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Study of Light Weight High Performance Concrete Filled Steel Tube Columns

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I. INTRODUCTION

Composite construction as we know it today was first used in the construction of a building and a bridge in the U.S. over a century ago. The first forms of composite structures incorporated the use of steel and concrete for flexural members, and the issue of longitudinal slip between these elements was soon identified.

Composite steel concrete beams are the earliest form of the composite construction method Concrete encased steel sections was used at the beginning to overcome the problem of fire resistance and to ensure that the stability of the steel section was maintained throughout loading.

The steel section and concrete act compositely to resist axial force and bending moments. Composite tubular columns were developed much later during the last century. They were used because they provided permanent and integral formwork for a compression member and were instrumental in reducing construction times and consequently cost.

Thus, 2 types of steel-concrete columns were developed:

A. Steel section in-filled with concrete
B. Steel section encased with concrete

Nowadays, the composite structural elements are increasingly used in tall buildings, bridges and other types of structures. It is still based on the fundamental principle that steel is most effective in tension and concrete is most effective in compression. Thus, the disadvantage of two materials can be compensated for and the advantages can be combined, providing efficient structural system. The steel-concrete composites are considered as an advantageous system for carrying large axial load benefitting from the interaction between the concrete and the steel section. The steel section reinforces the concrete to resist any bending moments, tensile and shear forces.

The concrete in a composite column reduces the potential for buckling of the steel section in addition to resisting compressive loading.

The use of composite columns, encased or in-filled, results in significant reduction of the column size when compared to regular reinforced concrete columns needed to carry the same load.

Hence, considerable economic savings can be obtained. Also, the column size reduction is advantageous where floor space is at a premium, such as in office blocks and car parking’s.

In addition, closely spaced composite columns connected with spandrel beams can be used around the outsides of the high rise buildings for lateral loads resistance by the tabular concept.

Concrete encased steel composite sections are favored for many seismic resistant structures. When the concrete encasement cracks under severe flexural overloading, the stiffness of the section reduces but the steel core provides shear capacity and ductile resistance to subsequent cycles of overload. Additionally, the surface area of the enclosed steel sections is intact by the concrete cover, thus required no painting and fire proofing costs.

Concrete filled steel tube (CFST) columns are favored for many earthquake resistant structures, columns in high rise buildings, bridge piers subject to high strain rate from traffic and railways decks. Concrete filled steel tubes necessitate supplementary fire resistant insulation if fire protection of the structure is crucial.

The CFST structures have better constructability because the steel tubes can be used as the formwork and the shoring system for casting concrete in construction. Moreover, CFSTs provide high compressive and torsional resistance about all axes when compared with concrete encased steel composite sections.

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II. EFFECT OF D/T RATIO

Table No. 1 the Results of D/T Vs L.C.C. For Circular & Rectangular CFST Specimens

Sr.No	Shape	Shape Properties				Eurocode-4 (kN)	ABAQUS Load (KN)	Experimental L.C.C. (kN)
		Dimension (mm)	D	Thickness (mm)	D/t			
1	Circular	80ϕ	80	4	20.00	445.393	462.65	514.60
2	Circular	80ϕ	80	4	20.00	432.252	459.89	490.22
3	Circular	80ϕ	80	4	20.00	421.650	455.12	475.90
4	Circular	80ϕ	80	4	20.00	410.890	450.52	466.35
5	Circular	80ϕ	80	3	26.67	328.800	355.25	384.05
6	Circular	80ϕ	80	3	26.67	327.861	350.22	373.70
7	Circular	80ϕ	80	3	26.67	326.852	345.28	365.67
8	Circular	80ϕ	80	3	26.67	312.735	338.18	355.66
9	Circular	80ϕ	80	2	40.00	236.952	231.96	264.20
10	Circular	80ϕ	80	2	40.00	245.995	251.05	272.30
11	Circular	80ϕ	80	2	40.00	245.110	238.98	283.50
12	Circular	80ϕ	80	2	40.00	244.161	248.15	257.70
13	Rectangular	80 × 40	40	2	20.00	218.346	225.73	232.62
14	Rectangular	80 × 40	40	2	20.00	187.349	192.73	223.10
15	Rectangular	80 × 40	40	2	20.00	186.644	166.58	189.00
16	Rectangular	80 × 40	40	2	20.00	254.865	160.28	296.50
17	Rectangular	80 × 40	40	3	13.33	250.227	282.78	314.35
18	Rectangular	80 × 40	40	3	13.33	249.252	257.80	320.15
19	Rectangular	80 × 40	40	3	13.33	176.144	190.25	194.90
20	Rectangular	80 × 40	40	3	13.33	179.324	185.50	197.00
21	Rectangular	80 × 40	40	4	10.00	305.378	318.96	319.80
22	Rectangular	80 × 40	40	4	10.00	240.330	274.24	284.20
23	Rectangular	80 × 40	40	4	10.00	302.672	257.22	303.75
24	Rectangular	80 × 40	40	4	10.00	233.110	234.05	289.20

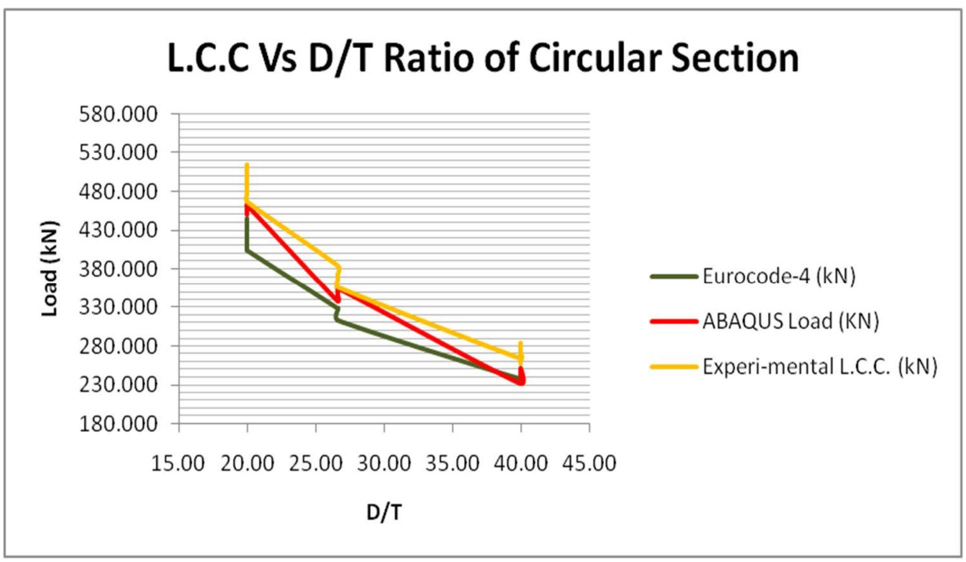

Figure No. 1 L.C.C V_S D/T for Circular CFST Specimens

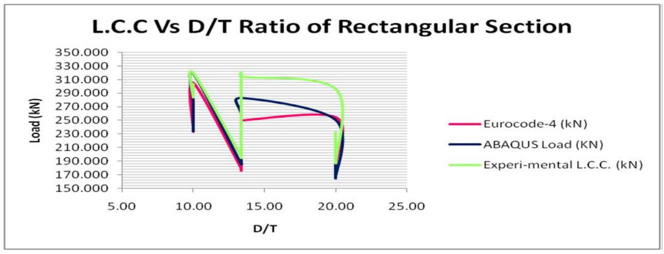

Figure No. 2 L.C.C V_S D/T for Rectangular CFST Specimens

When length is constant and thickness is increases by 1mm, The L.C.C. of CFST specimen is increase as D/t ratio decrease. The decrease of d/t ratio by increasing the thickness of specimens and keeping the overall cross section constant denotes following results. From figures it is observed that as d/t ratio decreases when thickness is increased and lateral dimension kept constant the load carrying capacity of the CFST column specimen's increases.

A. For circular CFST by 25% decrease in d/t ratio L.C.C. increases by 25.36%.

B. For rectangular CFST by 33.35% decrease in d/t ratio L.C.C. increases by 27.34%.

III. EFFECT OF L/D RATIO

Table No.2 Difference of L.C.C at Eurocode-4, ABAQUS & Experimental Result with respect to L/D Ratio For Circular & Rectangular CFST Specimens

Sr.No	Shape	Dimension (mm)	L/D	Eurocode-4 (kN)	ABAQUS Load (KN)	Exp. L.C.C. (kN)	Difference between Eurocode-4 & Exp. Result	Difference between ABAQUS & Exp. Result
1	Circular	80	7.500	445.393	462.65	514.60	13.45	12.45
2	Circular	80	8.125	432.252	459.89	490.22	17.11	7.16
3	Circular	80	8.750	421.650	455.12	475.90	14.85	3.36
4	Circular	80	9.375	410.890	450.52	466.35	13.37	0.79
5	Circular	80	7.500	328.800	355.25	384.05	14.39	11.94
6	Circular	80	8.125	327.861	350.22	373.70	12.27	7.61
7	Circular	80	8.750	326.852	345.28	365.67	10.62	4.23
8	Circular	80	9.375	312.735	338.18	355.66	12.07	0.12
9	Circular	80	7.500	236.952	231.96	264.20	10.31	12.20
10	Circular	80	8.125	245.995	251.05	272.30	9.66	7.80
11	Circular	80	8.750	245.110	238.98	283.50	13.54	15.70
12	Circular	80	9.375	244.161	248.15	257.70	5.25	3.71
13	Rectangular	80X40	15.000	218.346	225.73	232.62	6.14	2.96
14	Rectangular	80X40	16.250	187.349	192.73	223.10	16.02	13.61
15	Rectangular	80X40	17.500	186.644	166.58	189.00	1.25	11.86
16	Rectangular	80X40	18.750	254.865	160.28	296.50	14.04	15.46
17	Rectangular	80X40	15.000	250.227	282.78	314.35	20.40	10.04
18	Rectangular	80X40	16.250	249.252	257.80	320.15	22.15	19.48
19	Rectangular	80X40	17.500	176.144	190.25	194.90	9.62	2.39
20	Rectangular	80X40	18.750	179.324	185.50	197.00	8.97	5.84
21	Rectangular	80X40	15.000	305.378	318.96	319.80	4.51	0.26
22	Rectangular	80X40	16.250	240.330	274.24	284.20	15.44	3.50
23	Rectangular	80X40	17.500	302.672	257.22	303.75	0.35	15.32
24	Rectangular	80X40	18.750	233.110	234.05	289.20	19.40	19.07

EC4 covers concrete encased and partially encased steel sections and concrete filled sections with or without reinforcement. This code uses limit state concepts to achieve the aims of serviceability and safety by applying partial safety factor to loads and material properties. The L.C.C. of specimens calculated by Eurocode-4 and experimental results are compared as below:

From above results it is seen that the experimental findings are more than that of the Eurocode-4.The theoretical capacity of CFST sections as per Eurocode-4 compared with experimental results

1) For circular CFST experimental results are 12.25% more than the axial strengths estimated by Eurocode-4.
2) For rectangular CFST experimental results are 11.52% more than the axial strengths estimated by Eurocode-4.

Therefore the experimental results are 11.885% more than the axial strengths estimated by Eurocode-4.

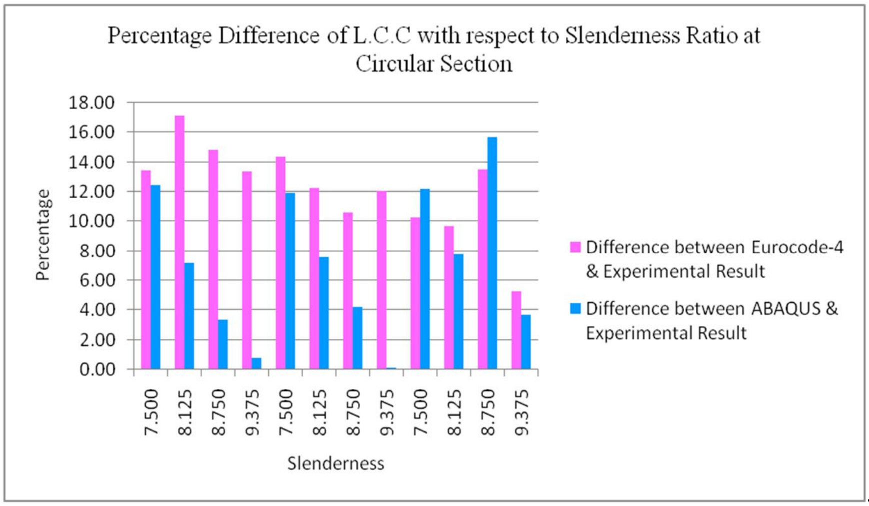

Figure No. 3 Percentage Difference of L.C.C at Eurocode, ABAQUS & Experimental Result with respect to Slenderness Ratio at Circular Section

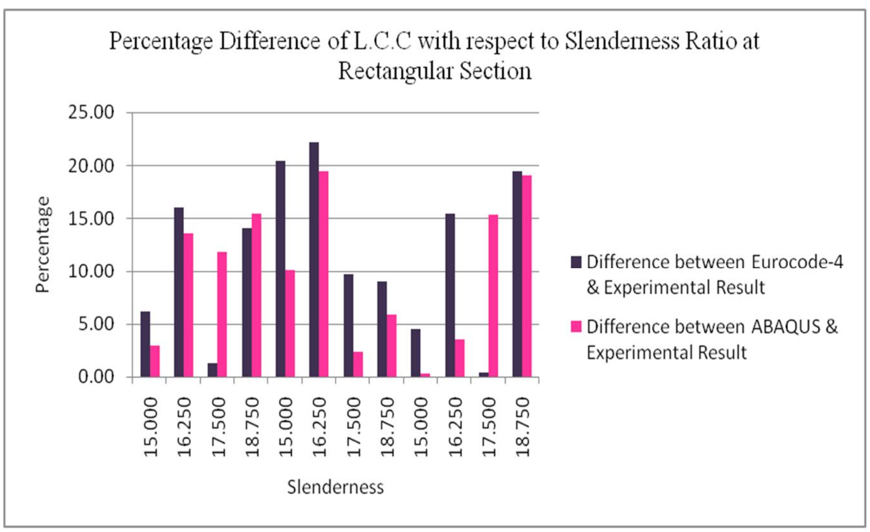

Figure No. 4 Percentage Difference of L.C.C at Eurocode, ABAQUS & Experimental Result with respect to Slenderness Ratio at Rectangular Section

ABAQUS is the simulation software used for finite element analysis of different structural members, it also used for finite element analysis of many mechanical parts. The L.C.C. find out by Experiments and in ABAQUS are compared and tabulated as below.

From above results it is seen that the experimental findings are more than results found out in ABAQUS 6.13.1 software.

1) For circular CFST experimental results are 7.26% more than the axial strengths estimated by ABAQUS.
2) For rectangular CFST experimental results are 9.98% more than the axial strengths estimated by ABAQUS.

Therefore the experimental results are 8.62 % less than the axial strengths estimated by ABAQUS.

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IV. FAILURE MODES OF CFST SPECIMENS

The CFST column specimens are tested under axial load to find out load carrying capacity. Concrete filled steel tube column fails due to crushing of concrete and buckling of steel tube. Local buckling of specimen is occurred close to mid height of specimens. Various failure modes of CFST specimens are tabulated as below.

Table No.3 Failure Modes of CFST Specimens

Sr.No	Shape	Shape Properties			Failure Pattern
		Dimension (mm)	Length (mm)	Thickness (mm)	
1	Circular	80ϕ	600	4	Excessive compression
2	Circular	80ϕ	650	4	Buckling
3	Circular	80ϕ	700	4	Buckling
4	Circular	80ϕ	750	4	Local Buckling
5	Circular	80ϕ	600	3	Excessive compression
6	Circular	80ϕ	650	3	Excessive compression
7	Circular	80ϕ	700	3	Buckling
8	Circular	80ϕ	750	3	Buckling
9	Circular	80ϕ	600	2	Buckling
10	Circular	80ϕ	650	2	Buckling
11	Circular	80ϕ	700	2	Buckling
12	Circular	80ϕ	750	2	Buckling
13	Rectangular	80 × 40	600	2	Excessive compression
14	Rectangular	80 × 40	650	2	Excessive compression
15	Rectangular	80 × 40	700	2	Local Buckling
16	Rectangular	80 × 40	750	2	Buckling
17	Rectangular	80 × 40	600	3	Excessive compression
18	Rectangular	80 × 40	650	3	Excessive compression
19	Rectangular	80 × 40	700	3	Excessive compression
20	Rectangular	80 × 40	750	3	Excessive compression
21	Rectangular	80 × 40	600	4	Excessive compression
22	Rectangular	80 × 40	650	4	Buckling
23	Rectangular	80 × 40	700	4	Buckling
24	Rectangular	80 × 40	750	4	Buckling

Figure No. 3 Deformed Circular CFST Columns after Experiment

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Figure No. 4 Deformed Rectangular CFST Columns after Experiment

V. MODULUS OF ELASTICITY WITH THE HELP OF STRESS VS STRAIN GRAPH

The modulus of elasticity depends on the slope of stress and strain graph. The value of E is constant for whole section under loading and hence the slope of the graph of stress and strain is taken and E is calculated at 101.004 KN/MM2.

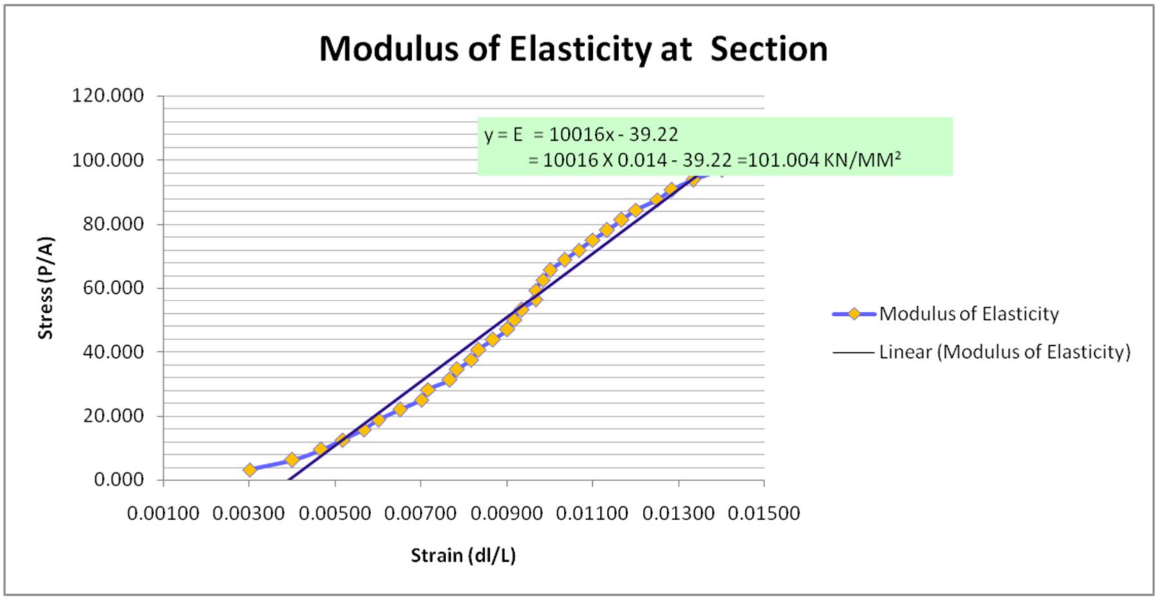

Figure No. 5.25 Modulus of Elasticity at Section

VI. CONCLUSION

Following Conclusions were drawn from the study carried out in this dissertation.

1) By using Sintagg lightweight aggregate concrete of M30 grade helps to reduce the self-weight of structural members up to 25.30%.
2) It is observed that as d/t ratio decreases the load carrying capacity of the CFST column specimen's increases as per following details
a) For circular CFST specimens when d/t ratio decreases by 25% then L.C.C. increases by 25.36%.
b) For rectangular CFST specimens when d/t ratio decreases by 33.35% then L.C.C. increases by 27.34%.

3) The theoretical capacity of CFST sections as per Eurocode-4 is compared with experimental results; it is observed that experimental results are 11.885% more than the axial strengths estimated by Eurocode-4.
4) The slenderness ratio increases the load carring capacity decreases that are slenderness ratio is universally proportion to load carring capacity i.e. 0.934 at experiment result.
   a) From circular results it is observed that 0.934 at experiment result.
   b) From rectangular results it is observed that 0.175 at Eurocode-4.
5) The load carrying capacities are decreases as per length increase.
6) The modulus of elasticity depends on the slope of stress and strain graph. The value of E is constant for whole section under loading and hence the slope of the graph of stress and strain is taken at 4, 3 & 2mm thick section is 0.975, 0.992, 0.987, resp.
7) The axial strengths found in ABAQUS are compared with experimental results; it is observed that for experimental results are 8.62% more than the axial strengths estimated by ABAQUS.

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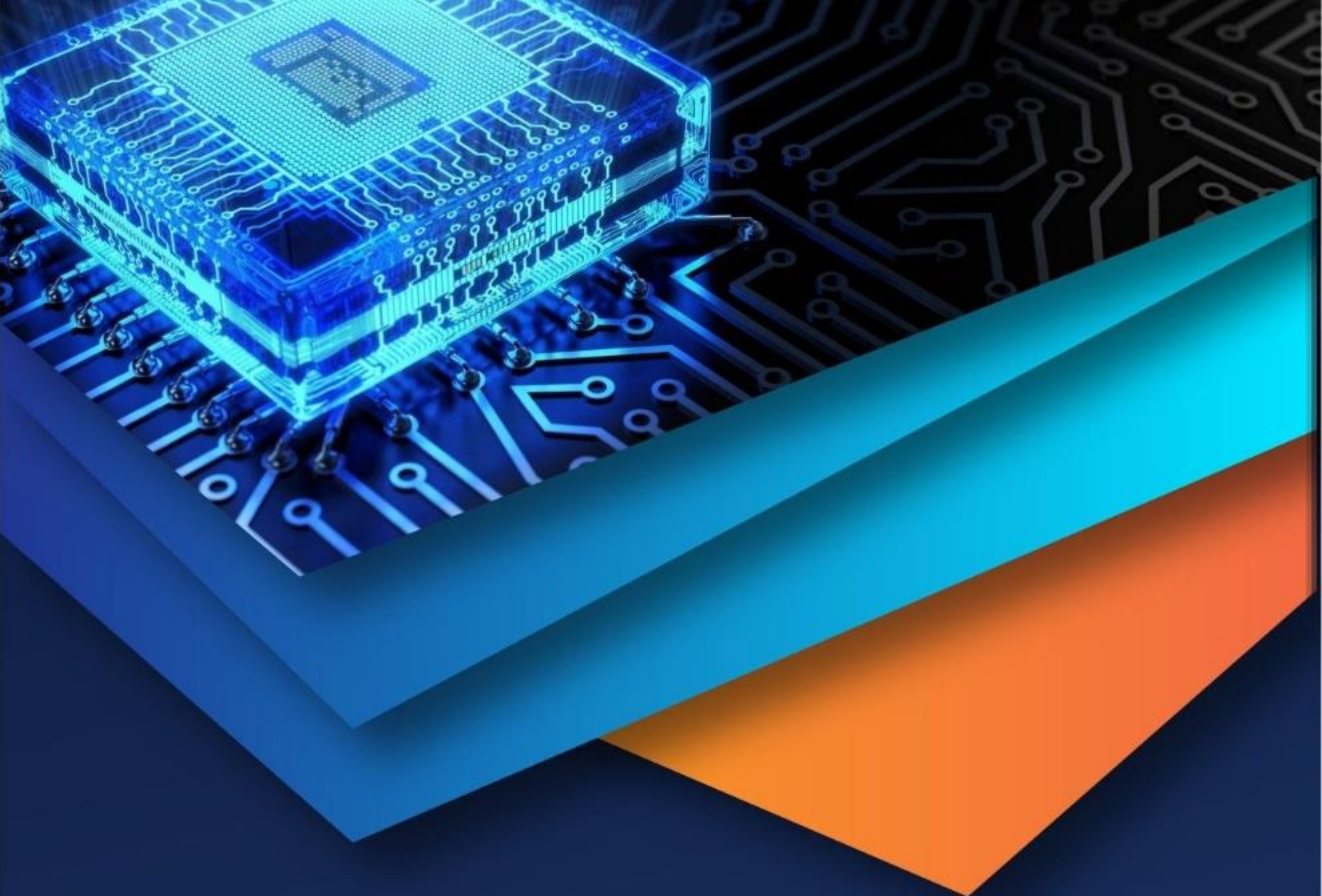

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