_ULS_1.5DL+1.5WRL+1.5WDL (+) X	-755.321	-623.784	0.000	0.000	0.000	-195.814	-32.327	**83.621**
Min Mxy	3728	102 TANK_FULL_ULS_1.5DL+1.5WRL+1.5WDL (+) X	-807.403	554.007	0.000	0.000	0.000	-179.564	-48.975	**-96.343**



VIII. CONCLUSIONS

Based on the study carried out, the following conclusions are drawn:.

1) The distribution of pressure below the foundation is very with the change subgrade modulus.
2) Maximum reduction in the negative moment along the MY and MX is more at top solid raft
3) The overturning resisting moment is increased in case soild raft
4) The steel is reduced by providing ring Beam system to the annular foundation.
5) During the analysis it has been observed that moments of the raft changes with respect to SBC.
6) The variation in ring beam size effect moment and shear force annular raft foundation.
7) It is also observed that the saving in cost of construction is 12% by the provision of Beam over the annular raft. There is about 10% saving in steel.

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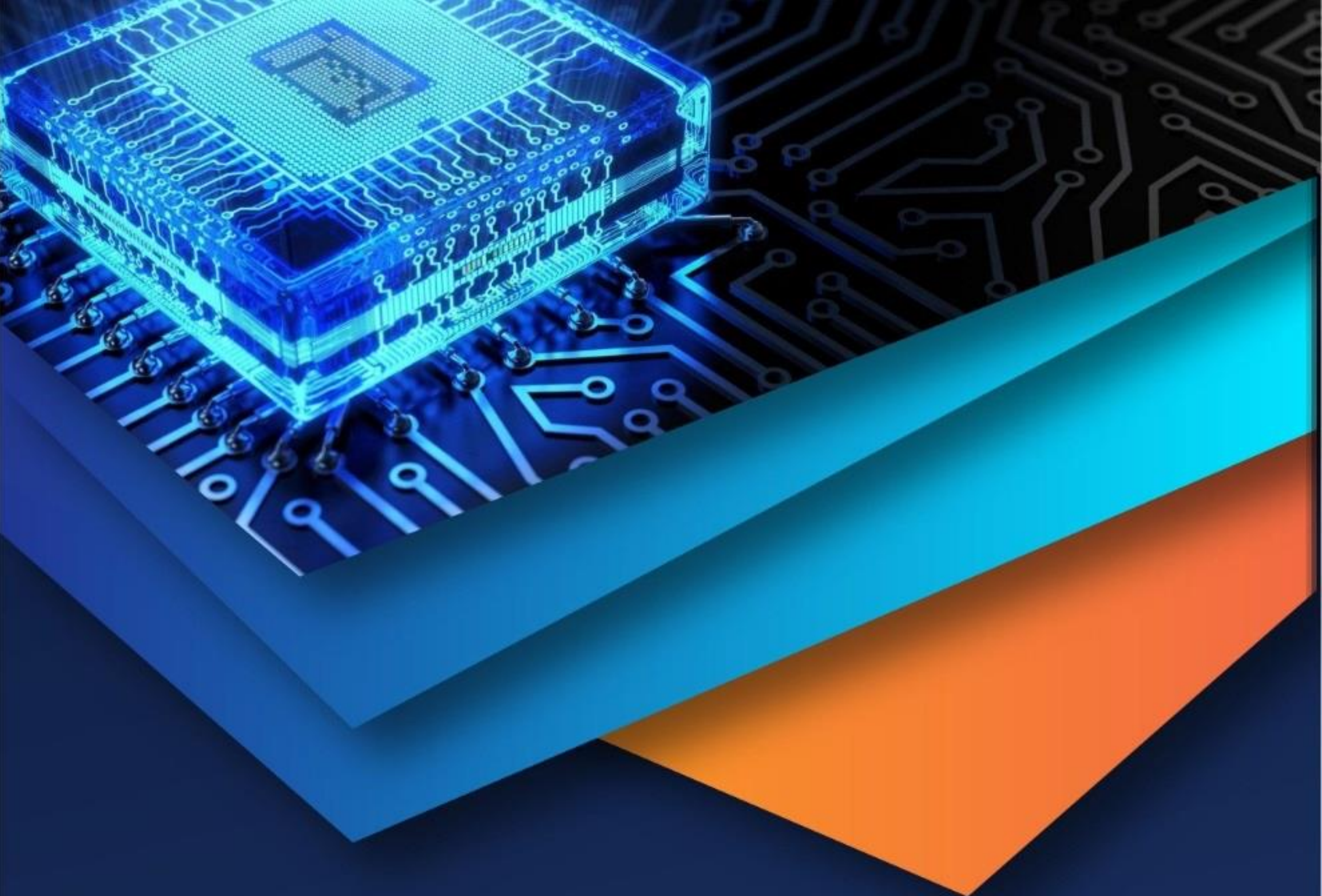

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