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FEM Analysis of Balanced Cantilever Bridge Deck Slab with Different Skewness

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Abstract: The current explores the finite element method (FEM) analysis of balanced cantilever skew bridges under the higher loading class of IRC 6:2017. The study delves into how increased skewness of the deck impacts the structural responses. For this study, a part of bridge is taken with 14m span and 3.5m width of lane taken into account for analysis. Using different skew angles, total 7 cases have created and analysed. After analysis the checks have been performed to verify the deck slab performance. Different conclusions have been drawn on deck slab, other structural members such as pier and longitudinal girder. Findings indicate that greater skewness results in elevated stress levels, particularly in the deck slab. The analysis reveals a direct proportionality between the degree of skewness and the magnitude of stress observed, underscoring the significance of skew angle in structural performance assessments.
Keywords: Balanced cantilever bridge, Finite element analysis, Skew angle, Bridge deck, IRC loading

I. INTRODUCTION

In modern infrastructure, balanced cantilever skew bridges are extensively used for spanning large distances with minimal support, particularly over obstacles like rivers, railways, and highways. Their prominence has been enhanced in the current scenario due to adaptability, shorter construction periods, and limited disturbance to the underlying terrain. The alignment of the structure with oblique crossings, such as angled intersections or irregular site layouts, is achieved through the provision of skewness in bridge design to optimize land usage and traffic flow. Complexities in load distribution and structural behavior are introduced by the presence of skew angles, leading to non-uniform stress patterns and differential deflections. Increased torsion, reduced load capacity, and challenges in deck slab design are commonly observed in skew bridges compared to straight bridges. These challenges are addressed through advanced tools like finite element methods, which ensure the performance and safety of the structure. The application of balanced cantilever methods, along with appropriate skew angle considerations, has made these bridges an efficient choice for modern transportation networks.

II. OBJECTIVES OF THE PRESENT STUDY

Following heads shows the objectives selected for the current study and need to fulfil to achieve research goal. The objectives for behavior of deck slab by skewness on balanced cantilever bridge are:-

1) To determine and compare maximum displacement in X, Y and Z direction for all the cases of deck skewness.
2) To study the difference in maximum support reactions and find out the efficient case among (CB-FEM1 to CBFEM7) for all the cases of deck skewness.
3) To determine and relate the maximum shear forces and bending moment in plate members and find out the efficient case among (CB-FEM1 to CBFEM7) for all the cases of deck skewness.
4) To evaluate Principal Stresses, Equivalent Stresses and Maximum Shear Stresses in plate members (deck slab) and find out the efficient case among (CB-FEM1 to CBFEM7) for all the cases of deck skewness.
5) To recommend the feasibility of research on effect of deck slab skewness by analysing the result parameters by FEM analysis.

Output result parameters selected

It is essential to use various output parameters that will require analyzing the behavior of each case. Some of the selected output result parameters are:-

For deck slab

Nodal displacement	Support reactions	Shear force and bending moment in plates	Stresses in plates

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III. PROCEDURE AND 3D MODELING OF STRUCTURE

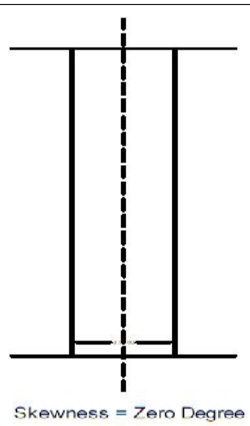
For the analysis of the of balanced cantilever skew bridge, as per gap of the previous studies, it is essential to create different models for accuracy in comparative study. Reference Indian Standard taken is IRC 6:2000 since it provides different types of loading and its configuration to achieve effective results. From this, models will have to be created mentioned in sequence wise. Comprehensive input data and its descriptions about the model given below.

Table 1: General data used

Constraint	Input data used
Concrete grade	M30
Rebar grade	500
Dead load	Self-Weight
IRC loading	70R
IRC code used	IRC 6:2017
Width of lane	3.5m
Span as per skew angle	14m
Skew angles	0 degree, 7 degree, 14 degree, 21 degree, 28 degree, 35 degree and 42 degree
Thickness of deck slab	300mm
Longitudinal girder dimensions	0.4m x 0.8m
Diameter of pier	1.2m
Cross girder	0.4m x 0.8m
Height of pier	10m
Damping ratio	5%

Table 2: Various cases used for skew analysis

Models framed for analysis	Abbreviation
Cantilever bridge with FEM analysis at 0 degree skew angle under 70R loading	CB-FEM1
Cantilever bridge with FEM analysis at 7 degree skew angle under 70R loading	CB-FEM2
Cantilever bridge with FEM analysis at 14 degree skew angle under 70R loading	CB-FEM3
Cantilever bridge with FEM analysis at 21 degree skew angle under 70R loading	CB-FEM4
Cantilever bridge with FEM analysis at 28 degree skew angle under 70R loading	CB-FEM5
Cantilever bridge with FEM analysis at 35 degree skew angle under 70R loading	CB-FEM6
Cantilever bridge with FEM analysis at 42 degree skew angle under 70R loading	CB-FEM7



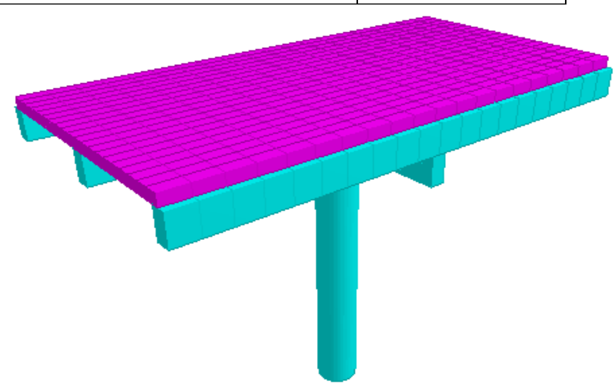


Fig. 1: Plan and 3D view of CB-FEM1

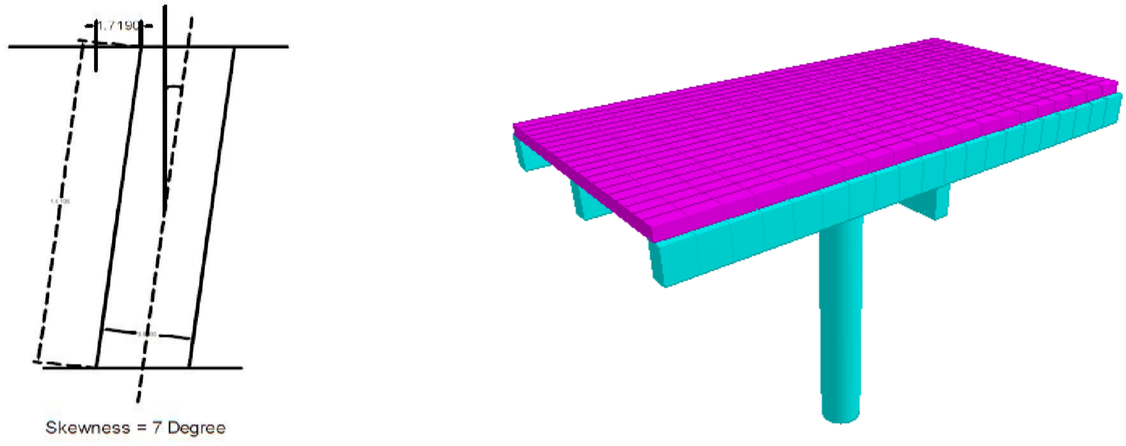


Fig. 2: Plan and 3D view of CB-FEM2

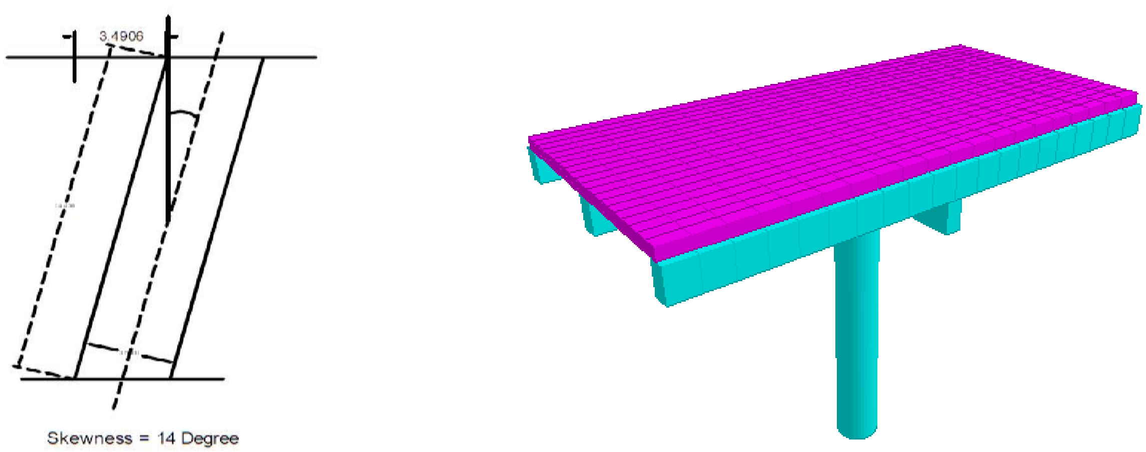


Fig. 3: Plan and 3D view of CB-FEM3

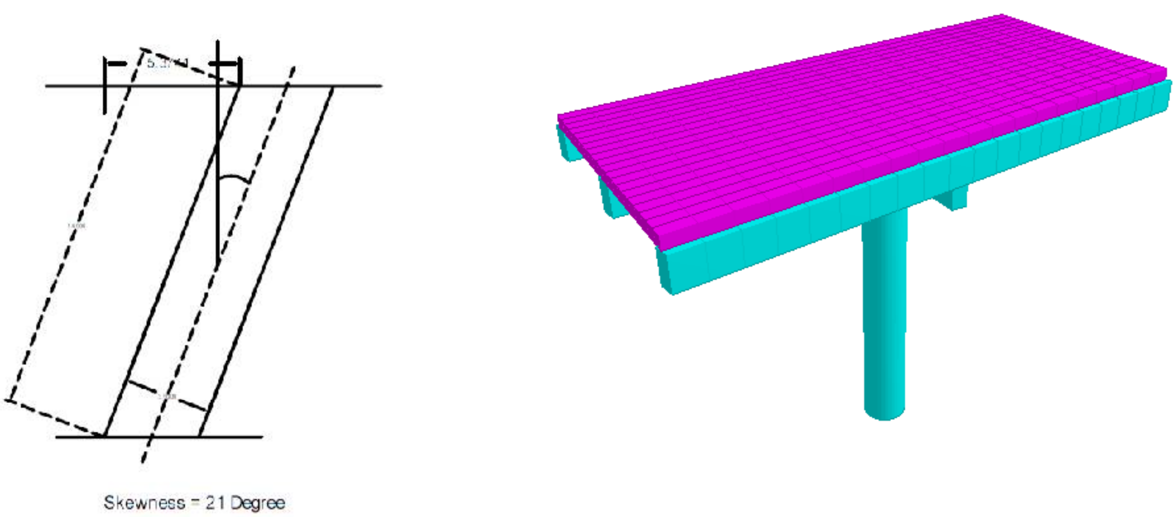


Fig. 4: Plan and 3D view of CB-FEM4

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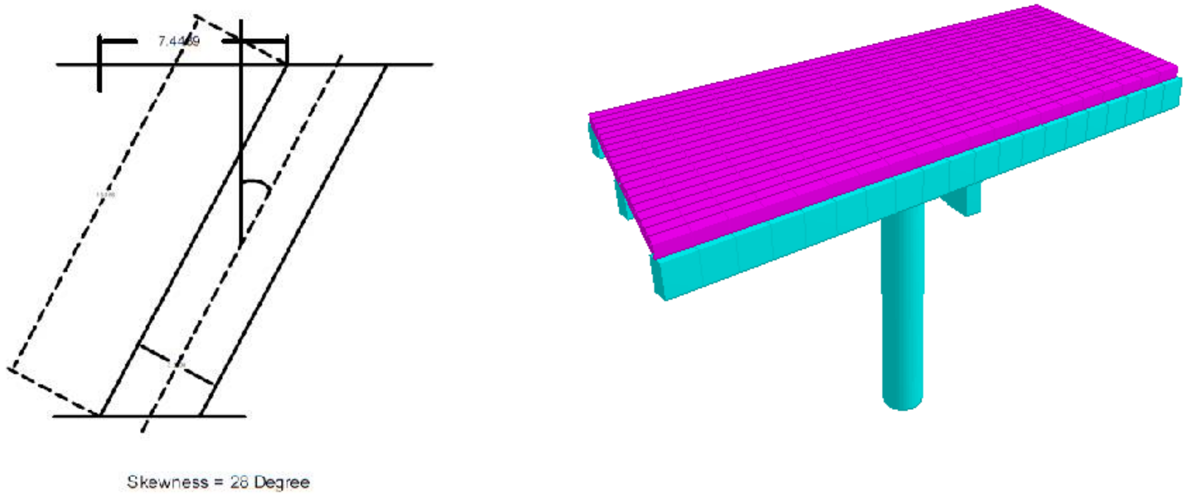

Fig. 5: Plan and 3D view of CB-FEM5

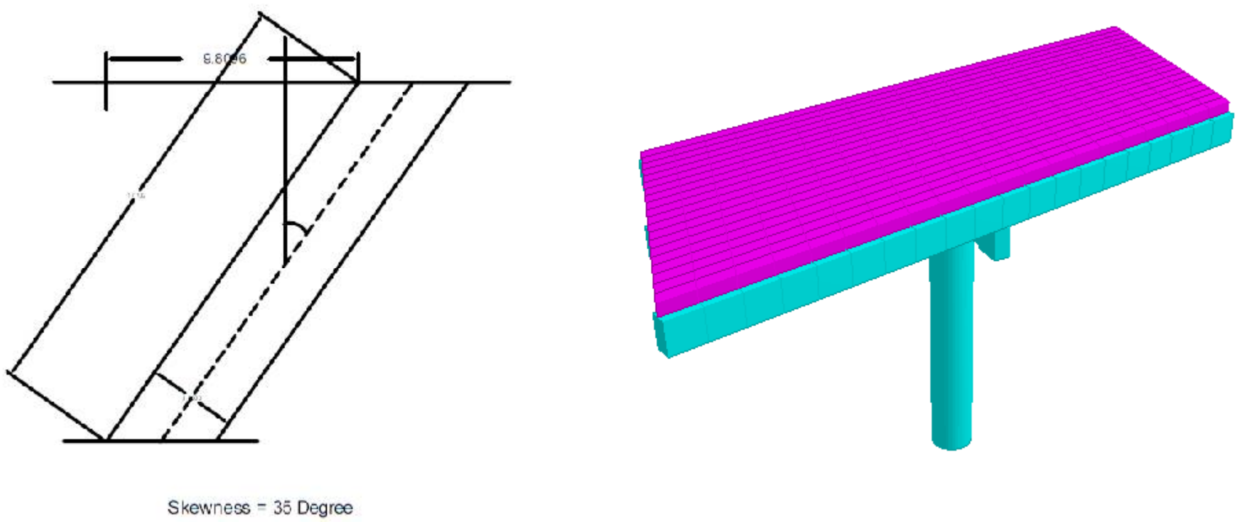

Fig. 6: Plan and 3D view of CB-FEM6

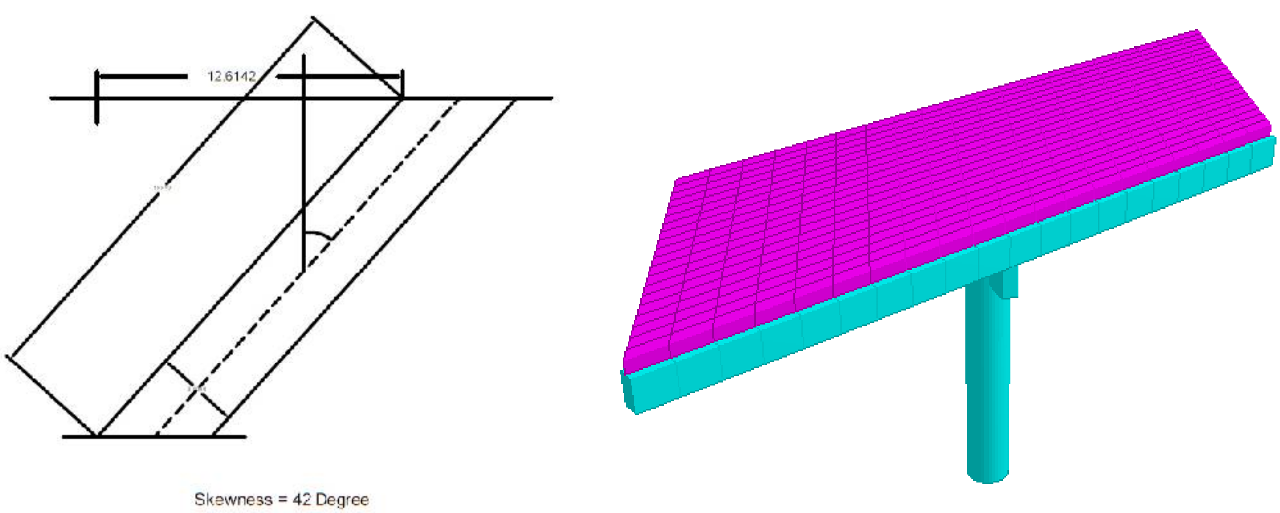

Fig. 7: Plan and 3D view of CB-FEM7

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IV. RESULTS AND DISCUSSION

As per the objectives and the parameters selected for the behavior of deck slab by skewness on balanced cantilever bridge, the following results were obtained as follows:-

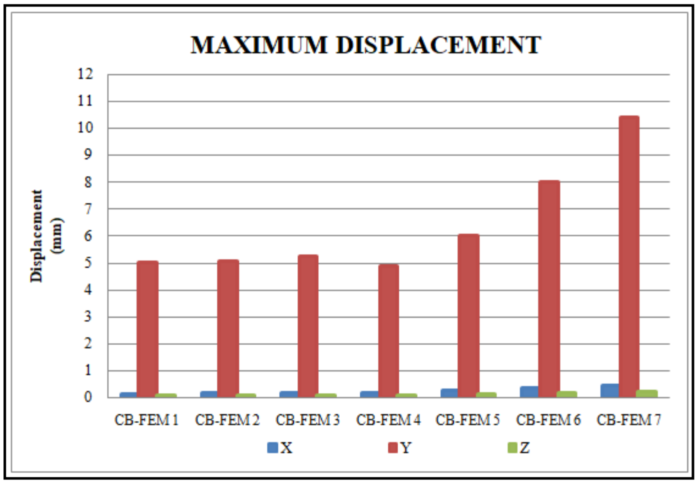

Fig. 8: Maximum Displacement for all cases

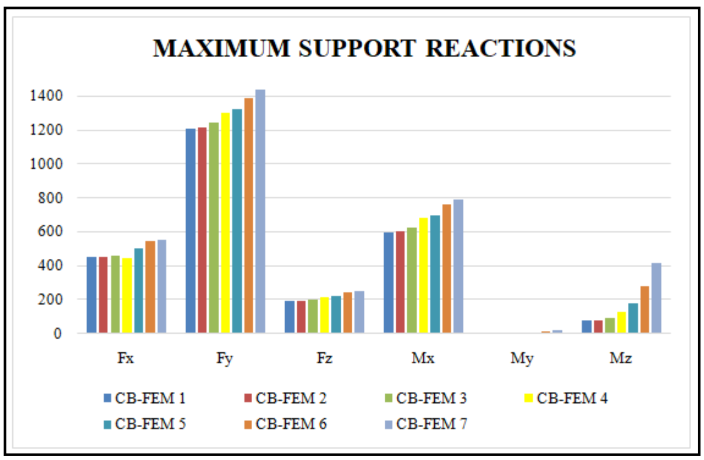

Fig. 9: Maximum Support Reactions for all cases

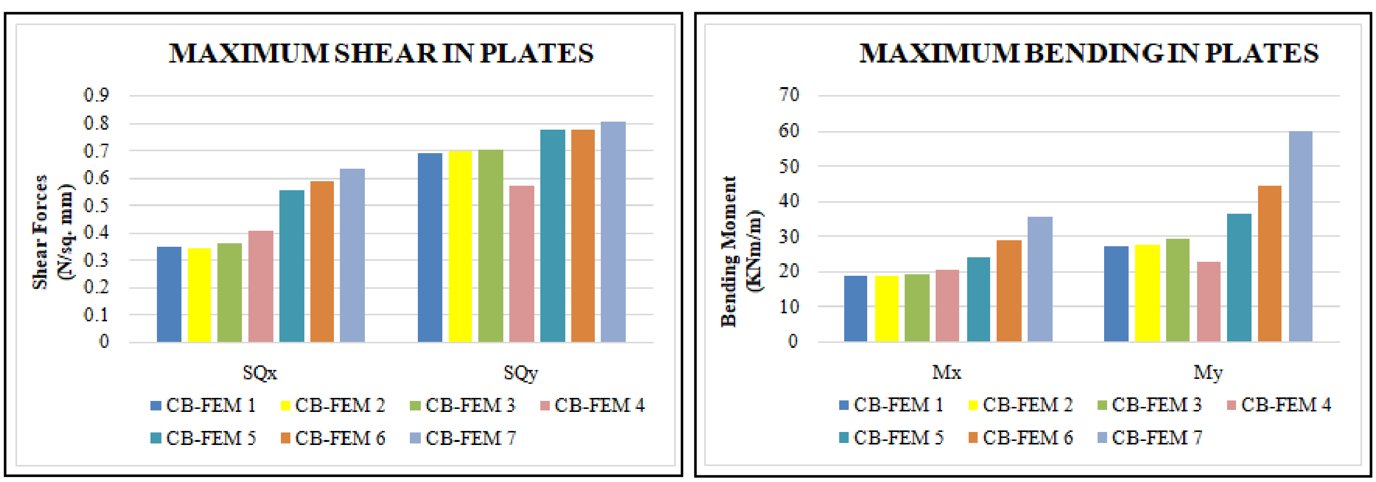

Fig. 10: Maximum Shear and Bending in Plates for all cases

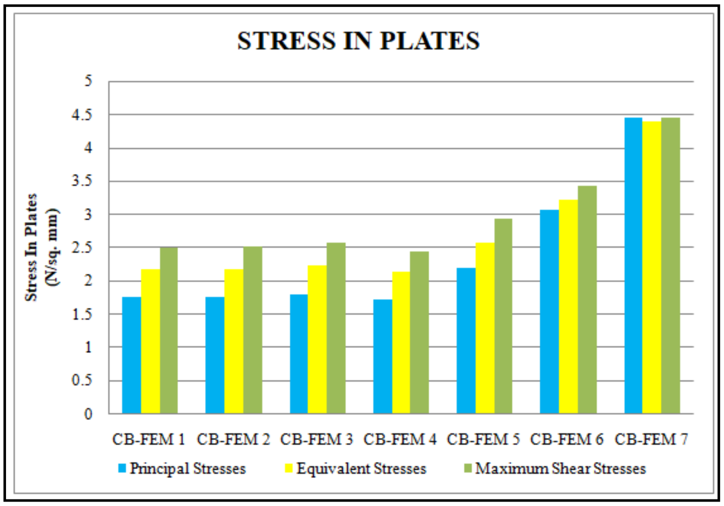

Fig. 11: Maximum Stress in Plates for all cases

V. CONCLUSIONS

On the basis of above parameters, following conclusions obtained from this comparative study:-

1) On comparing 0 degree, with increase in skew angle upto 42 degree, the deck slab displacement increases by 223.178% in x direction, 107.641% in y direction and 115.38% in Z direction respectively for 300mm depth.
2) For support reactions, on comparing 0 degree, with increase in skew angle upto 42 degree, different parameters increases respectively as Fx = 22.64%, Fy = 18.91%, Fz = 33.27%, Mx = 32.86%, My = 822% and Mz = 436.68%.
3) With increase in skew angle, the deck slab shear forces increases by 82.18% in SQx direction and 16.35% in SQy direction respectively for 300mm depth.
4) With increase in skew angle, the deck slab bending moment increases by 91.10% in X direction and 121.57% in Y direction respectively for 300mm depth.
5) For principal stresses the deck slab stresses increases by 152.5% respectively for 300mm depth.
6) For equivalent stresses, the deck slab stresses increases by 102.39% respectively for 300mm depth.
7) For shear stresses, the deck slab stresses increases by 77.68% respectively for 300mm depth.

This project concluded that the more skewness of the deck will generate results in higher side, since the members are interconnected with each other, it should be noted that the higher results generated over the deck slab during simulation by FEM analysis will be directly proportional to the degree of the skewness. The recommendation will be usage of lesser degree will e benefitted to the deck slab and bridge.

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