iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** X **Month of publication:** October 2021

DOI: https://doi.org/10.22214/ijraset.2021.38390

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue X Oct 2021- Available at www.ijraset.com

Comparative Analysis of Two cell and Three cell Box Culvert for Different Aspect Ratio

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Abstract: ***Culverts serves primarily as the hydraulic conduits conveying water from one side of a roadway or similar traffic embankment to the other; therefore, culverts serves the dual purposes of functioning as hydraulic structures as well as acting as traffic load bearing structures. They are normally cheaper than bridges, which make them the natural stream passes through channels. Box culvert are most stable and safe among various types of culverts. It can be constructed for soft soil conditions also. Therefore these are the best alternative to the major bridges for the small span and for cross drainage situation. In this work, we analyze the R.C. box culvert of two cell and three cell with different L/H ratio with the use of STAAD Pro software. In this study, we consider the span of culvert bridge as 10 m and we done the analysis for two cell and three cell culvert on the same span and varies the height with respect to span of the culvert bridge for different aspect ratio. Here we considered the traffic loading of Class AA loading as per IRC:6 2014 and also consider all the loading conditions as per IS codes. The structure designing includes the considerations of pressure cases (Box empty, Full, surcharge load) and factors such as Impact load, Braking force, Dispersal of load through fill, Effective width, Coefficients of earth pressure, Live load etc. The analysis of structure as per limit state method IS 800-2007. The IS standard requirements in the design manual for roads and bridges (IRC-6-2014, IS 112-2011) is used in the structural designing of concrete box culverts. The structural elements of two cell and three cell Box culverts are compared with respect to its maximum moments respectively for the different L/H ratio on the same span of the culvert. In the results we conclude that the moments are less than the two cell Box culvert with comparison to three cell Box culvert for the constant span of both the cases of culverts. In the present study, this paper provides full discussion on the provisions in the codes, considerations and justifications of all the above aspects of design.***

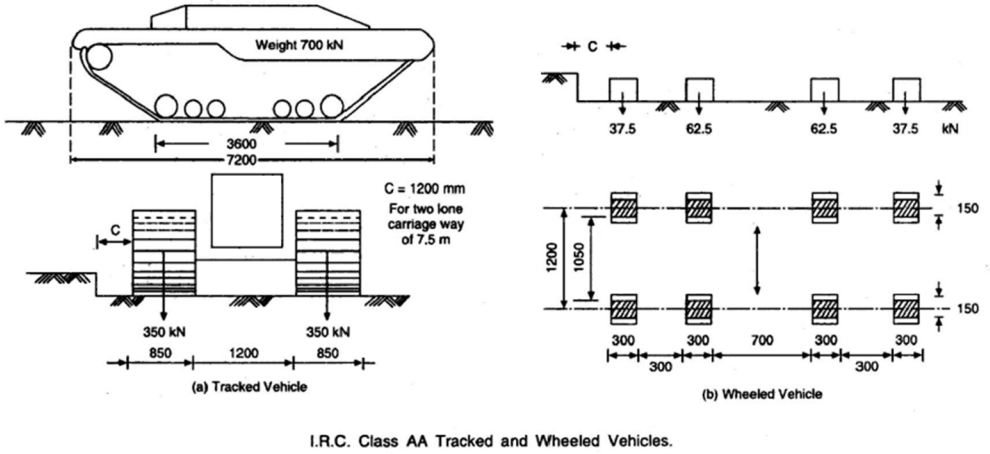
Keyword: ***Box culvert, aspect ratio, Staad pro, IRC codes.***

I. INTRODUCTION

A culvert is a compact channel that permits water to stream under a street, railroad, trail, or comparative hindrance from one side to the next. Regularly implanted in order to be encircled by soil, a culvert might be produced using a pipe, reinforced concrete or other material. Culverts are generally utilized both as cross-channels to alleviate seepage of ditches at the side of the road, and to pass water under a street at normal waste and stream intersections. A culvert might be an extension like structure intended to permit vehicle or walker traffic to get over the stream while permitting satisfactory section for the water. Box culvert is a type of culvert that provides movement of traffic having an opening without closing it and consisting of a rectangle or square opening whose length and height of the side walls is limited to 4 m. It is appropriate where the bearing capacity of the soil is low and discharge in cross drainage structure is medium. A box culvert is an ideal structure in such a situation. The carriageway can be at the top level of box culvert or may be at some height due to soil filling or cushioning box over the culvert. Culverts are always cheaper than those bridges where the discharge opening is less than $15m^2$ and especially where the road crosses relatively waterways on high embankment. Box culverts can have multi cells like single cell, double cell and triple cell so on. They control water flow and drainage for irrigation and municipal services, control storm water, and perform multiple other services. All of the above reasons represent a good motivation for researchers in culvert design method and construction technique. These constructions should oppose enormous vertical and sidelong earth pressures, and are regularly exposed to huge loadings during development of the bank. Because of the dirt construction collaboration impacts, the condition of weight on the course relies upon the stiffness of both the design and the inlay material. Although the pressing factors applied to the construction are very intricate, a basic methodology should be utilized for examination and configuration because of the huge number of culverts that are being fabricated.

II. IRC CLASS AA LOADING

This loading as described by IRC: 6-2000 for bridge design based on 2000. This was before loading IRC Class 70R has highest quantity of loading magnitude. This loading before starting IRC Class 70R was considered for the design of bridges for the military sector, industrial area and Highway loading. As IRC Class 70R IRC loading in the same way the Class AA loading also had a maximum load of 350Kn for single wheel and as longitudinal load length 3.6m.



I.R.C. Class AA Tracked and Wheeled Vehicles.

Figure1. Representation of IRC class AA Loading

III. MODELLING

In present study, the three dimensional Two cell and Three cell R.C. Box culvert of same span and varying depth for which the model of different L/H ratio are considered such as 1, 1.1, 1.2 ,1.3, 1.4, 1.5. The R.C. two cell and three cell box culvert are design and analysis according to IS 800: 2007 and IRC 6: 2014 by using STAAD PRO connect edition V22. The analysis performs on the direct application of vertical moving loads on the top slab of the box culvert bridge and along with the dead load of the structure. The lateral earth pressure and water pressure is also considered for the analysis. The behavior of box culvert is studying in terms of moments and shear stress on the top, bottom and side wall slabs for the different aspect ratio.

A. Geometrical Modeling

Table1: Geometric properties of culvert

Geometric Details			
Structure	Culvert structure		
Span	10 m		
Type of Culvert	Two cell R.C. Box culvert	Three cell R.C. Box culvert	
No. of cell	2	3	
No. of models	6	6	
Carriage Way	2	2	
Aspect Ratio (L/H)			
Cases for Two cell R.C. Box culvert	**Length(L) in metre**	**Height (H) in metre**	**Ratio (L/H)**
I	5.00	5.00	1
II	5.00	4.54	1.1
III	5.00	4.16	1.2
IV	5.00	3.84	1.3
V	5.00	3.57	1.4
VI	5.00	3.33	1.5
Aspect Ratio (L/H)			
Cases for Three cell R.C. Box culvert	**Length (L) in metre**	**Height (H) in metre**	**Ratio (L/H)**
I	3.33	3.33	1
II	3.33	3.02	1.1
III	3.33	2.77	1.2
IV	3.33	2.56	1.3
V	3.33	2.37	1.4
VI	3.33	2.22	1.5

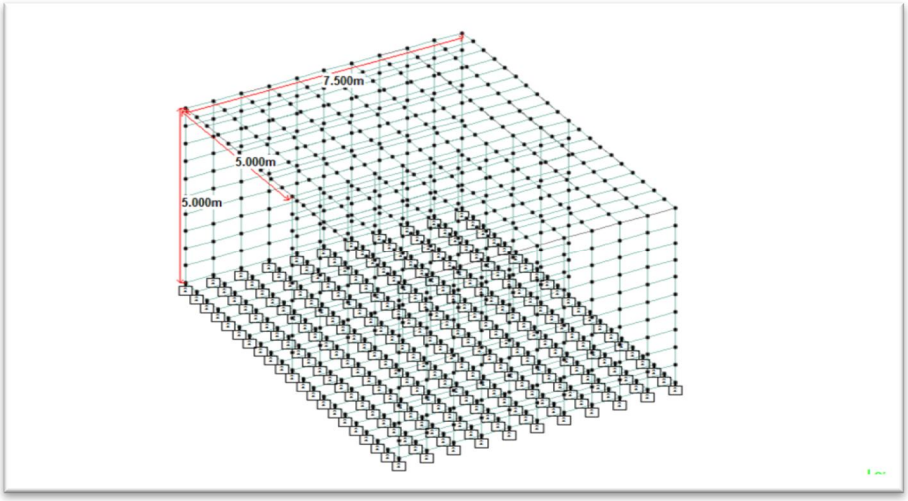


Figure 2. Two cell Box culvert Model

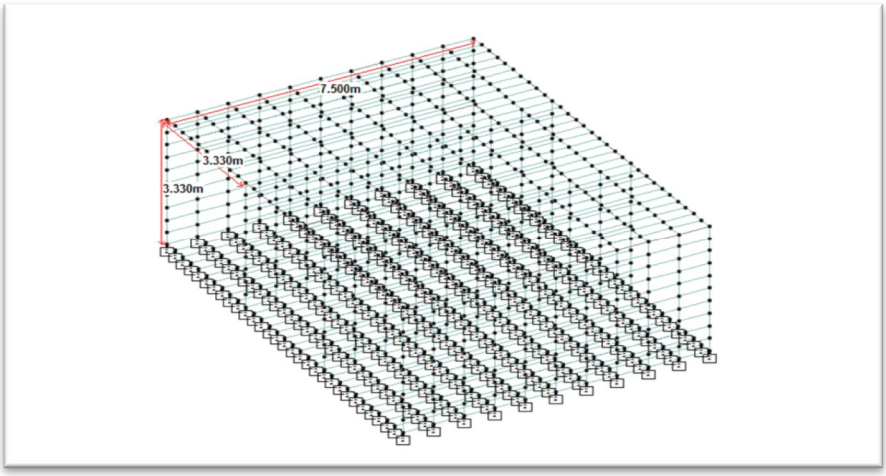


Figure 3. Three cell Box culvert Model

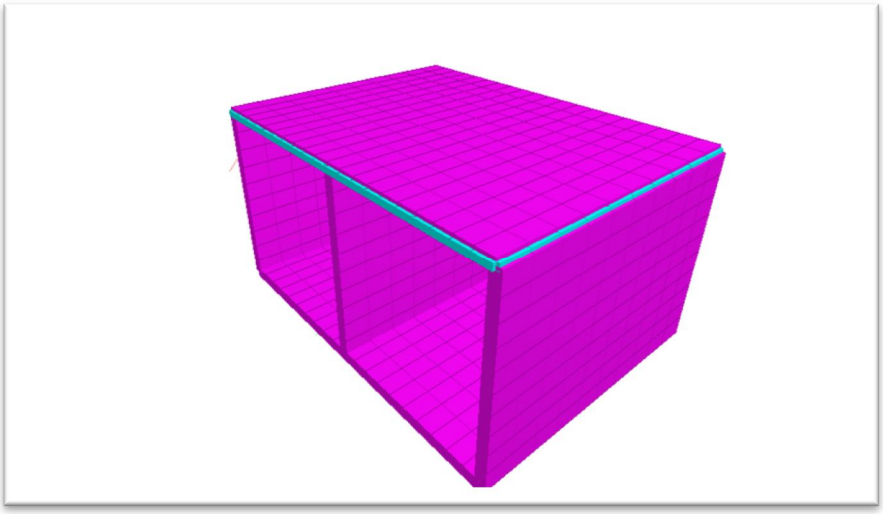


Figure 4. 3D view of Two cell R.C. Box Culvert

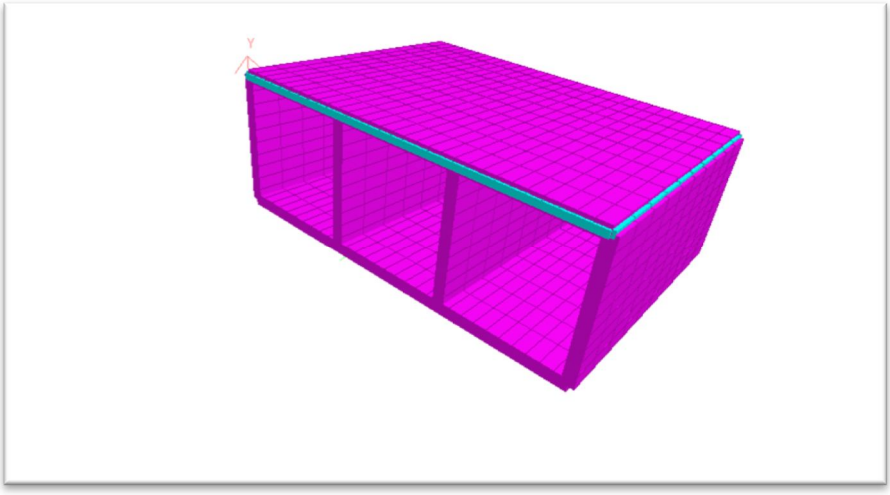


Figure 5. 3D view of Three cell R.C. Box Culvert

B. Material Properties of Structure

Table 2: Specification of Material Properties

Material Properties (Concrete)	
Grade of concrete	M-30
Weight per unit Volume(Kn/m^2)	25 Kn/m^3
Modulus of Elasticity, E (MPa)	27386.12
Material Properties (Steel Rebar)	
Grade of Steel	Fe-415.
Weight per unit Volume(Kn/m^2)	78.5 Kn/m^3
Modulus of Elasticity, E (MPa)	2x10^5
Material Properties (Soil)	
Unit weight of Earth (Kn/m^3)	20
Coefficient of active earth Pressure (Ka)	0.33
Modulus of Subgrade Reaction	300000Kn/m^2/m
Member Properties	
Top Slab Thickness (mm)	300 mm
Bottom Slab Thickness (mm)	300 mm
Side Wall Slab Thickness (mm)	300 mm
Size of Hidden Beams	150mmx150mm
No. of Plate Meshing Division	10
Meshing Type	Quadrilateral
Top Cushion	0.00mm

IV. RESULT AND DISCUSSION

The analysis are based on the limit state design method according to IS- code 800:2007 and IS 456:2000. In this study we also adopt the code IRC -6:2014 and IRC 112-2011 for the analysis of the culvert model for different aspect ratio. The results are compared for the maximum moments of Two cell and Three cell Box Culvert for their different L/H ratio of Top slab, Bottom slab, Side wall slab respectively.

Table 3 Maximum Moments for two cell and three cell box culvert on Top slab

L/H ratio	Moments for 2 cell box culvert in Kn.m/m	Moments for 3 cell box culvert in Kn.m/m
1	61.022	37.486
1.1	60.355	36.908
1.2	59.759	36.395
1.3	59.177	35.927
1.4	58.722	35.470
1.5	58.255	35.086

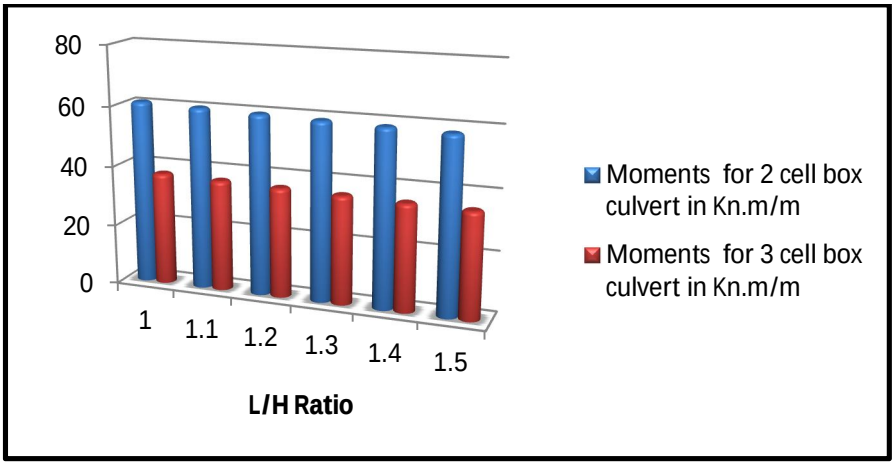


Figure 6 Comparison of moments at top slab for 2 cell and 3 cell box culvert

Table 4 Maximum Moments for two cell and three cell box culvert on Bottom slab

L/H ratio	Moments for 2 cell box culvert in Kn.m/m	Moments for 3 cell box culvert in Kn.m/m
1	32.876	20.318
1.1	30.180	19.997
1.2	28.958	19.738
1.3	27.601	19.517
1.4	26.469	19.312
1.5	25.884	19.202

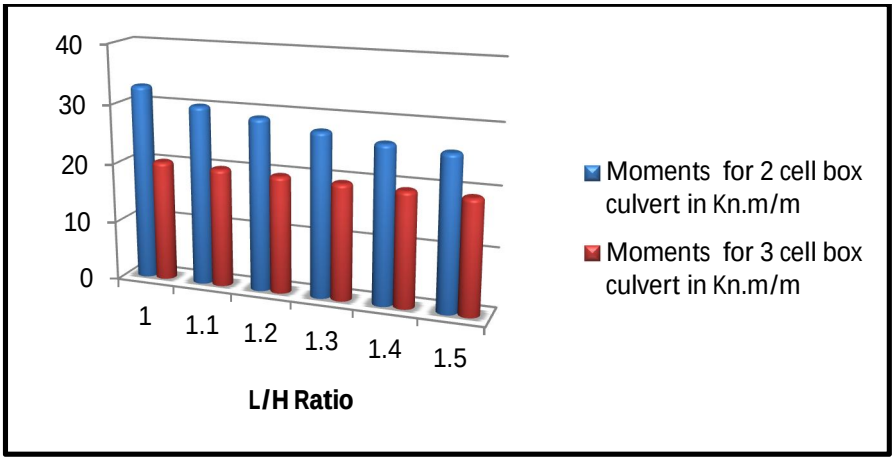


Figure 7 Comparison of moments at Bottom slab for 2 cell and 3 cell box culvert

Table 5 Maximum Stresses for two cell and three cell box culvert on Top Slab

L/H ratio	Stresses for 2 cell box culvert in N/mm^2	Stresses for 3 cell box culvert in N/mm^2
1	0.338	0.298
1.1	0.339	0.299
1.2	0.340	0.300
1.3	0.341	0.301
1.4	0.342	0.302
1.5	0.343	0.303

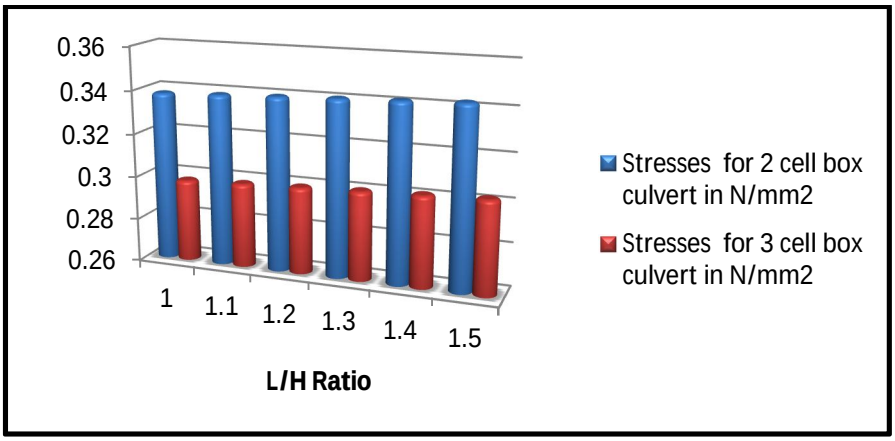


Figure 8 Comparison of Shear stresses at top slab for 2 cell and 3 cell box culvert

Table 6 Maximum Stresses for two cell and three cell box culvert on Bottom Slab

L/H ratio	Stresses for 2 cell box culvert in N/mm^2	Stresses for 3 cell box culvert in N/mm^2
1	0.254	0.242
1.1	0.253	0.241
1.2	0.251	0.238
1.3	0.249	0.237
1.4	0.248	0.236
1.5	0.246	0.234

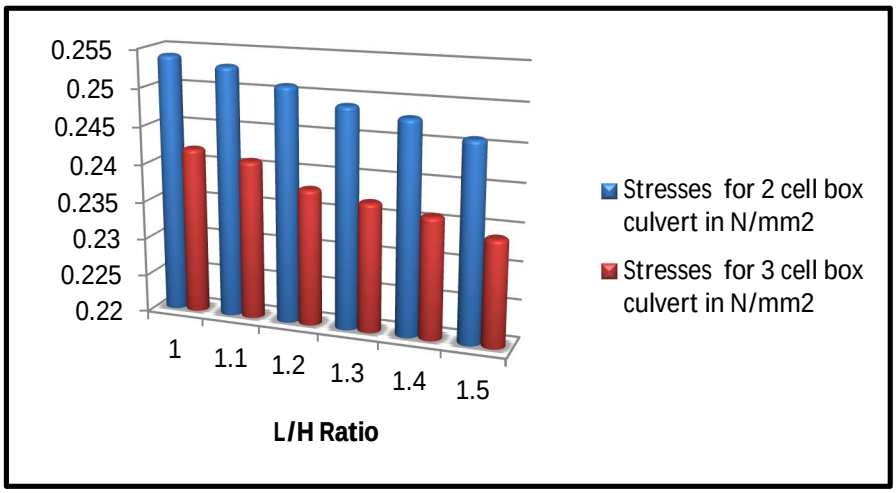


Figure 9 Comparison of Shear stresses at Bottom slab for 2 cell and 3 cell box culvert

V. CONCLUSION

In the analysis of Two cell R.C. Box culvert with different loading combinations and for different L/H ratio all the models are analyzed. In that analysis, the moments and shear stresses values for the slabs both the cell of the culvert are obtained. Here, comparing the moments and shear stresses values of both the Two cell and Three cell of the culvert for different L/H ratio on the same span length. The following conclusions are based on the research work are as follows-

A. In this analysis, the maximum moment values are reduced significantly for the three cell box culvert as compared to the two cell culvert. The deduction in percentage for Top slab is 38.56%, for Bottom slab is 38.19%.

B. As it shows the change in the moments values in three cell box culvert that are less than that of two cell box culvert at the top and bottom slab. But in side wall also the three cell box culvert moment values are 39.50% less than that of two cell box culvert.

C. For the shear stresses analysis, the values are again reduced for the three cell box culvert on comparison with the two cell Box culvert for different L/H ratio with same span. The values reduction in percentage are for Top slab is 11.83%, for Bottom Slab is 4.72%,

D. For three cell box culvert side wall Slab moment values are 17.50% less than that of two cell Box Culvert. It shows that the values are decreasing in three cell box culvert for the same span as compared to two cell box culvert for same loading conditions.

E. Hence, overall concludes that for the same span, the maximum moments and stresses values are reduced in significant amount on the Three cell Box culvert as compared with the Two cell Box culvert for different L/H ratio

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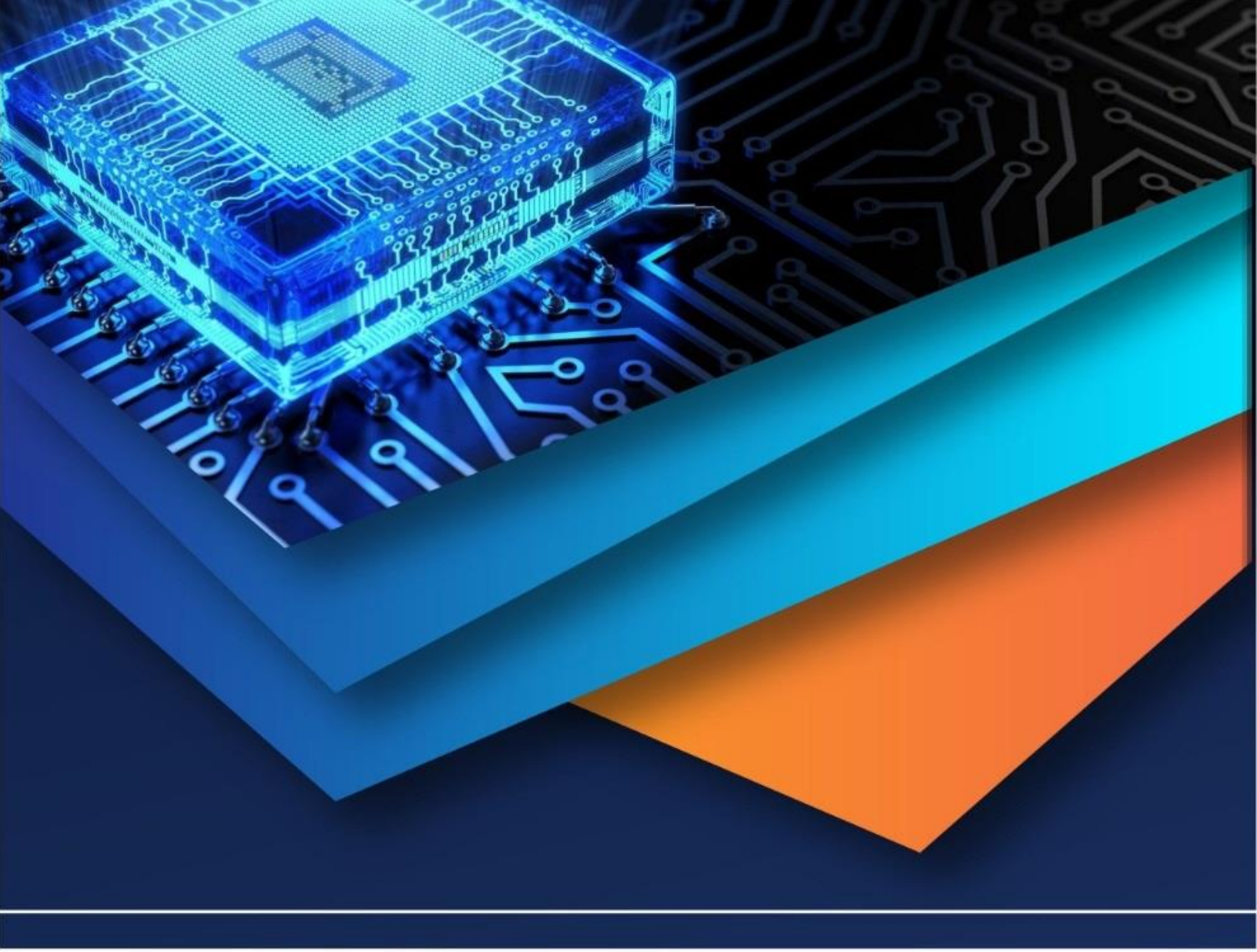

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