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Effect of Skew Angles on Longitudinal Girder and Deck Slab of Prestressed Concrete T Beam Girder Bridges

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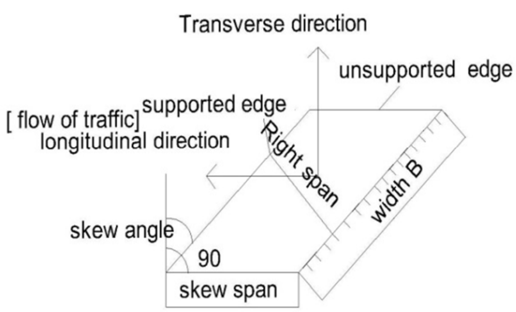
Abstract: The present paper shows the effects of varying skew angles on pre-stressed concrete (PSC) bridges using finite elemental method. Studies are carried out on PSC bridge decks to understand the influence of skew angle and loading on behaviour of bridges. The results of skewed bridges are compared with straight bridges for IRC Class AA Tracked loading. Also, a comparative analysis of the response of skewed PSC Slab Bridge decks with that of equivalent straight bridge decks is made. The variation of maximum longitudinal bending moment (BM), maximum transverse moment, maximum torsional moment, and maximum longitudinal stresses deflection at obtuse corner, acute corner with skew angles are studied for bridge deck. It is found that Live load longitudinal bending moments decreases with an increase in skew angle, whereas a maximum transverse moment and maximum torsional moment increases with an increase in skew angle. The benefit of pre-stressing is reflected in considerable decrease in the longitudinal bending moment, transverse moment and longitudinal stresses. The models are analysed with the help of software CSI-Bridge V 20 Version.
Keywords: Skew angle effect, Longitudinal moment, Transverse moment, CSI- Bridge software, Deck slab, Finite element method.

I. INTRODUCTION

A bridge is a structure built to span boundaries such as water or road without closing the way underneath. It is constructed to provide passage over the obstacle. There are many different designs that each serve a particular purpose and apply to different situations. Generally, a bridge with a skew angle of less than 20° is designed as a normal bridge. If the inclination is more than 20° there is a change in the structural behaviour due to skewness. Due to efficient dissemination of congested traffic, economy, durability and aesthetic desirability, pre-stressed concrete (PSC) girder bridges have become increasingly popular nowadays in modern highway systems. The Structural response of the bridge to stresses in slab and reactions on abutments can be significantly altered by the skew angle of the substructure.



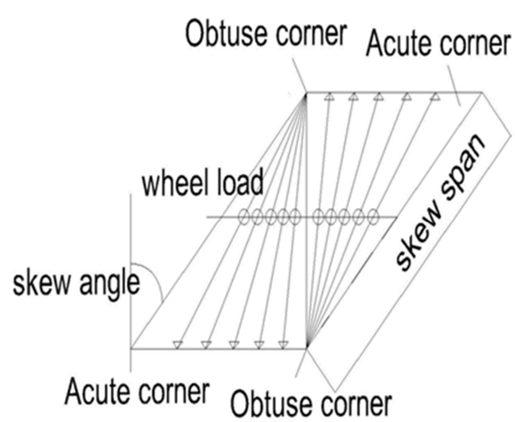


Fig 1: Skew bridge Fig 2: Loads on skew bridge
[Courtesy: www.citeseerxist.psu.edu and www.slideshare.net]

Fig.1 and Fig. 2 show terminology related to skew bridges. The present work is devoted to behavioural study of skew bridges with longitudinal girder and deck slab, subjected to the static as well as the dynamic loads.

A. Objective Of Study

The present study aims at

1) Finite element analysis PSC T Beam Girder Bridge of span 30 m with varying skew angles equal to 0˚, 15˚, 30˚, 45˚ and 60˚.
2) Study of the effect of skew angles on longitudinal, lateral and torsional moments of PSC girders.
3) Study of Effect of skew angle on deck slab stresses and deflection.
4) Study of Effect of skew angle on shear of longitudinal girders

II. LITERATURE REVIEW

Many researchers have worked on skew bridges and shared their findings. Naik et al. [1] used two distinct types of sheathing, HDPE and corrugated Bright metal pipes, to analyse and construct a PSC box girder Type Bridge. The FEM-based programme CSI Bridge 2017 was used to analyse a superstructure with a total length of 35.0m and an overall width of 16.6m with 4 lanes loading of a 70R wheeled vehicle. Various losses caused by different phenomena such as elastic shortening, Creep, shrinkage, friction, and wobbling loss have been considered. Deepak C and Sabeena MV [2] presented their research on the finite element modelling of a simply supported skew slab with different skew degrees using ANSYS software. It is discovered that as the skew angle grows, so does the uplift at both acute corners. The data also implies that as the skew angle grows, so does the load carrying capacity.

Pranithi Reddy, Karuna S (2015) [3] have demonstrated that the presence of skew angle in bridge decking has a significant impact on bridge behaviour. In this study, an attempt was made to compare the skew bridge to the regular bridge at skew angles of 10, 20, 30, 40, and 50. Using the SAP2000 ver.14 software, finite element analysis is performed for single span, two span, and three span decks for dead load and moving load (IRC class 70R) loading. The outcomes are given in terms of displacement, bending moment, and shear force.

Omkar Velhal, J.P.Patankar [4] have presented their findings in Skew bridges are frequently found in highway design where geometry does not allow for proper bridges. Using Finite Element Analysis software, the behavioural characteristics of skewTbeam bridges are explored and compared to those of straight bridges in this paper. This study demonstrates that the effect of skew angle on torsional moment of longitudinal girder is significant, implying that torsional moment must be considered while building skew bridges.

III. METHODOLOGY, MODELING AND ANALYSIS

Two lanes PSC T Beam Girder Bridge of span 30 m is analysed by finite element method for different skew angles.

Width of road=7.5m, Kerb-600mm on each side, Thickness of wearing coat-80mm,

For deck slab-M 20 Grade and for PSC girder- M 50 Grade concrete is considered.

Cube strength at transfer = 40 N/mm^2, Loss ratio = 0.85, Spacing of cross girders = 5 m,

High tensile strands of 15.2 mm diameter conforming to IS 6006-1983 & Fe 415 grade HYSD bars are used.

Four main girders are provided at intervals of 2.5 thickness of deck slab = 250 mm, Spacing of cross girders = 5 m. Overall depth of main girder is assumed at 50 mm per mete of span,

Overall depth of girder =50×30= 1500 mm

Thickness of top and bottom flanges = 400 mm, Thickness of web = 200 mm.

The cross section of the bridge deck and the girders are shown in Fig.3 and 4.

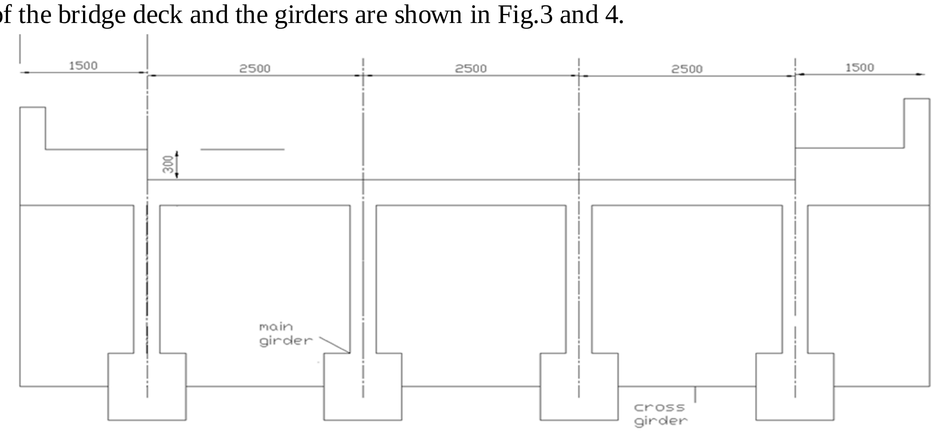


Fig 3: - longitudinal section of Bridge Deck

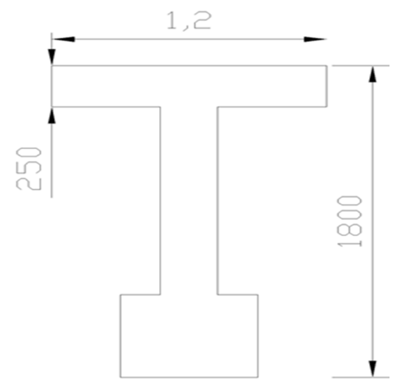


Fig 4:- Cross section in mm of main girder of skew bridge

A. Steps in Modelling

1) Step 1] Choose a deck section with a slab thickness of 330mm (including the wearing coat).
2) Step 2] Choose the material property of the sections and fill in the girder's sectional attributes.
3) Step 3] Attach the section's diaphragm, abutment, and foundation spring. After that, we can modify the bridge with the cross beam in the section of the PSC T beam girder. All section girders are additionally provided by prestress tendons. The mesh size must then be provided.
4) Step 4] Add vehicle class data, convert the load of vehicle data
5) Step 5] Add load pattern which analyse girder section
6) Step 6] Run analysis
7) Step 7] Computations of results

B. Analysis

The finite element approach is used to analyse a two-lane PSC T Beam Girder Bridge with a span of 30 m for varied skew angles for dead load and vehicle live loading. CSIBRIDGE software is used to create a total of five models. The models have been tested for dead load as well as for live load. The live load is used in accordance with IRC 6, 2014. The live load included for analysis is IRC CLASS AA tracked, and the bridge's slab deck is analysed using the Finite Element method for different skew angles for dead load and vehicle live loading with rigid supports, followed by hogging BM's with elastomeric bearing supports. The underlying idea behind this method is that a body or structure can be broken into smaller finite-dimensional pieces called finite elements. However, in Finite element analysis, the accuracy of the output is determined by the size of the mesh. The mesh is a collection of coupled nodes made up of interconnected finite components that represent the shape. Mesh size of 200 mm is used in the present work.

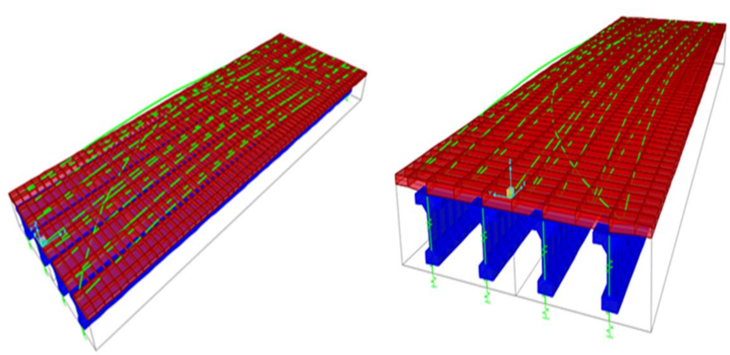


Fig 5:-Model of 3D view of 30 m Span with mesh size 200 mm using Csi-Bridge

For displacement functions, a polynomial series can be assumed, and this simplifies the finite element formulation. Because the stresses transmission mechanism in skew bridges differs from that in straight bridges, there is an additional concentration of reactions in the form of obtuse deck slab corners and uplift at acute corners.

IV. RESULTS AND DISCUSSION

A. Effect Of Skew Angle On Shear Of Obtuse, Acute And Central Girder Of Skew Bridge

The entire bridge was modelled using CSI- Bridge using the finite element method to validate the FE modelling of a PSC T Beam Girder Bridge with a span of 30 m and a mesh size of 200 mm. Figure 6 depicts the variation of shear force over a full span of 30 m with acute, central, and obtuse girders. This figure shows that up to 200, shear nearly remains constant in all girders; however, beyond 200, shear decreases for obtuse, acute, and central longitudinal girder corners. Shear is reduced by 40% for acute and obtuse corner girders, and 30% for central girders from 30^0 to 60^0.

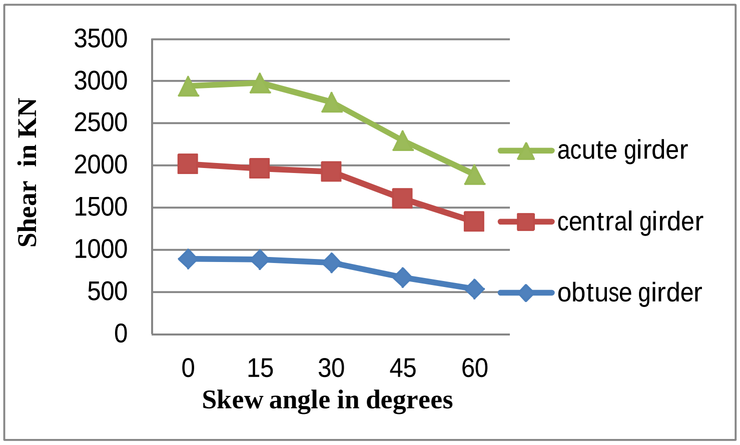
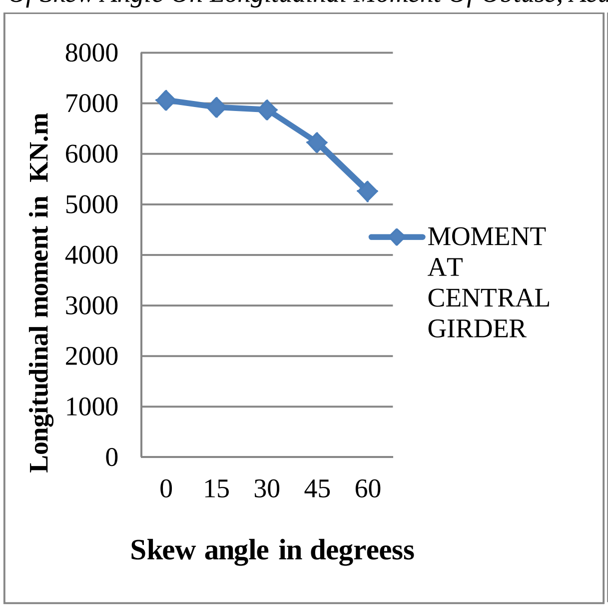


Fig 6:- Shear of Longitudinal girders of skew bridges

B. Effect Of Skew Angle On Longitudinal Moment Of Obtuse, Acute And Central Corner



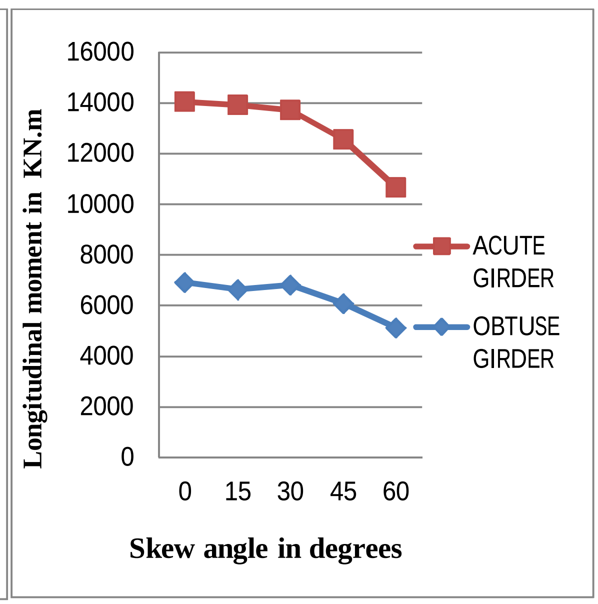


Fig 7:-Longitudinal moment of central obtuse girder of skew bridge Fig 8:-Longitudinal moment of acuteand girder of skew bridge

The bridge was modelled by using CSI- Bridge according to finite element method to verify the FE modeling of PSC T Beam Girder Bridge of span 30 m span with mesh size 200 mm. Variation of **longitudinal moment** of central, acute and obtuse girders in full span of 30 m are shown in Fig. 7 and 8 respectively. The trend in longitudinal moment is observed that the maximum dead and live load longitudinal bending moment and longitudinal bending moment for skewed compared to that of straight deck slab decreases with the increase in skew angle. This is because the force flow between the support lines is through the strip area connecting the obtuse angled corners, as skew increases the length of strip area decreases therefore the moment decreases. There is gradually reduction in longitudinal bending moment. There is a 23% decrease in longitudinal moment for acute and, 26% decrease for central girder and obtuse corner girder from 30^0 to 60^0.

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C. Effect Of Skew Angle On Torsional And Lateral Moment Of Obtuse, Acute And Central Corner

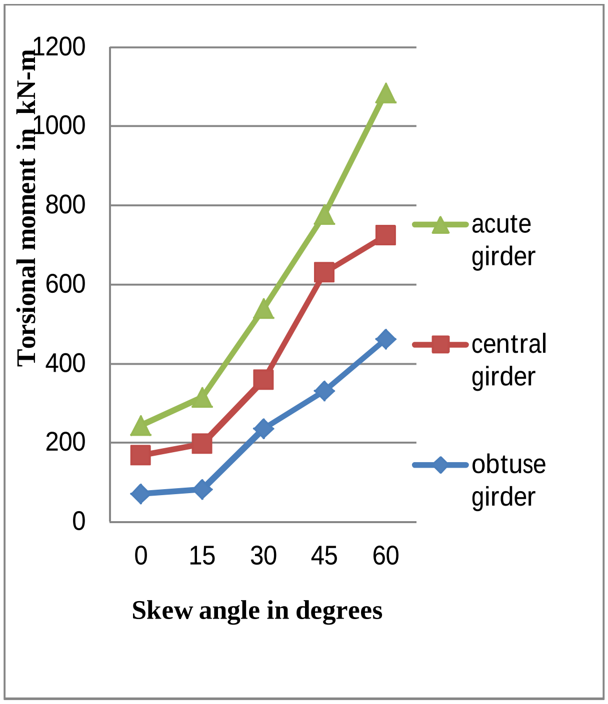

Fig 9:-Torsional moment of central, acute and obtuse girders respectively

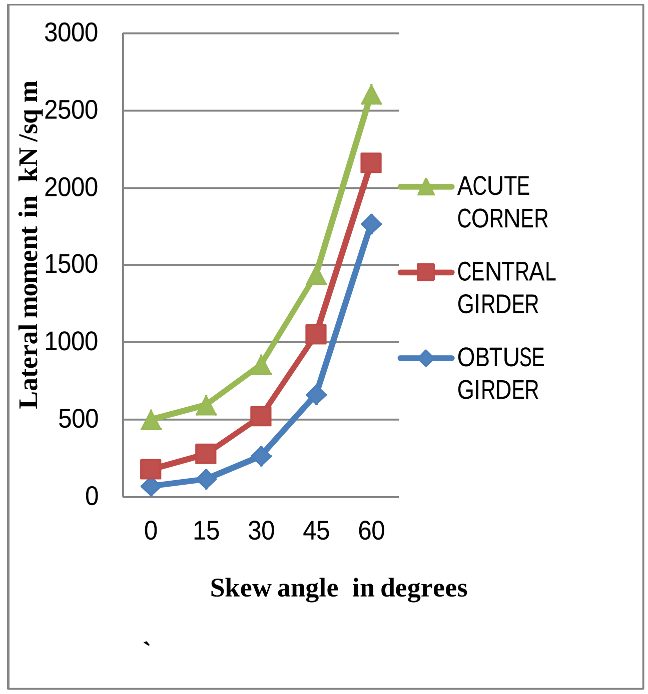

Fig 10:- Lateral moment of central, acute and obtuse girders respectively

The bridge was modelled using CSI- Bridge using the finite element method in order to validate the FE modelling of a PSC T Beam Girder Bridge with a span of 30 m and a mesh size of 200 mm. Figures 9 and 10 show the variation of Torsional and Lateral moments of central, acute, and obtuse girders over a full span of 30 m. Torsional moment increases by 15% for both obtuse and central girders from 0^0 to 15^0 skew angle, but increases by 36% for acute girders when compared to non-skew girder bridges. Following that, the torsional moment of the obtuse, central, and acute girders gradually increases by 85 percent, 64 percent, and 79 percent, respectively, up to 60^0skew. The nature of the torsional moment changes as the skew angle changes. Lateral moment increases by 40% for the obtuse girder, 34% for the central girder, and only 0.85% for the acute girder. After that, the lateral moment of the obtuse girder increases to 96 percent, the central girder to 65 percent, and the acute girder to 40 percent until the skew angle reaches 60^0 degrees. Figure 10 shows that the lateral moment increases less for acute girders than for obtuse and central girders.

D. Effect Of Skew Angle On Stress Of Obtuse And Acute Corner Of Deck Slab Of PSC T Beam Girder Bridges

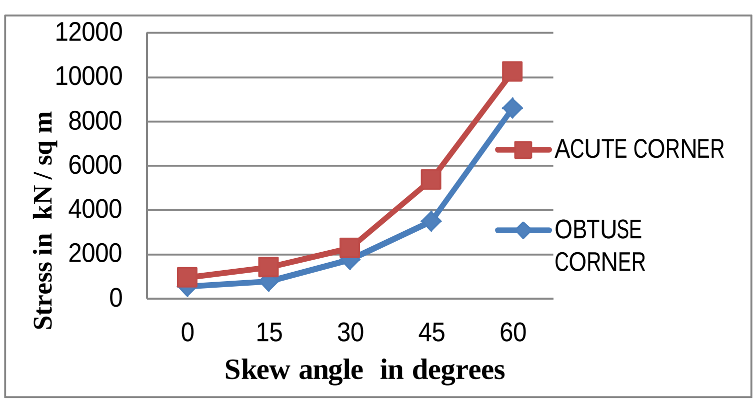

Fig 11:- Stress of obtuse and acute corner of deck slab of PSC T beam girder bridges

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The entire bridge was modelled using CSI- Bridge using the finite element method to validate the FEM modelling of a PSC T Beam Girder Bridge with a span of 30 m and a mesh size of 200 mm. Figure 11 depicts the variation of stress in a full span of 30 m with acute and obtuse deck slab corners of PSC T Beam girder bridges. Stress at the acute corner of the deck slab increases by 56 percent from 0^0 to 15^0 skew angles, then gradually increases to 76 percent until 60^0 skew angles.
However, stress at the obtuse corner of the deck slab increases from 0^0 to 15^0 skew angles, then gradually increases up to 94 percent until 60^0skew. The stress at the obtuse corner is greater than the stress at the acute corner.

E. Effect Of Skew Angle On Deflection Of Obtuse And Acute Corner Of Deck Slab Of PSC T Beam Girder Bridges

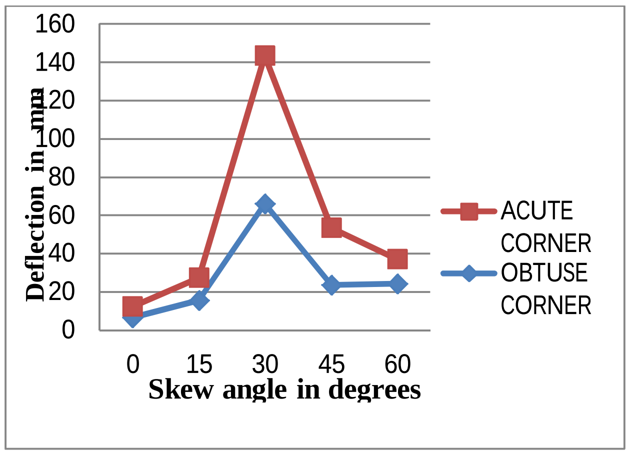

Fig 12:- Deflection of obtuse and acute corner of deck slab of PSC T beam girder bridges

The entire bridge was modelled using CSI- Bridge using the finite element method to validate the FE modelling of a PSC T Beam Girder Bridge with a span of 30 m and a mesh size of 200 mm. Figure 12 depicts the variation of deflection in a full span of 30 m with acute and obtuse deck slab corners of PSC T Beam girder bridges. Deflection at an acute corner of a deck slab increases by 52 percent and 92 percent for skew angles of 0^0 to 15^0 and 15^0 to 30^0, respectively. In contrast, increasing the skew angle from 30^0 to 45^0 reduces the deflection at the acute corner by 62 percent, and increasing the skew angle from 45^0 to 60^0 increases the deflection by up to 84 percent. Deflection at the obtuse corner of the deck slab increases by 58 percent and 90 percent for skew angles of 0^0 to 15^0 and 15^0 to 30^0, respectively. In contrast, as the skew angle increases from 30^0 to 45^0, the deflection at the acute corner decreases by 65 percent, while the deflection at the obtuse corner increases by up to 64 percent. When comparing the deflection of the deck slab, the deflection at the acute corner is greater than the deflection at the obtuse corner, as shown in Fig. 13 and 14.

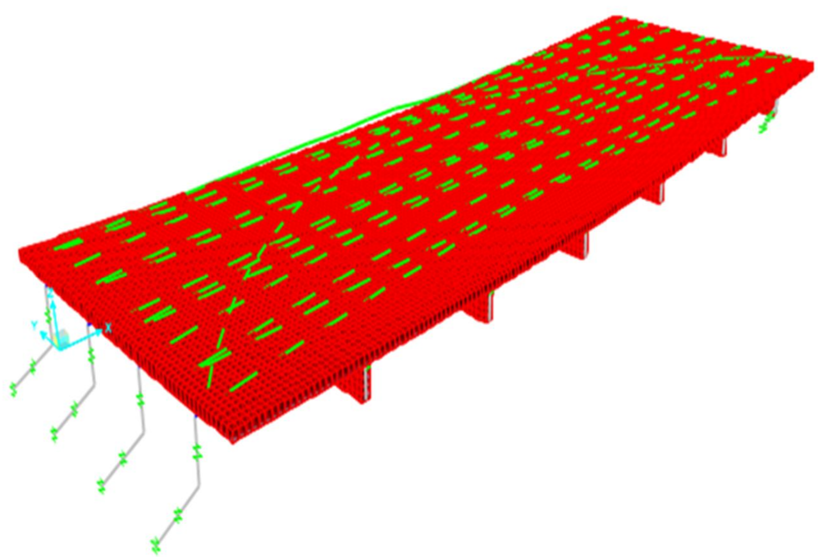

Fig 13:-Deformed shape of PSC T Beam girder with deck slab

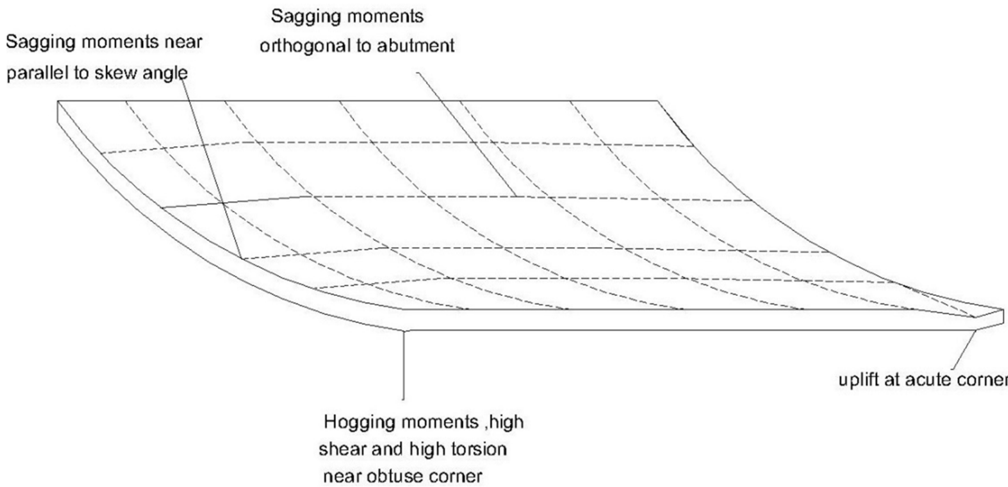

Fig 14:- Behaviour of Deformed shape of PSC T Beam girder with deck slab

V. CONCLUSION

The following conclusions are drawn upon,

A. In comparison to a non-skew bridge, the shear force of a skew bridge's longitudinal girder decreases as the skew angle increases.
B. When compared to a non-skew bridge, the longitudinal moment of a skew bridge's acute, obtuse, and central girders decreases as the skew angle increases.
C. The lateral moment of the acute, obtuse, and central girders of a skew bridge, as well as the stress of the acute and obtuse corner of the deck slab of a skew bridge, increase as the skew angle increases when compared to a non-skew bridge.
D. Deflection at the acute corner is greater than at the obtuse corner, resulting in uplift of the deck slab at the acute corner of a skew bridge as the skew angle increases in comparison to a non-skew bridge.

VI. RECOMMENDATION

When designing bridges with skew angles, it is recommended that the maximum skew angle be less than 30°. Designers should be concerned about torsion while the bridge is skew, as well as the resulting deflection and stress.

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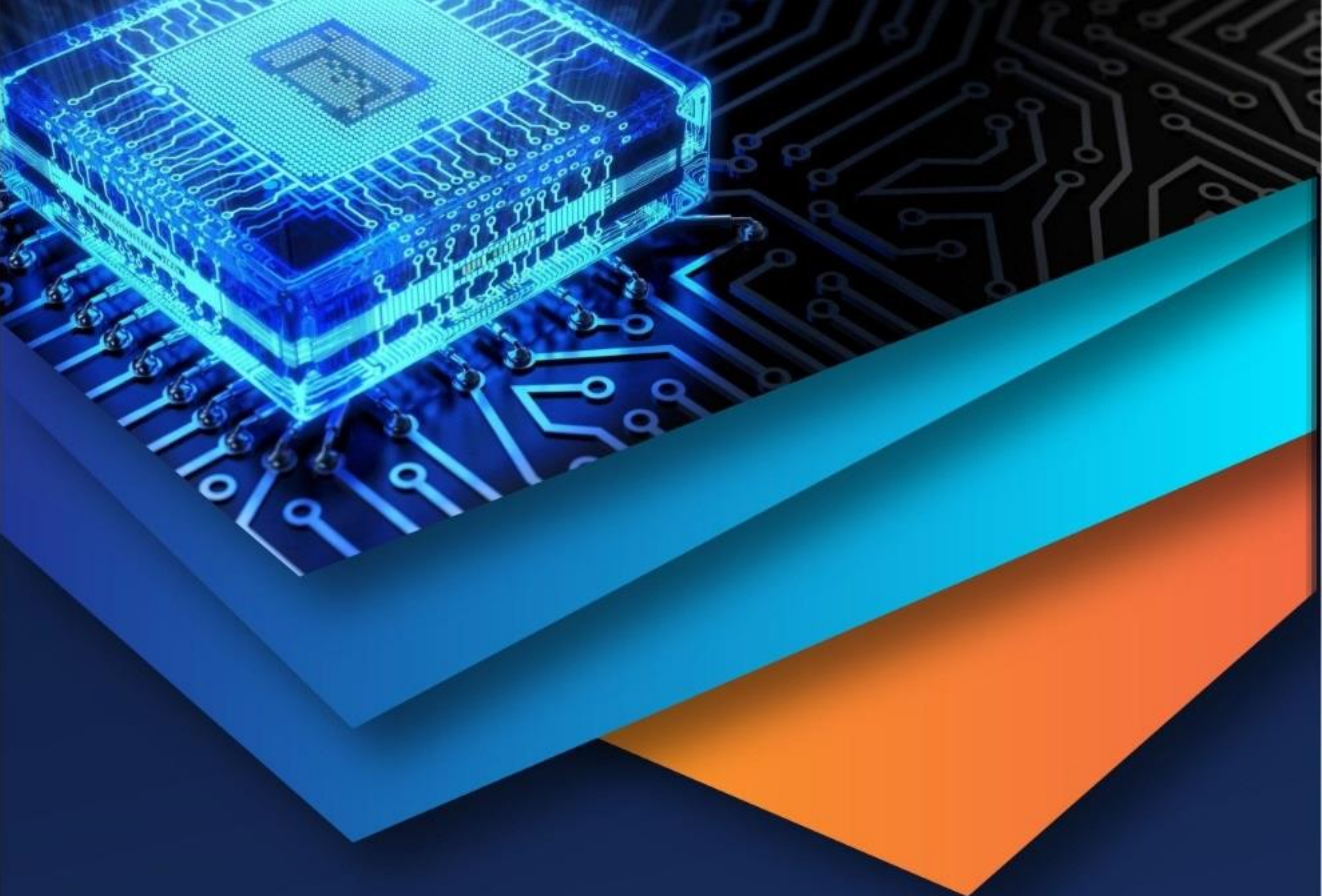

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