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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.

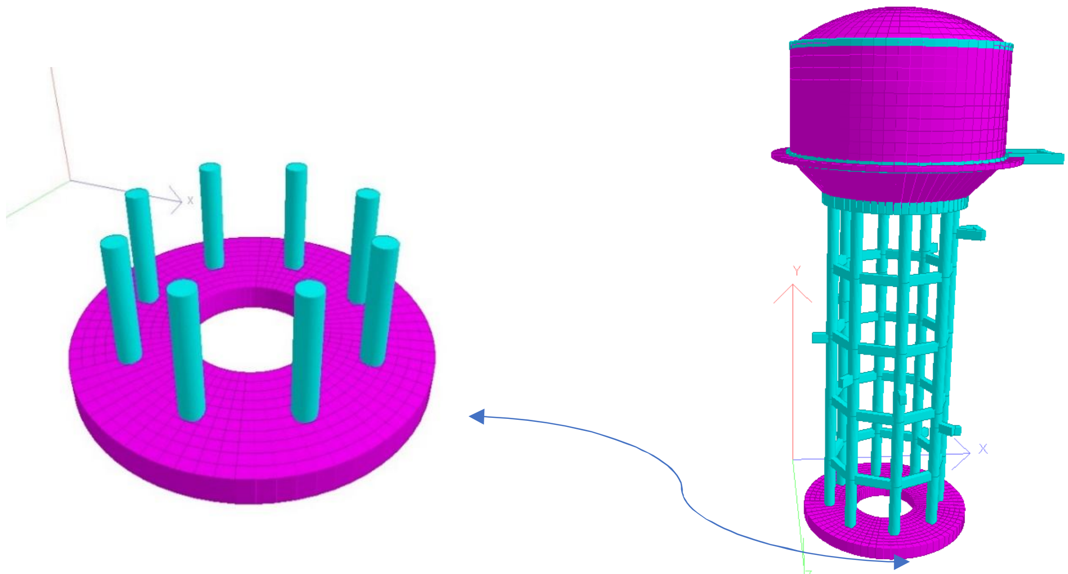

Fig:- Annular Mat Foundation

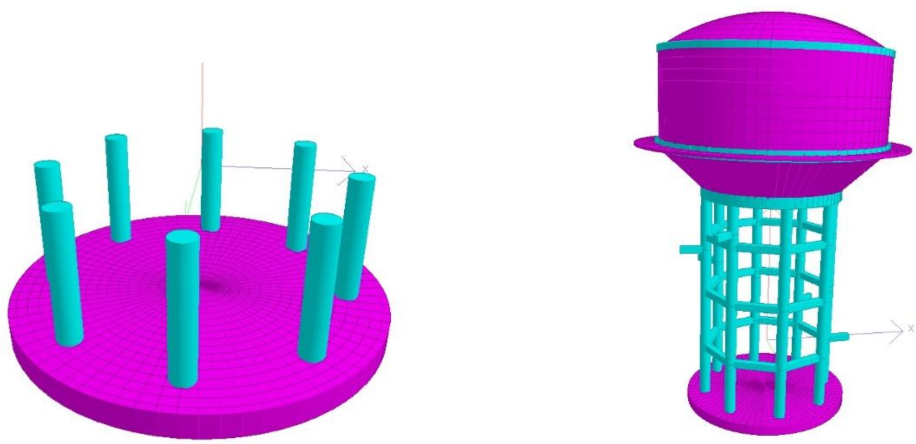

Fig:- Solid Raft foundation

## 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.

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 |
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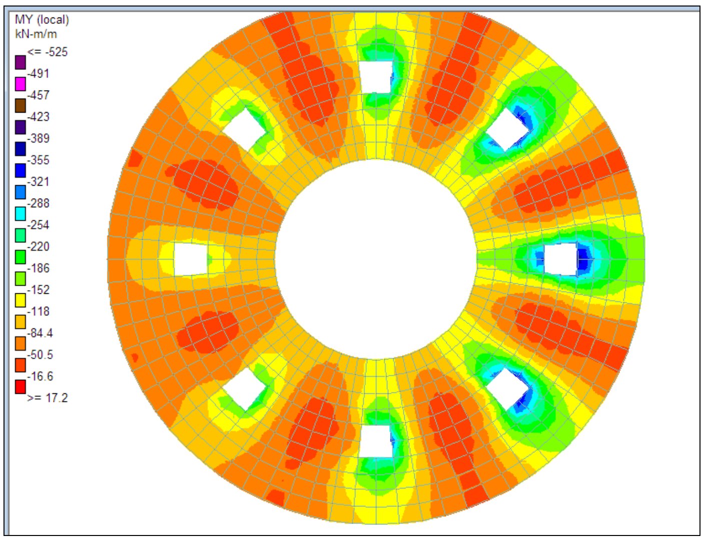
| Min Sxy | 4434 | 101 TANK_FULL_ULS_1.5DL+1.5HT+1.5LL | 89.688 | -30.295 | 0.000 | 0.000 | **0.000** | -0.514 | -145.731 | 3.855 |
| Max Mx | 4071 | 135 TANK_EMPTY_ULS_0.9DL+1.5WDL (+) X | -322.415 | 76.782 | 0.000 | 0.000 | 0.000 | **66.015** | 23.405 | -0.589 |
| Min Mx | 4419 | 102 TANK_FULL_ULS_1.5DL+1.5WRL+1.5WDL (+) 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** |

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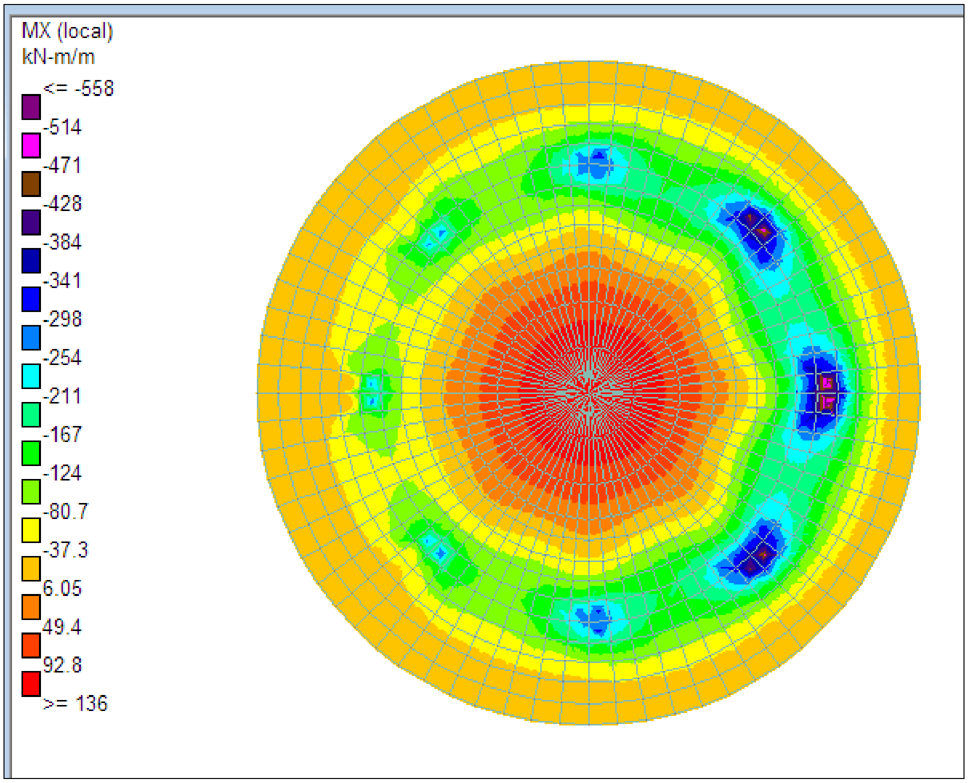


## VIII. CONCLUSIONS

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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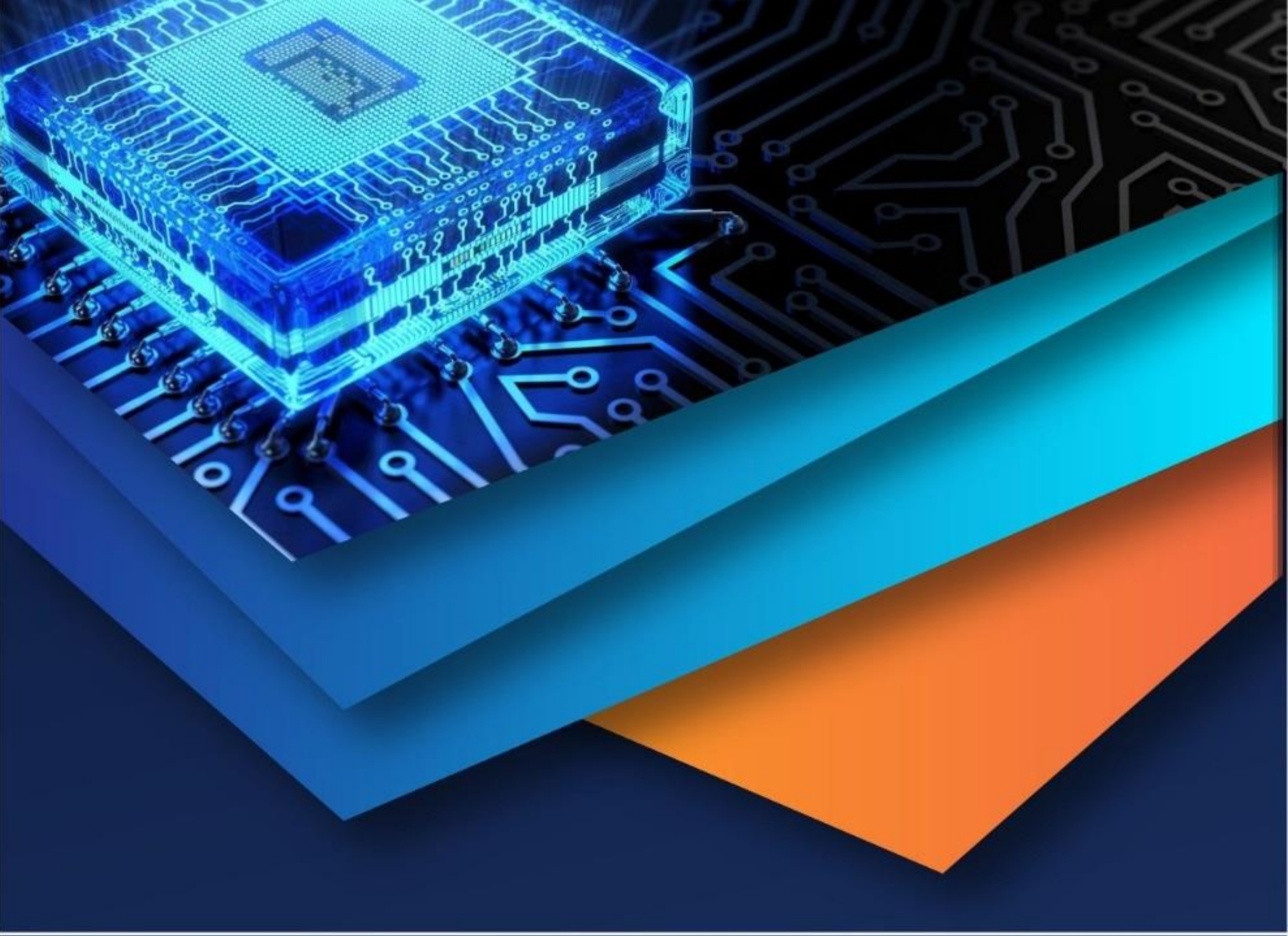


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