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Stresses & Strains in Plate Girder with Different Bracing Systems under Combination of Loadings

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Abstract: Lateral buckling is one of the most important factors in the design of steel plate girder. This buckling in the girder can be controlled by many methods. The most popular method is to add the intermediate bracing systems along the length of girder. The unsafely designed intermediate bracing systems can easily lead to serious consequences in the construction stage due to lateral buckling by torsion which happens rapidly and suddenly when the internal force in girder exceeds the ultimate value. Reversely, if the intermediate bracing systems are designed excessively, their specific stiffness will be larger than the required one then it is very costly in both material and installing process In the present study different types of torsional bracing systems are used in twin plate girder of span 8m. As the behavior of plate girders with different type of bracing system changes differently along the length and depth. Changing the layout of bracing systems could also make the design easy and more economical.
Keywords: Cross-frame Bracings, Horizontal Bracings, Plate Girder, Finite Element Analysis

I. INTRODUCTION

Steel structures are obviously one of the most common choices for residential building constructions in the world. Among these buildings, different types of braced structures are probably the most favorite types, due to less skill needed for welding and joints, and possibility to use common and lighter section for beams and braces. Braced frames categorize into two different types, concentric and eccentric, which have specific characteristics and design requirements. In this research, different types of bracings including X, horizontal dimensional braced frames are analyzed using a commercial software and the differences and the advantages of each type is tried to be evaluated. Although the method for this investigation does not cover all the aspects of the models and structures, this analysis still provides a good comparison between all the common bracing types. These models are compared in different aspects, such as economical viewpoint with evaluating the weight of the structure, the maximum displacement under wind load and UDL

A. Plate Girder

In this study, two types of steel concentric braced frames were used for comparative study. Two models of plate girder bridge with dimensions as shown in Fig. 1. To avoid modeling of dual systems and the effect of moment frames, simple connections have been considered between beams and columns in all these models and the bridge model is assumed to be central span of railway bridge. For static structural analysis ANSYS R19.2v was used with considering material homogeneity & non-linear structural model. Plate girders were designed as per the specifications of IS 800:2007 and the loadings were applied as per accordance of RDSO equivalent uniformly distributed load EUDL specifications. The bending moment for design of plate girder of 8m span was used and accordingly the depth of web of girder was used in modeling. The plate girders were provided with lateral vertical stiffeners on inner side and lateral bracing systems were provided. Stiifeners were also provided at supports.

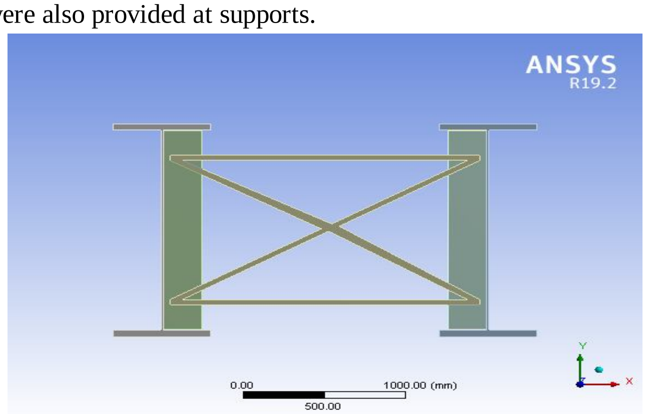


Fig -1: plate girder with cross-frame bracings

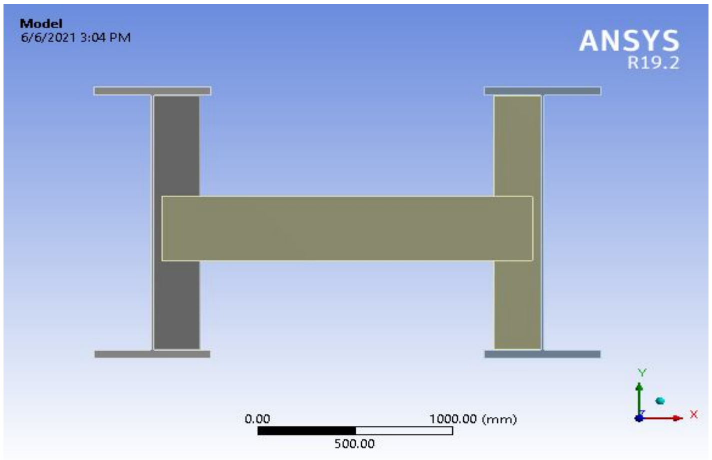


Fig -2: plate girder with horizontal bracing system

B. Finite Element Analysis

The finite element method is a powerful numerical technique devised to evaluate complex physical processes.

A finite element analysis with the general-purpose finite element package ANSYS was conducted to investigate the elastic buckling behavior of a simply supported and a clamped rectangular plate, as well as the webs in I-girders under patch loading. Uniform loads were applied on the top edge of the plate over a limited length or on the flanges of I-girders.

II. METHODOLOGY

A. Depth of Web of Girder

Deck type plate girder bridge, Effective span; l_0 =8m c/c between plate girders =2m dead load on each girder= $200l_0$ + 600N/m dead load on track with sleeper= 6000N/m

Lateral load = 9000N/m (WIND LOAD)

As per specifications of EUDL,

Total load for bending moment;W_0 =981KN

Total load for shear force; V_0 =1154KN

Using max. design bending moment= $wl^2/8$

M_0= 891KN/m

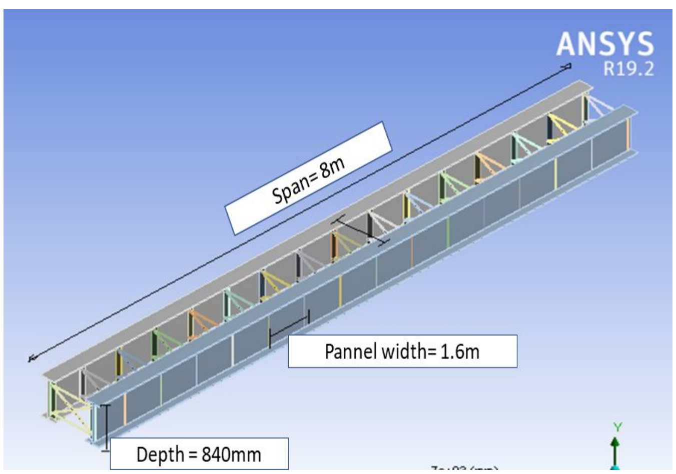
Design shear force;V_0= 520KN

Depth of web; d= 840mm

Thickness of web t_w= 12mm

Thickness of flange t_f= 20mm

Length of flange b_f= 342mm



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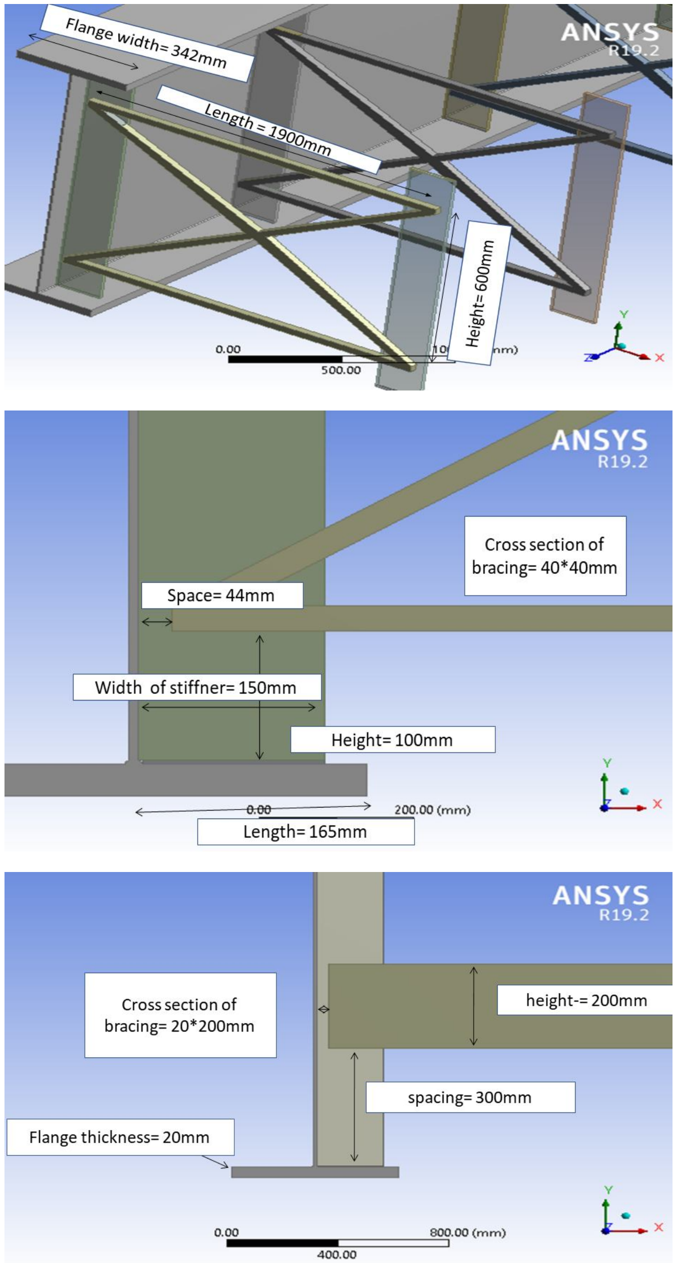


Fig -3: dimensions of models span, height, depth, thickness, spacing.

Table -1: Description Of Plate Girder

COMPONENTS	DETAILS
Span of girder	8m
Type of bridge	Railway bridge
Material used	Fe250
Depth	840mm
Web thickness	12mm
Flange width	342mm
Flange thickness	20mm
Bracing types used	X-bracing, Channel bracing

B. Finite Element Modeling

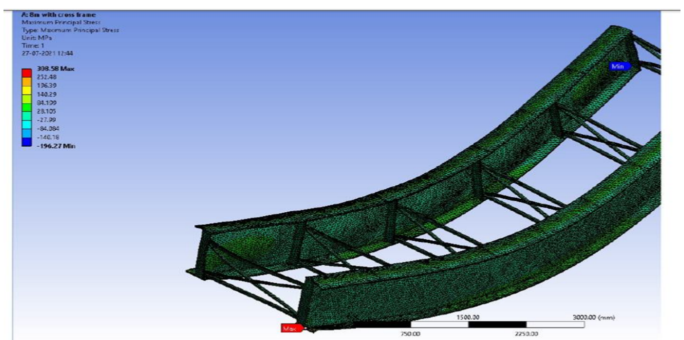
In this study, the finite element program ANSYS was used to develop finite element models. The models have accounted for the measured geometry, initial geometric imperfections and measured material properties of flange and web portions. The nonlinear material properties and loading conditions are incorporated in the load-displacement nonlinear analysis. The 3-node element was used to model the flanges and web of the plate girder steel Bridges. In order to choose the finite element mesh that provides accurate results with minimum computational time, convergence studies were conducted. It is found that approximately 15mm provides adequate accuracy in modelling the webs as well as the flanges. The structural steel used in the tests were modelled using the stress-strain curves given in the IS 800:2007 with measured values of the yield stress (f_y) and ultimate stress (f_u) used in the tests. The material behavior provided by ANSYS allows a nonlinear stress-strain curve to be used. The first part of the nonlinear curve represents the elastic part up to the proportional limit stress with Young's modulus of (E) 200 GPa and Poisson's ratio of 0.3 were used in the finite element model.

C. Load Application

As per EUDL specifications of force for bending moment and shear force , uniformly distributed loads were applied on the upper flanges of girder. The test model was assumed to be hinge support at the edges of girders lower flanges (simply supported beam). Two uniform distributed load (pressure) were applied on the faces of upper flanges accounting for self weight of girder & sleepers of magnitude 0.0168N/mm^2 & 0.336N/mm^2. One more force of 9KN was applied along the span of the girder in negative x-direction accounting for the wind load that may occur on bridge.

D. Parametric Studies and Discussions

The main objective of study was to compare the behavior of plate girders under the above specified loadings. The parameters of study were taken as the maximum stress and strain occurring in the girder with these different lateral bracing systems provided in between them. The ability of lateral bracings to control the deflections and reduce the maximum stress in the girder were checked at various point using probe feature of the ANSYS software. As the loads were applied the elements of girder were stressed. Being a ductile material Fe250, the Rankine's theory of failure was used and the maximum principal stress, equivalent stress & maximum shear stress in member were checked. In model 1 the girder was provided with cross frame bracings at 1.6m spacing. The cross frame designed assumed to be in a plane. Whereas, In model 2 the girder is provide with horizontal bracing at mid height of web. The weight of steel used for making the bracings are kept same in both cases, While the extra amount required for connections in cross-frame will be higher than the horizontal bracing it is assumed here to be same.



(a)

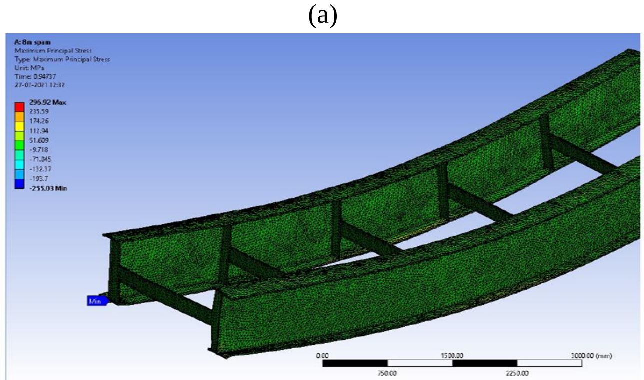
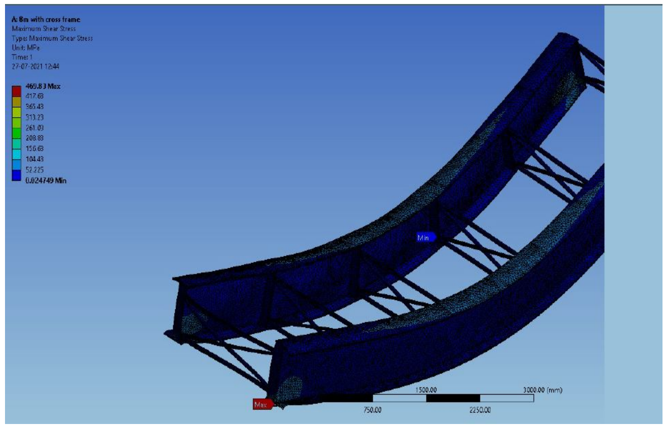
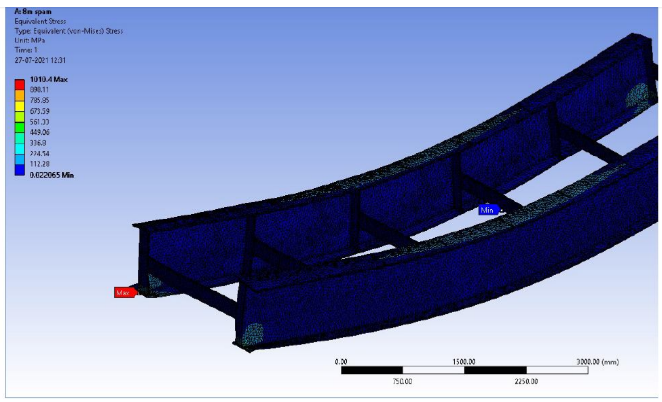


FIGURE 24

(b)



(c)



(d)

Fig-4: (a) maximum principal stress in plate girder with cross-frame bracing
(b) Figure showing maximum principal stress in plate girder with horizontal bracing
(c) Figure showing maximum shear stress in plate girder with cross-frame bracing
(d) Figure showing maximum shear stress in plate girder with horizontal bracing

While the ends being hinged the deflection at end comes out to be zero in both cases but recorded maximum stresses value in both case were different. As in case of SSB (simply supported beam) the maximum bending stress occurs at point of loading or at the mid span in case of UDL. Here the maximum values were recorded and tried to compare in graphical form. In other analysis points were taken at continuous interval of 1m along the span & the parameters were recorded and compared as shown graphically.

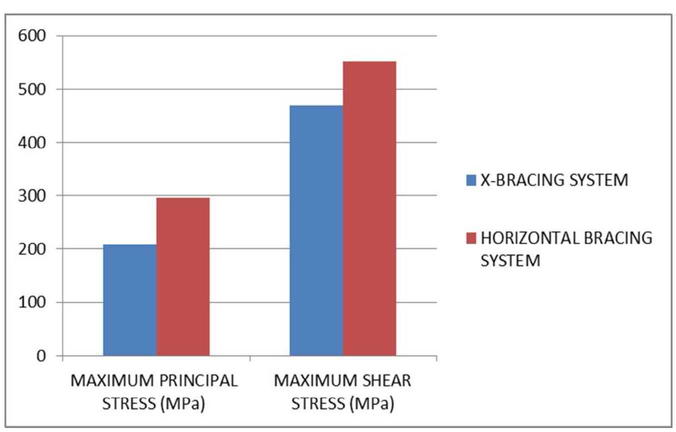


Fig -5: comparison of maximum principal and maximum shear stress in both models

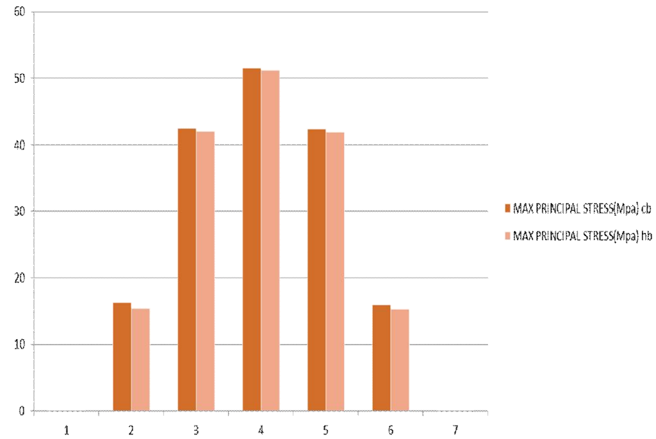


Fig -6: comparison of maximum principal stress at selected sections of girder

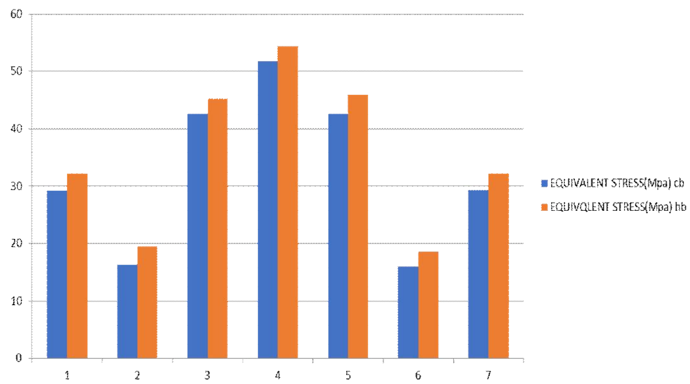


Fig -7: comparison of equivalent stress at selected sections in both models

In above charts, chart-1 shows the comparison of maximum principal stress in models. It is clearly observable that the plate girder with cross frame bracing has a lesser value of maximum stress i.e. it has better strength or cross-frame bracings increased the strength of girder to a considerable value. Chart-2 shows the maximum principal stress values at selected section which are 1m distance in the upper flange of girder. Chart-2 shows a higher values in model with cross frame bracing but the gap between is comparatively very low. Chart-3 showing the values of equivalent stresses in girder at selected sections and here also the stress value for model with horizontal bracings is high. Above outcomes of analysis performed on models show that the stability of girder was relatively increased higher in case of model provided with cross-frame bracing system.

III. CONCLUSIONS

Taking into consideration the economy & strength of structure, by above results here we can draw a few conclusions While the maximum principal stress values are close but the margin in equivalent stress & maximum shear stress comes out to be very large which shows that girder with cross-frame bracing system provides better strength compared to horizontal bracing system. The performance of girder against stress have been better improved by cross-frame bracing system.

IV. ACKNOWLEDGEMENT

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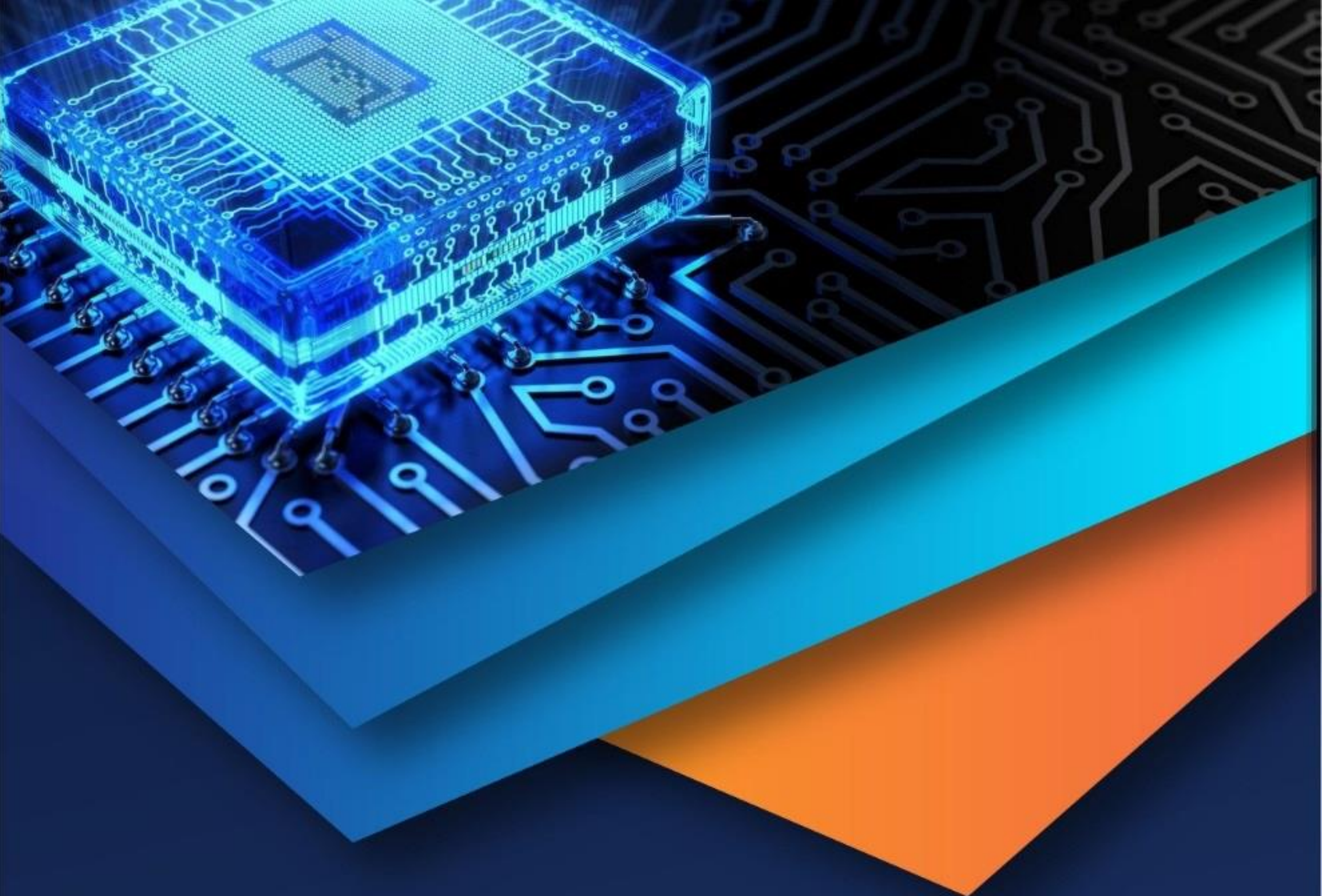

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