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Comparative Studies of Steel Member with Different Country Code

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Abstract: Steel structure now days are very popular today. Industrial building require huge span structure. Hence demand of steel structure is very significant. In today world, there are construction of high rise building with heavy strength against natural forces like gravity ,winds and earthquake . In steel structure a complex shape building can be easily framed and constructed but in RCC there is a lot of limitation. Hence there is essence need to compare code of different countries. This study include IS 800:2007,Australian code AS 4100,Euro code EN 1993-1-1:2005 and American code AISC 360-16. This studies compare different codal formulas for different strength like bending strength ,shear strength Axial capacity. I have gone through many research paper and dicussed with my classmates and experienced professor also. For more knowlwdge I also discuss with structure consultant. After the all conclusion, I took decision to compare codal provision,. All codes using Limit state of design and they used different material safety factor according to their standard of the country. Earlier most of the countries were using working stress design philospy but a lot of research work and experiment develop limit state of design philospy . Now most of the countries are using limit state design philospyfor the design as vast research has been done in the field of structural engineering in past 50 years. There is tremendious change intechnology and engineers were facing the problem with previous design code (IS 800:1984), the Bureau of Indian Standard, New Delhi had requested the faculties of Indian Institute of Technology-Madras to help and prepare the new code based on current practices of the various countries. The work of providing new design code (IS 800:2007) was carried out as a project with the financial support from the Institute for Steel Development and Growth(INSDAG), Calcutta. Various international codes have been used for introducing IS800:2007. The new code has adopted various parameters from international `codes and it has also introduced provisions on partial safety factor depends on limit state design, design against fatigue, design for fire load, design for durability, design by testing. The previous design philosophy, Working Stress Method(WSM) was based on linear elastic theory which has been replaced with limit state design theory in most of the countries. Working stress method was based on ultimate strength of steel and ultimate loads. Working stress method was developed in 1950.

After it, probablistics concept was adopted for the design. The philosophy was based on the theory that different uncertainties can be tackled more rationally in the mathematical framework of probability theory. The risk which was involved in design was quantified in terms of a probability of failure which is known as reliability based method.

To get a fruitful outcome/desirable outcome for above mentioned we describe two philosophy.

1) Working stress design philosophy

2) Limit state design philosophy

Codes will be compared only limit state design philosophy in context of design bending formula, shear strength formula.

Keywords: Laterally supported beam, Laterally unsupported beam, Web buckling strength, Web crippling, Lateral torsional buckling

I. INTRODUCTION

Steel member are defined as member that is made of steel element. With help of steel element properties today high rise steel structure is developed by engineers. Steel industry is growing rapidly in almost all the parts of the world. The use of steel structures is not only economical but also eco friendly at the time when there is a threat of global warming. Here, "economical" word is stated considering time and cost. Time being the most important aspect, steel structures is built in very short period.The structural performance of these buildings is well understood and, for the most part, adequate code provisions are currently in place to ensure satisfactory behavior in high winds . Steel structures also have much better strength-to-weight ratios than RCC and they also can be easily dismantled. that utilized by the people as shelter for living, working or storage.

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II. OBJECTIVE

1) Becoming familiar with "Limit State of Design" for steel structures which has been used in IS 800:2007, AISC 360-16, EN 1993-1-1(2005), AS 4100:1998
2) Learning as well as understanding the basis of various clauses concerned with section of design of members subjected to flexure and combined forces from IS 800:2007, AISC 360-16, EN 1993-1-1(2005), AS 4100:1998
3) Comparing similarities as well as difference between four standards .
4) Searching the area which has not been covered in each code .
5) To document step-by step procedure for designing different types of members, clearly highlighting different methodology adopted in four different countries so that it may be helpful to practicing engineers.

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III. METHODOLOGY

A. *Definition*

1) *Laterally Supported Beam:* A beam experiencing bending along major axis and when the compression flange is restrained from buckling such beams are called laterally unsupported beam.
2) *Laterally Unsupported Beam:* A beam experiencing bending along major axis and when the compression flange is not restrained from buckling such beams are called laterally supported beam.
3) *Web Buckling Strength:* Certain portion of beam at supports acts as column to transfer the load from beam to the support. Hence under this compressive force web may buckle. This may happen under a concentrated load on beam also.
4) *Web Crippling:* Web crippling and buckling are almost same phenomena but it takes place when it is being compressed. It also takes place at the beam support, where there is bottom flange resting on support, and top flange takes load.
5) *Lateral Torsional Buckling:* Lateral torsional buckling may occur in an unrestrained beam. Beam experiencing bending about the major axis and not restrained against the lateral buckling of compression flange may fail by lateral torsional buckling before material fails.

B. *Limit State method*

The main objective behind limit state method is "the structure will not damage during its entire service life because of collapse, excessive deflection etc, under the actions of all loads and load combinations."

1) *Basic of Limit State Design:* Limit states are defined as the limits for the safety and serviceability requirements for the structure before the failure occurs which are acceptable. In limit state design the stress in material is allowed to go beyond the yield limit and enter into the plastic zone to reach ultimate strength. There are two types of limit states which are existing. Limit state of design basically deals with that the design strength should be greater than design action which is acting on the structure.

a) Limit state of collapse
b) Limit state of serviceability

Design Action≤Design Strength

C. *Main Objectives of limit state Method*

1) Structure must be checked for relevant limit state For each type of limit state appropriate actions are to be considered
2) From the different parameters such as material properties and geometrical data it is necessary to verify that none of the limit state should be exceeded.

D. *Types of Limit States*

1) *Limit state of Collapse:* Strength and stability of the structure subjected to maximum design loads out of possible combinations of serval types of loads. The main objective of this is neither any part nor the whole structure should be collapsed or become unstable under any type of load or load combinations.
2) *Serviceability Limit State:* It basically deals with deflection and cracking of structures under service loads, durability under working environment during their anticipated exposure condition during service, stability as a whole, fire resistance etc.

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E. *Behaviour of Steel Beams*

Different types steel sections can be used for the efficient utilization of material in a beam is determined by the geometrical layout of web and flanges. The optimum section for flexure resistance is the one in which the material is located as far as possible from the neutral axis, in the form of flanges.

In the beam design process, there are three factors importance for determining the size of the necessary structural steel beam for a given set of condition. In order of priority they are:

1) Design based on stress due to bending
2) Design based on deflection
3) Design based on shear

F. *Modes of Failure*

1) *Bending Failure:* Bending failure may be due to crushing of compression flange or fracture of the tension flange of the beam. Instead of failure due to crushing, the compression flange may fail by column-like action with side sway or lateral buckling. Collapse would probably follow the lateral buckling.
2) *Shear Failure:* Shear failure would most likely to be observed as buckling of web of the beam near locations of high shear forces. Near reactions of concentrated loads, the beam can fail locally due to crushing or buckling of web.
3) *Deflection Failure:* Large beam deflections can also represent failure when the intended use of the beam places limits on deflection.

G. *Section Classification*

1) *Plastic:* Plastic cross section are those which can develop their full plastic moment Mp and allow sufficient rotation at or above this moment so that redistribution of bending moment can take place in the structure until complete failure mechanism is formed.
2) *Compact:* Cross sections which can develop their full-plastic moment Mp but where the local buckling prevents the required rotation at this moment to take place.
3) *Semi-Compact:* Semi-compact cross-sections are those in which the stress in the extreme fibres should be limited to yield stress because local buckling would prevent the development of the full plastic moment Mp.Only yield moment can be developed in such kind of sections.
4) *Slender:* Slender cross-sections are those in which yield in the extreme fibres cannot be attained because of premature buckling in the elastic range.

H. *Classification of Beams*

According to lateral restrained conditions, beams are divided in following categories.

1) Laterally supported beams (Unable to move laterally)
2) Laterally unsupported beams

a) *Laterally Supported Beam:* Laterally supported beams are those kinds of beams which are unable to move laterally. A part from that laterally supported beams are not affected by Lateral Torsional Instability.
b) *Laterally Unsupported Beams:* In laterally unsupported beam, compression flange of beam is not restrained against the lateral buckling. In it, bending also takes place in weaker direction
c) *Design Process of Beams:* IS800:2007, EN 1993-1-1(2005), AISC 360-16 and AS 4100:1998, all these codes follow the limit state method for the design process of beams. AISC 360-16 also gives allowable stress design approach for the design of beams.
d) *Partial Safety Factors:* For the limit state of design partial safety factors are being used. According to different clauses partial safety factors and capacity factors are used in different codes.

- *IS (800:2007) (Table 5)*

For the resistance governed by yielding and buckling ϒmo=1.10

- *EN 1993-1-1:2005(Clause 6.1)*

For the buildings:gmo=1.0

For the buildings:gmo=1.0

- *AS 4100:1998(Table 3.4)*

In AS4100:1998 code, capacity factor(F) has been used.

For member subjected to bending

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3) Full lateral support=0.9
4) Members without full lateral support=0.9
5) Web in shear=0.9
6) Web in bearing=0.9
7) Stiffener=0.9

AISC 360-16(Clause F1)
To design for flexure members in LRFD, capacity factor shall be taken as:
Fb=0.9
Section Classification
As per IS 800:2007

Parameters	Criteria
Yield stress	$\varepsilon = \sqrt{\frac{250}{f_y}}$
Plastic(b/t_f)(flange)	9.4ε
Plastic(d/t_w)(web)	84ε
Compact(flange) (b/t_f)	10.5ε
Compact(web)(d/t_w)	105ε
Semi Compact(flange)(b/t_f)	15.7ε
Semi Compact(web)(d/t_w)	126ε

Section classification as per EN-1993-1-1(2005)

Parameters	Criteria
Yield stress	$\varepsilon = \sqrt{\frac{235}{f_y}}$
Plastic(b/t_f)(flange)	9ε
Plastic(d/t_w)(web)	72ε
Compact(flange) (b/t_f)	10ε
Compact(web)(d/t_w)	83ε
Semi Compact(flange)(b/t_f)	14ε
Semi Compact(web)(d/t_w)	124ε

Section classification as per AS4100-1998

Section	Parameters	Section modulus(Z_e)
Compact	$\lambda_s \leq \lambda_{sp}$	Shall be lesser of S or 1.5Z
Non-compact	$\lambda_{sp} < \lambda_s \leq \lambda_{sy}$	$Z+[(\lambda_{sy}-\lambda_s)/(\lambda_{sy}-\lambda_{sp})](Z_e-Z)$
Slender Section	$\lambda_s > \lambda_{sy}$	$Z(\lambda_{sy}/\lambda_s)$(for sections with flat plate elements) $Z(\lambda_{sy}/\lambda_s)^2$(for section whose slenderness is determined by the value calculated for a flat plate element with maximum compression at an unsupported edge and zero stress or tension at other edge and which satisfies $\lambda_s > \lambda_{sy}$ $Z(\lambda_{sy}/\lambda_s)^{0.5}$(For circular hollow sections which satisfy $\lambda_s > \lambda_{sy}$

Section classification as per AISC 360-16

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Element	Width-to-thickness Ratio	Limiting width to thickness ratio	
		λ_p (compact/non compact)	λ_r (non-compact/non compact)
Flanges of rolled I section,channels and tees	b/t	$0.38\sqrt{\frac{E}{f_y}}$	$1.0\sqrt{\frac{E}{f_y}}$
Flanges of doubly and singly symmetric I-shaped built-up section	b/t	$0.38\sqrt{\frac{E}{f_y}}$	$0.95\sqrt{\frac{K_cE}{f_y}}$

Design bending resistance according to IS800:2007

When the factored shear force does not exceed 60 % of the design shear strength of the section, the following formula applies. In this case shear force does not have any influence on design bending strength
Design bending resistance for bending about major principal axis: (Clause:8.2.1)

$$M_d=\beta_b Z_p f_y/\gamma_{mo} \le 1.2 Z_e f_y/\gamma_{mo}$$

Md=Design bending resistance of the section Zp=Plastic section modulus
fy=yield stress of the material
ϒmo=Partial safety factor

β_b=1.0 for plastic and compact section

The additional check ≤1.2Zefy/ϒmo is provided for serviceability
When the factored shear force exceeds 60% of the design shear strength, the following formula applies. In this case, a member subjected to both bending and shear has to use its web to resist shear force as well as to assist flange in resisting moment. So, when cross section is subjected to both has a reduced moment resistance in the presence of high shear

- *For plastic and compact section:(Clause 9.2.2)*

$$M_{dv}=M_d-\beta(M_d-M_{dv}) \le 1.2 Z_e f_y/\gamma_{mo}$$

$$\beta=(2V/V_d-1)^2$$

Md=Design bending strength of the section according to equation
V=factored applied shear force as governed by web yielding or web buckling
Vd=Design shear strength as governed by web yielding or web buckling
Ze=elastic section modulus

- *For semi-compact section:(Clause 9.2.2)*

Mdv=Zefy/ϒmo

- *Design bending resistance according to EN 1993-1-1:2005*

When designed shear force is less than 50% capacity of the section the design bending resistance can be taken as follows: (Clause 6.2.5)

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For Class 1 and Class 2 cross section:

$$M_{c,Rd}=M_{pl,Rd}=\frac{W_{pl}f_y}{\gamma_{mo}}$$

For Class 3 cross section:

$$M_{c,Rd}=M_{el,Rd}=\frac{W_{el,min}f_y}{\gamma_{mo}}$$

For Class 4 cross section

$$M_{c,Rd}=M_{el,Rd}=\frac{W_{el,min}f_y}{\gamma_{mo}}$$

- *Design bending resistance according to AS4100:1998*

According to clause 5.1 of AS4100:1998,design bending resistance is to be given as below:
For the members with full lateral restrain, following formulas are to be used for design bending resistance:
$Mx^*\leq\phi Msx$ ...(3.11)
$Mx^*\leq\phi Mbx$ ….(3.12)
Mx^*=Design bending moment about the x-axis
ϕ=the capacity factor

- *Nominal member and section capacity:*

$Ms=f_yZ_e$
Z_e=effective section modulus

- *Design bending resistance according to AISC 360-16*

According to clause F-2 of AISC 360-16,the design bending resistance can be given as below.
For laterally supported beams, with doubly symmetric compact I-shaped members and channels bent about their major axis and for the doubly symmetric I-shaped members with compact webs and non-compact or slender flanges about their major axis, the nominal flexure strength shall be greater than the designed bending moment
Designed flexure strength=FMn
Mn=Nominal flexure strength=FyZx
Where
Fy=Specified minimum yield stress of the type of steel being use,ksi(MPa)
Zx=Plastic section modulus about x-axis

- *Shear Strength*

Shear force also exits with the bending in beam, so it necessary to check the shear capacity of the section.

- *Shear capacity of the section according to IS800:2007*

According to clause 8.2.1.2 of IS800:2007 shear capacity shall be checked as follows:
The factored design force shall be less than the shear capacity of the section
$V_n\leq V_d$
$V_d=V_n/\Upsilon_{mo}$

The nominal shear strength of a cross section Vn may be governed by plastic shear resistance or the strength of the web governed by shear buckling. The nominal plastic shear resistance under pure shear is given by $V_n = V_p$

$Vp = A_v f_{yw}/\sqrt{3}\,\Upsilon_{mo}$ …(3.19)

Where

Av=Shear area

f_{yw}=Yield strength of the web

- *Shear capacity of the section according to EN 1993 1 1:2005*

According to clause 6.2.6 of EN 1993-1-1:2005,shear capacity shall be given as follows:

The design value of the shear force VEd at each cross section shall satisfy

$(V_{ed}/V_{c,Rd}) \leq 1$ ….(3.20)

Where

V_{ed} =The design shear resistance

$V_{c,Rd}$ =Design plastic shear resistance

In the absence of torsion, the design plastic resistance is given by following formula:

$V_{pl,Rd} = A_v f_y/\sqrt{3}\Upsilon_{mo}$ ….(3.21)

Where,

Av=Shear area

fy=yield strength of the web

$V_{pl,Rd}$ =Design plastic shear resistance

- *Shear capacity of the section according to AS 4100:1998*

According to clause 5.11.1 of AS 4100:1198

A web subjected to design shear force shall satisfy

$V^* \leq \phi Vv$ ….(3.22)

ϕ=Capacity factor

Vv=Nominal shear capacity of the web

(i) When, $\frac{d_p}{t_w} \leq \frac{82}{\sqrt{\frac{f_y}{250}}}$

In this case, shear yield capacity of the web should be checked.

The nominal shear yield capacity of the web.$V_v = V_w$

$V_v = V_w = 0.6 f_y A_w$ ….(3.23)

Where

f_y=Yield strength of the web

A_w=Gross sectional area of the web

(ii) When, $\frac{d_p}{t_w} > \frac{82}{\sqrt{\frac{f_y}{250}}}$

In this case, shear buckling capacity of the web should be checked.

- *Shear capacity of the section AISC 360-16*

According to clause G2 of AISC 360-16,shear strength is to be given as follows.

Shear strength=ϕvVn ..(3.24)

V_n=0.6FyAwCv ..(3.25)

Where,

Aw=Area of web

Fy=Strength of the steel (N/mm2)

Cv=1.00

Fv=1.00(LRFD) for $h/tw \leq 2.24\sqrt{E/Fy}$

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IV. RESULTS AND CONCLUSION

A. In IS 800:2007 and EN 1993-1-1:2005, the sections are classified in to plastic, compact, semi-compact, slender and class1, class2, class3, class4 respectively. AS 4100:1998 and AISC 360-16 have classified sections into compact, non-compact and slender categories

B. In IS 800:2007 and EN 1993-1-1:2005, the value of partial safety factor has been taken as 1.1 and 1 respectively.In, AISC 360-16(LRFD) and AS 4100: 1998.the value of capacity factors has been used as 0.9 and both codes are using plastic section modulus for the calculation of design moment capacity.

C. All four codes give same formula for the shear strength of the section. The reason behind the variation of results is factors which are being used in different codes. EN 1993-1-1:2005 gives around 10% more shear strength than IS800:2007 because of partial safety factors discussed above.AS 4100:1998 and AISC 360-16 give same formula for finding out shear strength but AISC 360-16 suggests the value of capacity factor 1 while AS 4100:1998 gives the value 0.9 so the AISC 360-16 gives 10% more value of shear strength than AISC 360-16.

D. For laterally unsupported beams, IS800:2007 ,EN-1993-1-1:2005,AISC 360-16 give guidelines for not to check for lateral torsional buckling in certain cases.

E. For members subjected to combined forces all codes give equation for interaction ratio of the member capacity and section capacity expect AISC 360-16. AISC 360-16 gives formula only for member strength which easier than IS 800:2007 to implement.

F. AS 4100:1998 gives more detailed equations for all cases in members subjected to combined forces but it does not have reduction factor incase of simply supported beams

G. EN 1993-1-1:2005 does not have any formula to calculate moment capacity due to lateral torsional buckling.

V. LITERATURE REVIEW

Subramanian N. "Code of practice of practice on steel structures a review of IS 800:2007", Civil Engineering & construction review magazine, Issue: AUGUST:2008

This paper reviews the design philosophy of IS800:2007 after it was revised over IS 800:1984 which had adopted working stress method for the design. As there is continuous development in the field of structural engineering and design, though the Bureau of Indian Standards revises the codes almost after 20 to 25 years. Contradictory, the codes of practices for other countries are revised at regular intervals. For the members subjected to bending, short beams achieve plastic moment capacity depending on, heather the section is being selected plastic or compact. Long beams are prone to lateral-torsional buckling which results in reduced strength. The Indian code has adopted two curves for the design of laterally unsupported beams. (rolled section and welded section).IS 800:2007 gives simplified equation for Mcr for different beam sections subjected to different loadings and support conditions according to Annexure E.

Danny J. Yong, Aitziber Lopez and Migule A. Serna," A Comparative study of AISC-LRFD & EC3 approaches to beam-column buckling resistance", Stability & ductility of steel structures, D. Camotim et al. (Eds.) Lisbon, Portugal, Sepetember 6-8,2006

In this paper comparative study of AISC LRFD and the new European code for the design of steel structures, Eurocode 3 have been done. Similarities and differences between the two standards have been identified. Comparative study is performed for a rolled I-section with different slenderness

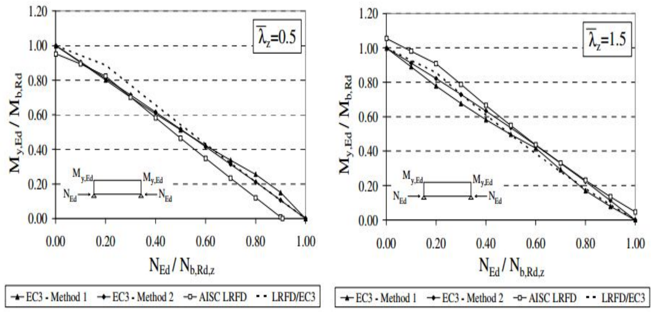
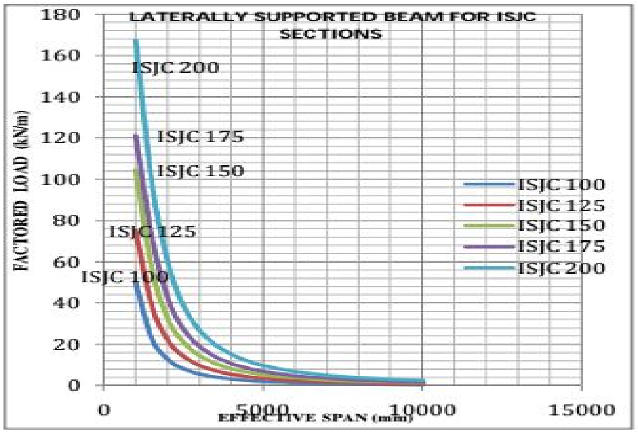
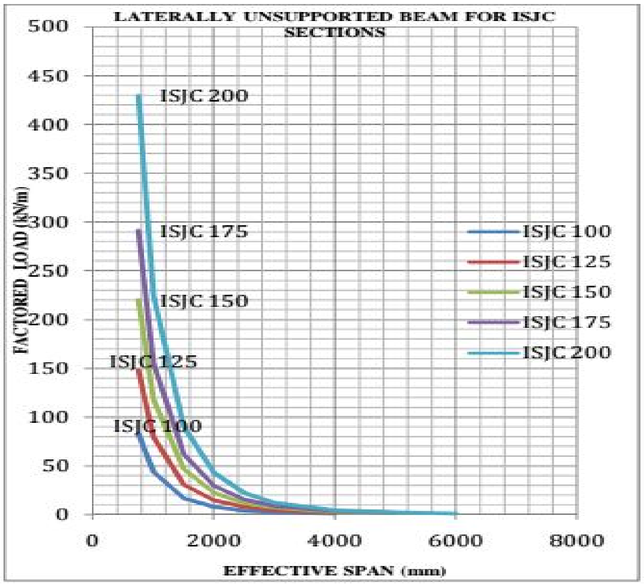


Figure 2: Beam-column resistance (HEB 300, $\bar{\lambda}_z = 0.50$ and $\bar{\lambda}_z = 1.50$, case 1)

Gayatri Bhanudas Purnaye & Prof U.R. Awari," Design Aids for Beams with Varying Conditions in Accordance with IS 800:2007", International Journal on Recent Innovation and Trends in Computing and Communication, Volume 3, Issue 5)

The paper discusses that there are no guidelines given in IS 800:2007 regarding selection of the initial section. Flow charts have been prepared for the design of laterally supported and laterally unsupported beams. Different sections have been used and graph has been plotted against the factored load vs. effective span for laterally supported and laterally unsupported beams.





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BIOGRAPY

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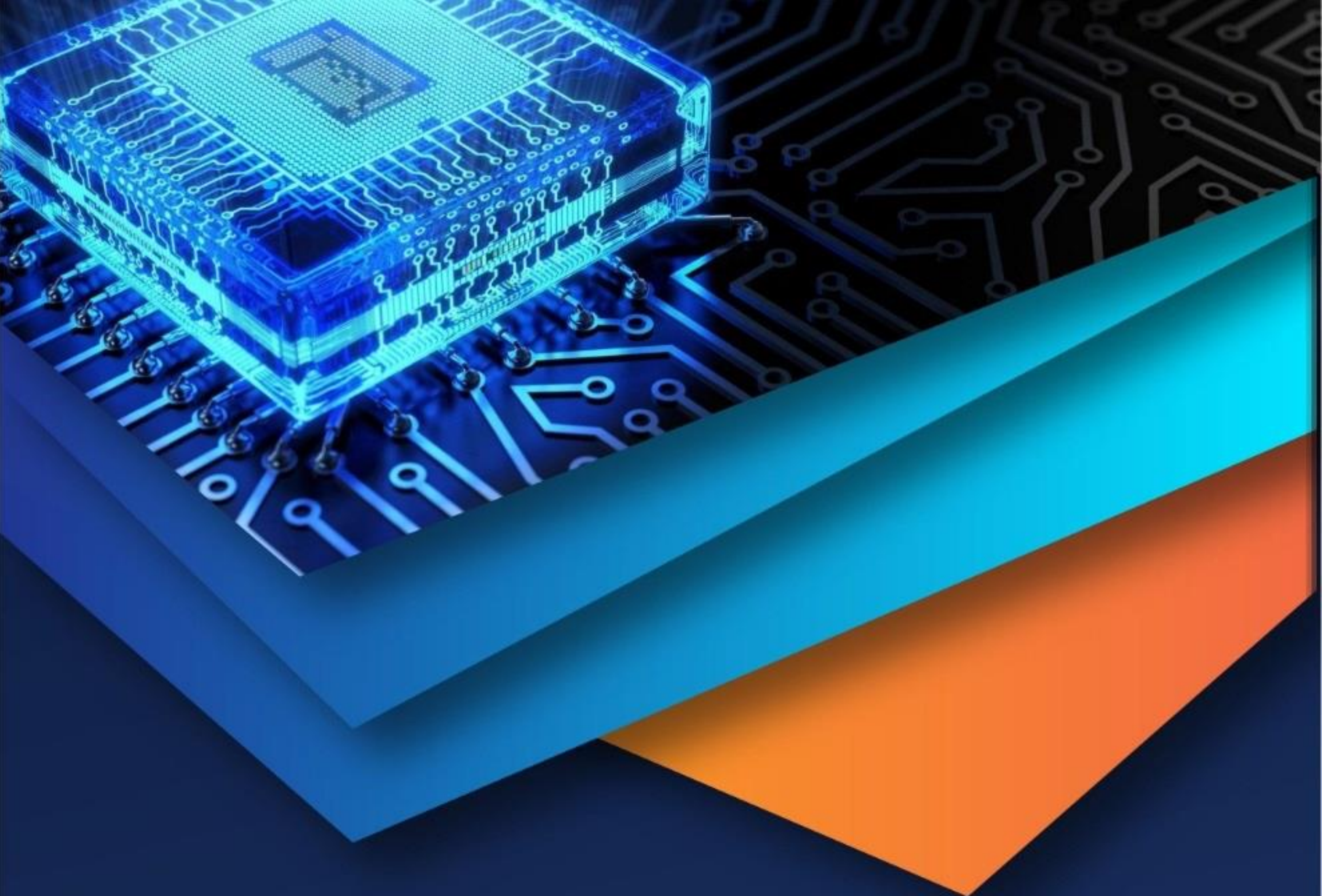

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