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Deck Slab Skewness Behavior on Pier and Longitudinal Girder of Balanced Cantilever Bridge: An Analytical Study

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Abstract: The finite element method (FEM) analysis of balanced cantilever skew bridges under the higher loading class of IRC 6:2017 is explored in this study. The impact of increased skewness in the deck on other structural members of the bridge is examined. For the analysis, a portion of a bridge with a span of 14 meters and a lane width of 3.5 meters is considered. Seven cases are created and analyzed using various skew angles. After the analysis, checks are performed to evaluate how the performance of the deck slab influences other bridge components, including the longitudinal girder. Conclusions are drawn regarding the pier and longitudinal girder based on the results. It is found that greater skewness in the deck slab leads to increased values of parameters such as axial forces, shear forces, bending moments, and torsional moments in the bridge. The analysis demonstrates a direct proportionality between the skew angle and the magnitude of stress, highlighting the critical role of skewness in structural performance evaluations.

Keywords: Balanced cantilever bridge, Finite element analysis, Skew angle, Bridge deck, IRC loading

I. INTRODUCTION

In modern infrastructure, large distances are spanned with minimal support using balanced cantilever skew bridges, especially over obstacles like rivers, railways, and highways. Their adaptability, reduced construction time, and minimal disturbance to the terrain have been prioritized in the current scenario. The alignment of structures with oblique crossings, such as angled intersections or irregular layouts, is facilitated by the inclusion of skewness in bridge design to optimize land usage and traffic flow. Complexities in load distribution and structural behavior are caused by skew angles, resulting in non-uniform stress patterns and differential deflections. Increased torsion, reduced load capacity, and challenges in deck slab design are frequently encountered in comparison to straight bridges. These issues are mitigated through the use of advanced tools like finite element methods, ensuring structural safety and performance. The adoption of balanced cantilever methods, combined with careful consideration of skew angles, is recognized as an efficient solution 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 other structural members by skewness on balanced cantilever bridge are:-

1) To study the effect of skewness of deck slab on pier by comparing maximum axial forces in pier and compare the efficient case among (CB-FEM1 to CBFEM7) for all the cases of deck skewness.
2) To conduct the study on the deviation in maximum shear forces in pier and find out the efficient case among (CB-FEM1 to CBFEM7) for all the cases of deck skewness.
3) To determine the variation in maximum bending moment in pier and find out the efficient case among (CB-FEM1 to CBFEM7) for all the cases of deck skewness.
4) To estimate the dissimilarity in maximum torsional moment in pier and find out the efficient case among (CB-FEM1 to CBFEM7) for all the cases of deck skewness.
5) To study the deviation in maximum shear forces and bending moment in longitudinal girder and find out the efficient case among (CB-FEM1 to CBFEM7) for all the cases of deck skewness.
6) To conduct the study on the dissimilarity in maximum torsional moment in longitudinal girder and find out the efficient case among (CB-FEM1 to CBFEM7) for all the cases of deck skewness.
7) To recommend the feasibility of research on effect of deck slab skewness over other structural members by analysing the result parameters by FEM analysis.

A. 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:-

B. For Pier

- Axial forces in pier
- Shear forces in pier
- Bending moment in pier
- Torsion moment in pier

C. For Longitudinal Girder

- Shear forces in longitudinal girder
- Bending moment in longitudinal girder
- Torsion moment in longitudinal girder

III. PROCEDURE AND 3D MODELING OF STRUCTURE

To analyze the balanced cantilever skew bridge, addressing gaps in previous research requires developing various models to ensure precision in comparative assessments. The Indian Standard IRC 6:2000 is utilized as a reference, offering diverse loading types and configurations for obtaining reliable outcomes. Based on this, the models are to be generated systematically, following a specific sequence. Detailed input data and descriptions of the models are provided as follows:-

- The grade of concrete taken as M30 with FE500 grade of steel.
- IRC loading taken as 70R with dead load as self weight.
- Width of lane taken as 3.5 m, 300 mm thickness of deck slab taken into account and span taken as 14m respectively.
- Dimensions of longitudinal girder taken as 0.4m x 0.8m, cross girder as 0.4m x 0.8m, height of pier as 10m for smooth passing of the vehicle under it and diameter of pier taken as 1.2m.
- 0 degree, 7 degree, 14 degree, 21 degree, 28 degree, 35 degree and 42 degree skew angles taken for analysis

Detailed data for various cases used for skew analysis and abbreviations of the models selected as follows:-

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

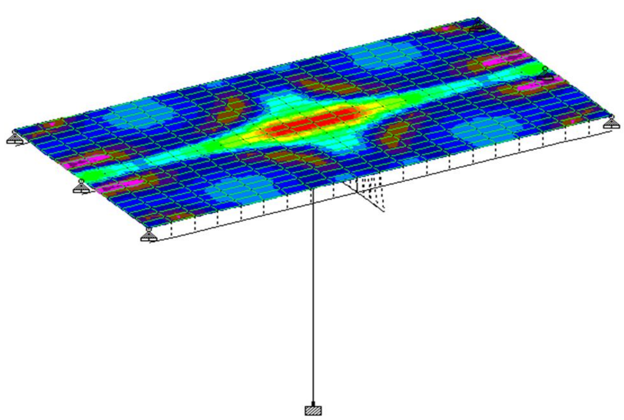

Fig. 1: Plate stress contour view of CB-FEM1

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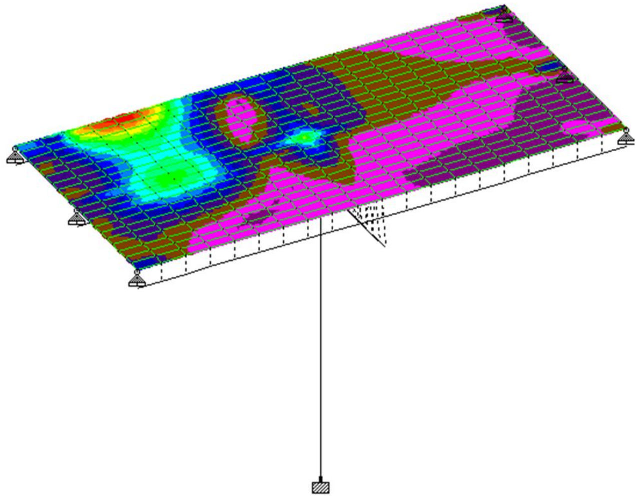


Fig. 2: Plate stress contour view of CB-FEM2

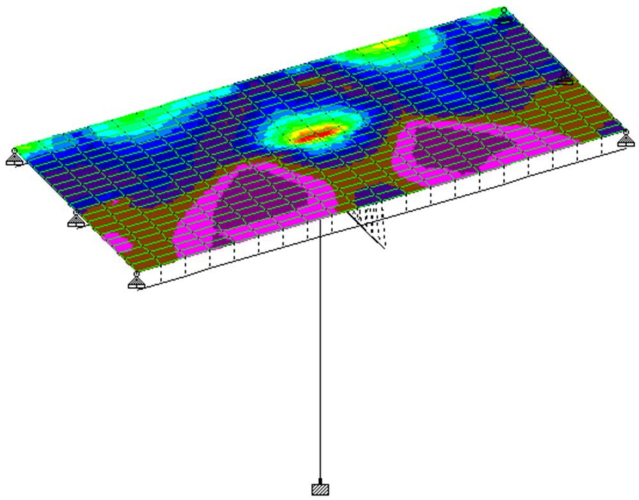


Fig. 3: Plate stress contour view of CB-FEM3

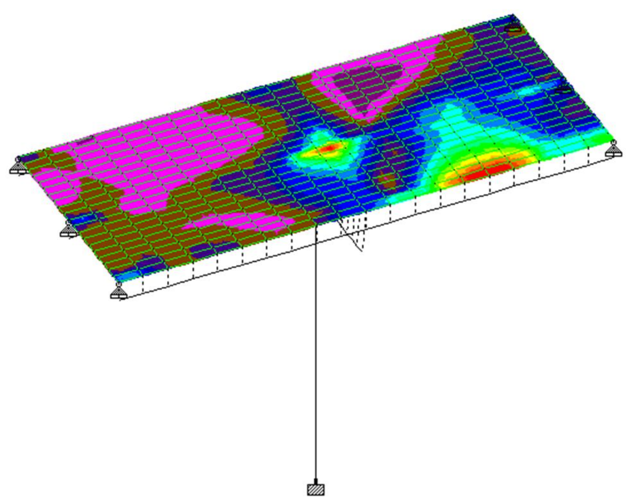


Fig. 4: Plate stress contour view of CB-FEM4

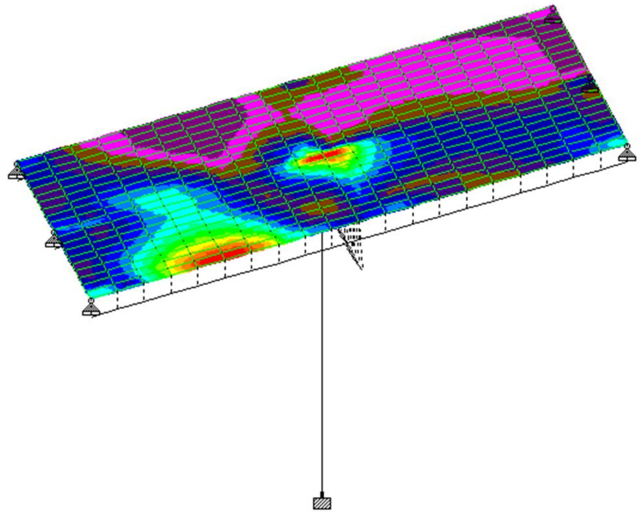


Fig. 5: Plate stress contour view of CB-FEM5

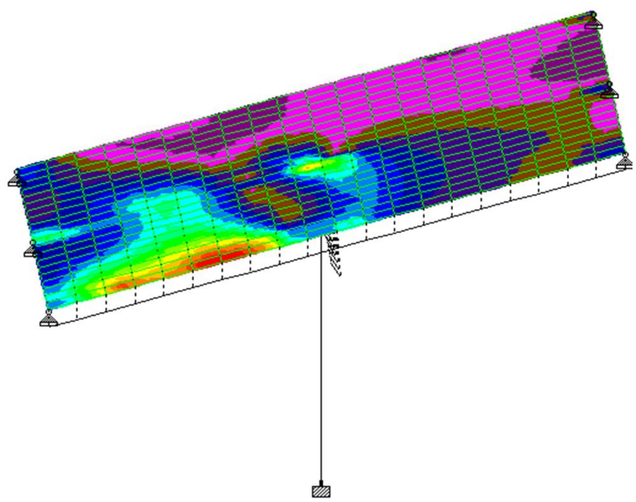


Fig. 6: Plate stress contour view of CB-FEM6

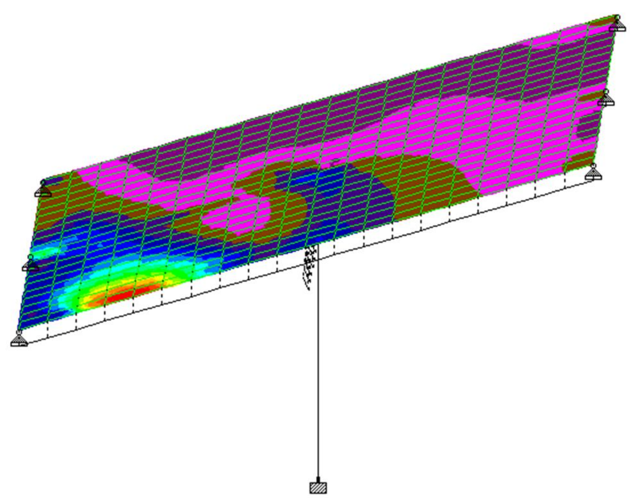


Fig. 7: Plate stress contour view of CB-FEM7

IV. RESULTS AND DISCUSSION

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

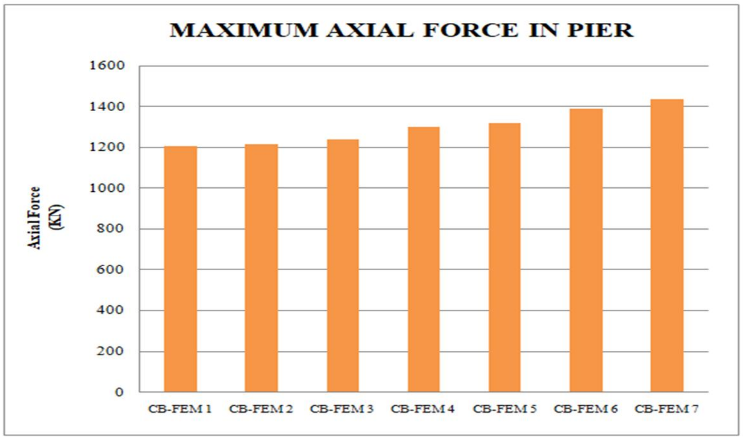
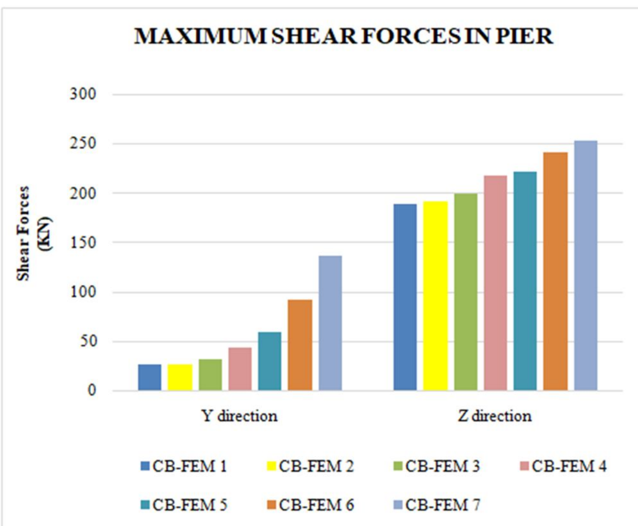


Fig. 8: Maximum Axial forces in pier for all cases



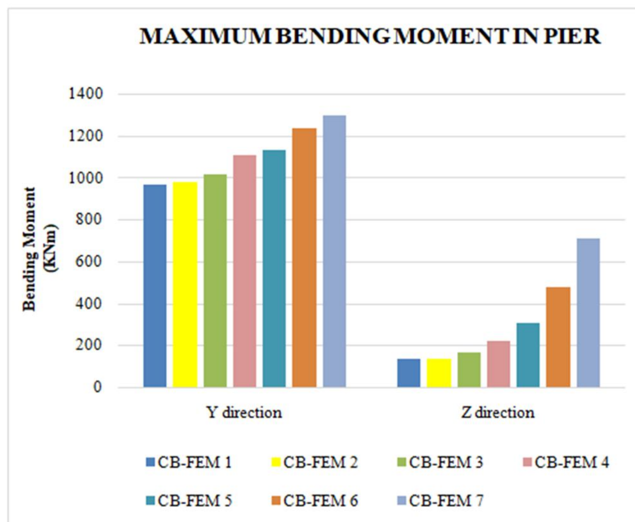


Fig. 9: Maximum Shear forces and Bending Moment in pier for all cases

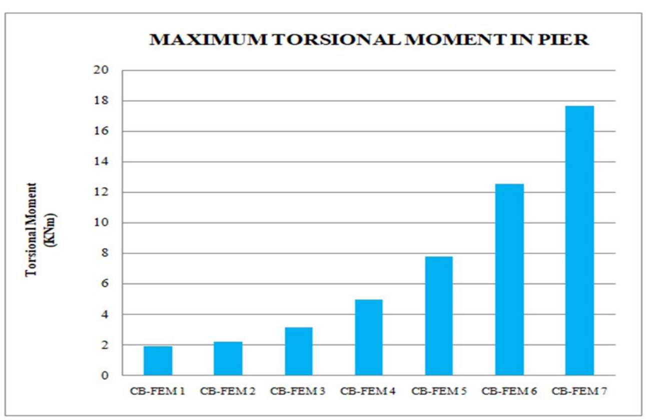


Fig. 10: Maximum Torsion Moment in pier for all cases

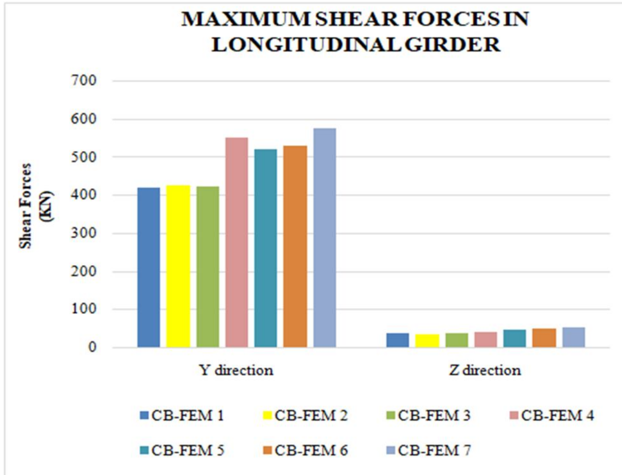


Fig. 11: Maximum Shear in longitudinal girder for all cases

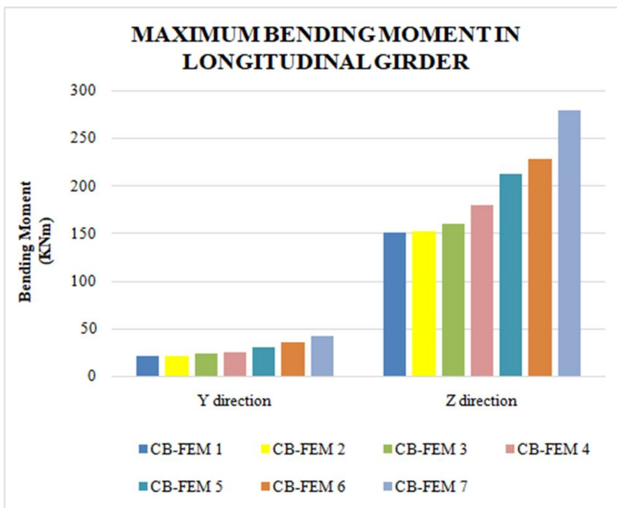


Fig. 12: Maximum Bending Moment in longitudinal girder for all cases

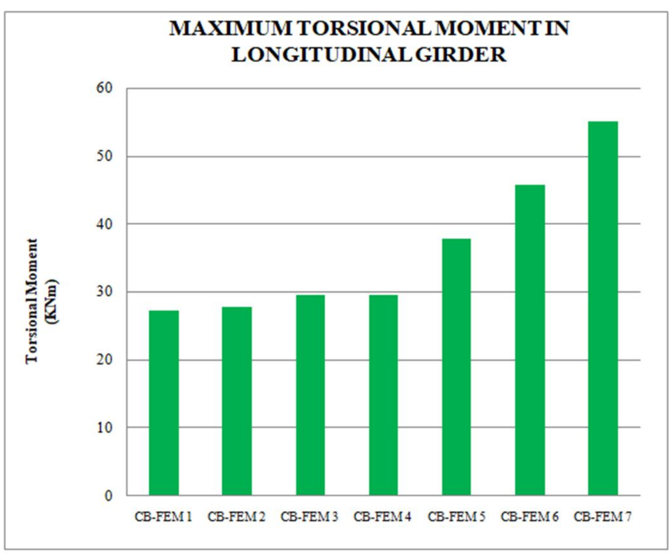


Fig. 13: Maximum Torsion Moment in longitudinal girder for all cases

V. CONCLUSIONS

On the basis of above parameters, following conclusions obtained on other members of balanced cantilever skew bridge from this comparative study:-

A. *For Pier*

1) On comparing 0 degree, with increase in skew angle, the axial forces in pier increases by 18.91% respectively for 300mm depth.
2) The shear forces in longitudinal girder increases by 429% in Y direction and 33.27% in Z direction respectively with increase in skew angle from 0 to 42 degree.
3) The bending moment in longitudinal girder increases by 33.93% in Y direction and 424.946% in Z direction respectively with increase in skew angle from 0 to 42 degree.
4) The torsional moment in longitudinal girder increases by 822.28% respectively with increase in skew angle from 0 to 42 degree.

B. *For Longitudinal Girder*

1) On comparing 0 degree, with increase in skew angle, the axial forces in pier increases by 18.91% respectively for 300mm depth.
2) The shear forces in longitudinal girder increases by 37.31% in Y direction and 49.88% in Z direction respectively with increase in skew angle from 0 to 42 degree.
3) The bending moment in longitudinal girder increases by 101.27% in Y direction and 85.45% in Z direction respectively with increase in skew angle from 0 to 42 degree.
4) The torsional moment in longitudinal girder increases by 102.309% respectively with increase in skew angle from 0 to 42 degree.

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 skewness of the deck affects the other structural members such as pier and longitudinal girder of the balanced cantilever skew bridge andthe higher results generated by the skewed 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 be benefitted to the bridge components respectively.

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