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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

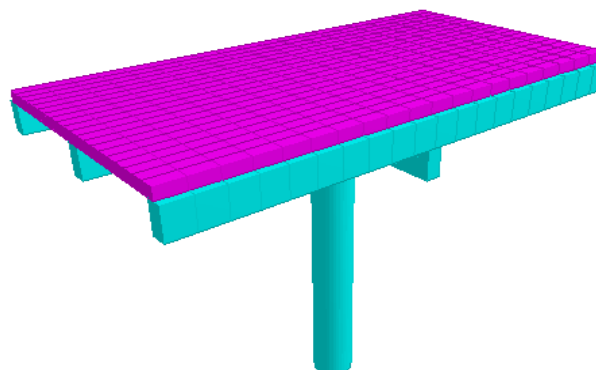
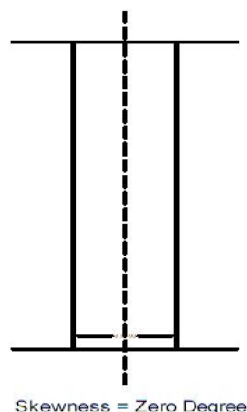


Fig. 1: Plan and 3D view of CB-FEM1

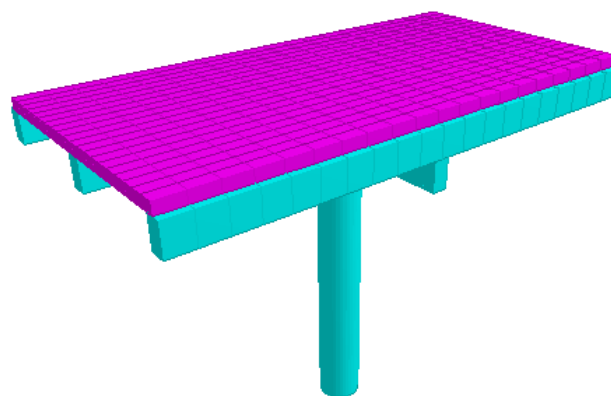
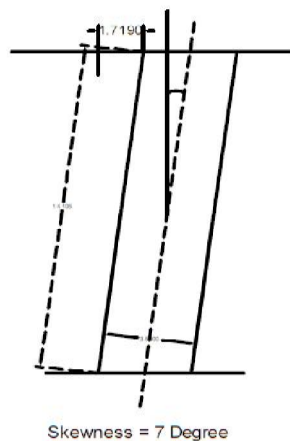


Fig. 2: Plan and 3D view of CB-FEM2

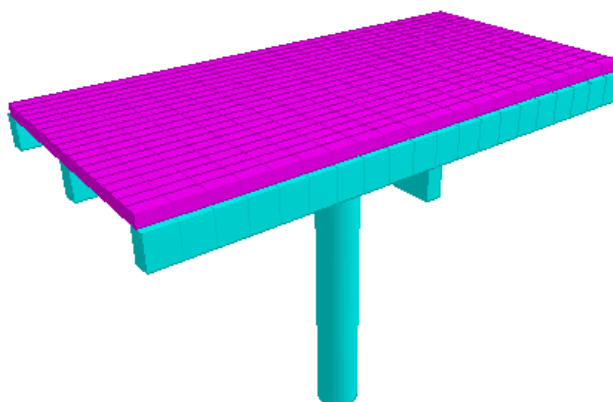
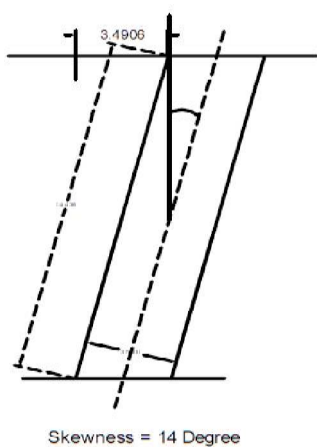


Fig. 3: Plan and 3D view of CB-FEM3

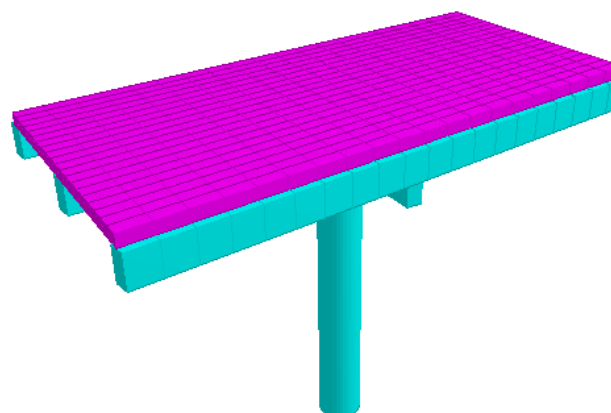
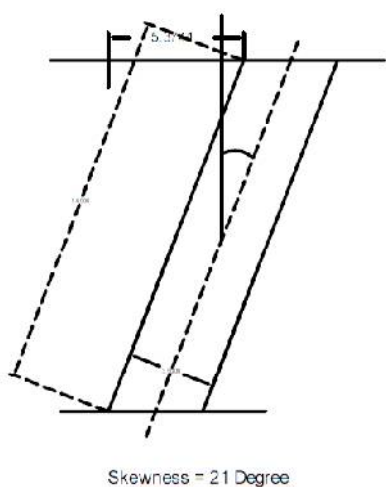
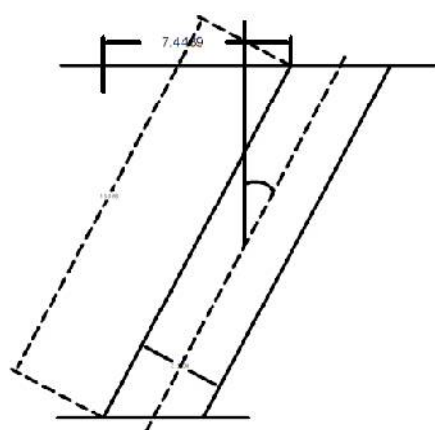


Fig. 4: Plan and 3D view of CB-FEM4





Skewness = 26 Degree

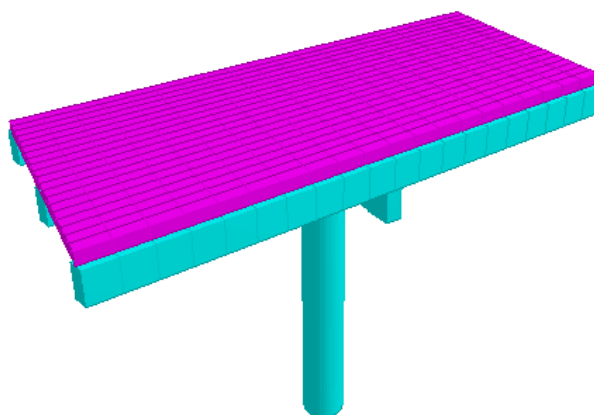
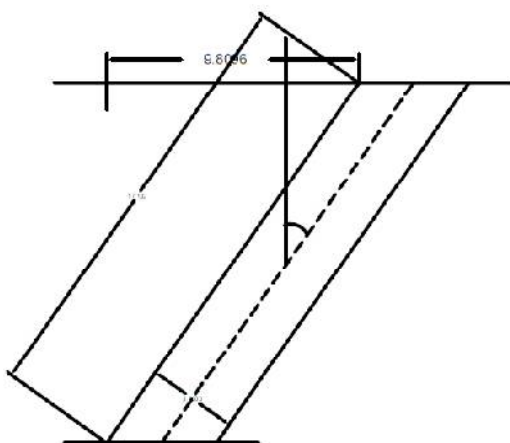


Fig. 5: Plan and 3D view of CB-FEM5



Skewness = 35 Degree

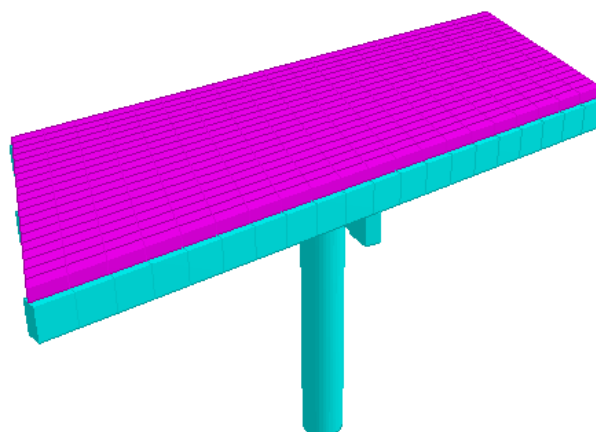
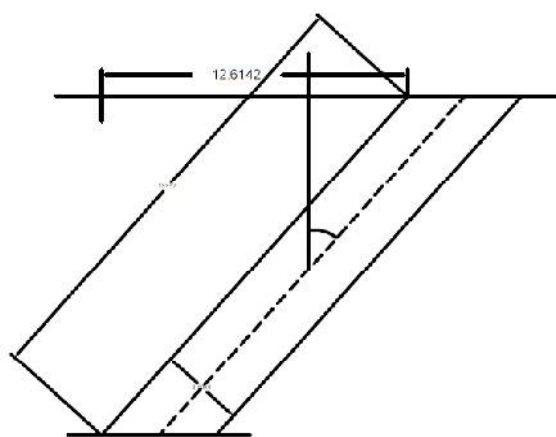


Fig. 6: Plan and 3D view of CB-FEM6



Skewness = 42 Degree

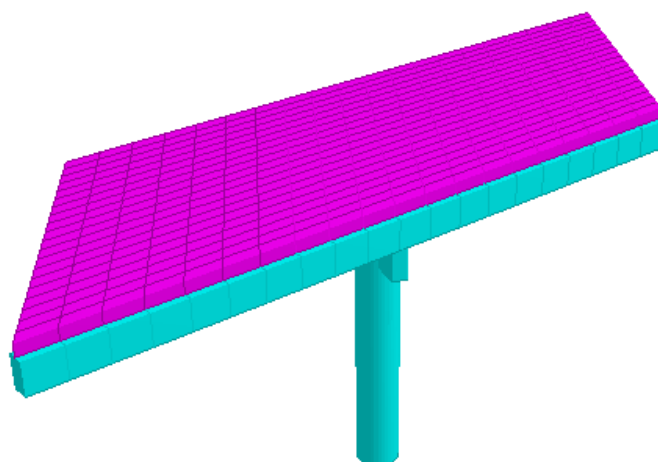


Fig. 7: Plan and 3D view of CB-FEM7

#### 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:-

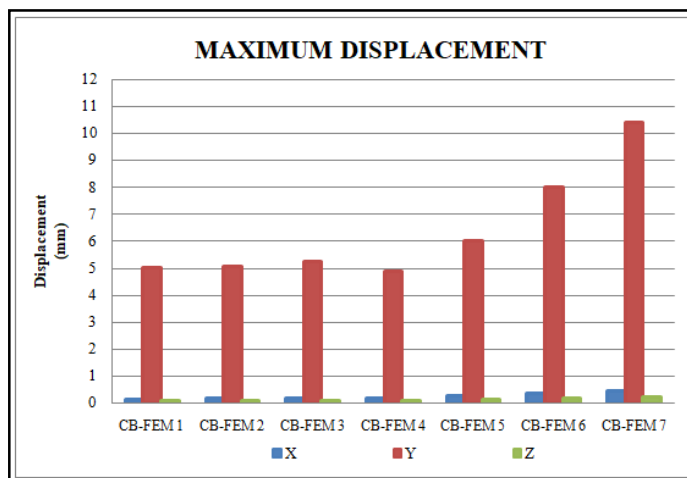


Fig. 8: Maximum Displacement for all cases

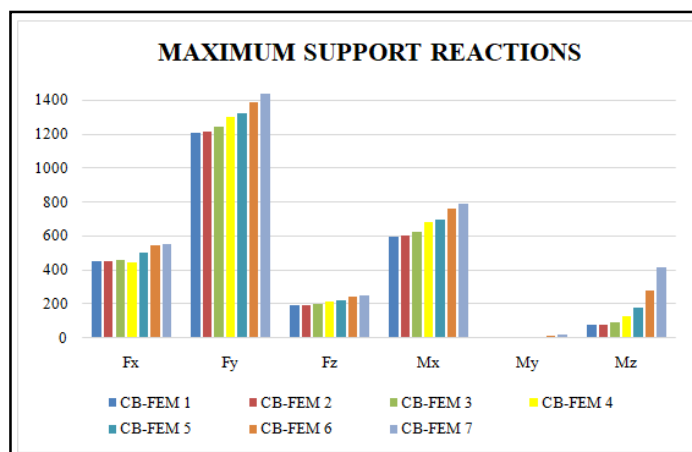


Fig. 9: Maximum Support Reactions for all cases

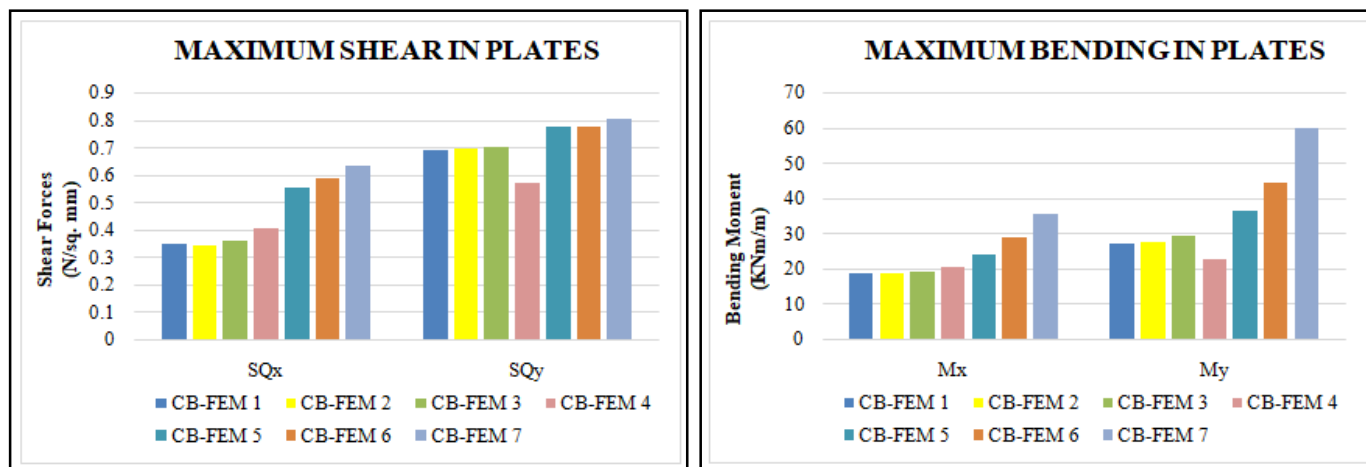


Fig. 10: Maximum Shear and Bending in Plates for all cases

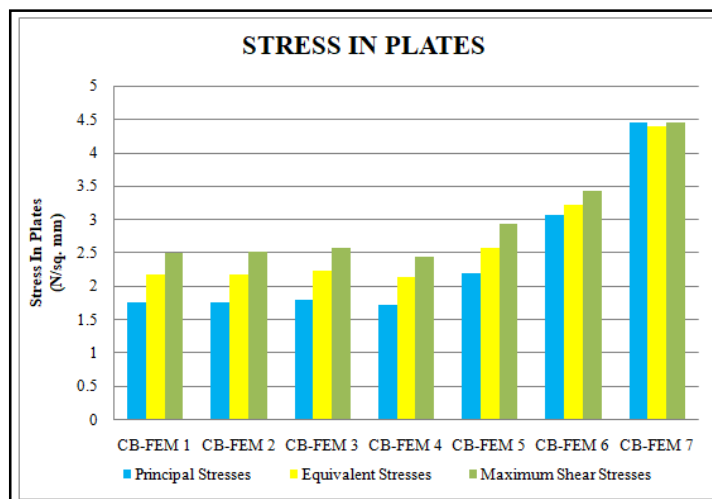


Fig. 11: Maximum Stress in Plates for all cases

## 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  $F_x = 22.64\%$ ,  $F_y = 18.91\%$ ,  $F_z = 33.27\%$ ,  $M_x = 32.86\%$ ,  $M_y = 822\%$  and  $M_z = 436.68\%$ .
- 3) With increase in skew angle, the deck slab shear forces increases by 82.18% in  $SQ_x$  direction and 16.35% in  $SQ_y$  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 be benefitted to the deck slab and bridge.

## VI. ACKNOWLEDGEMENT

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## REFERENCES

- [1] Dhar, A., Mazumder, M., Chowdhury, M., & Karmakar, S., (2013), "Effect of Skew Angle on Longitudinal Girder (support shear, moment, torsion) and Deck Slab of an IRC Skew Bridge", Indian Concrete Journal.
- [2] Rocha, B. F., & Schulz, M., (2017), "Skew decks in reinforced concrete bridges", Revista IBRACON De Estruturas E Materiais, Vol. 10, Issue 1, pp. 192–205.
- [3] Jeswani, B., & Budhlani, D., (2020), "Analysis And Design Of Bridge Component Using Staad Pro", International Journal of Creative Research Thoughts (IJCRT), Vol. 8, Issue 9, pp. 121–122.
- [4] Gayatri Deshmukh, Prof. Pandurang S. Patil, (2022), "Analysis of performance of various skew angles of deck slab bridges in MIDAS Software", International Research Journal of Engineering and Technology (IRJET), ISSN: 2395-0056, Volume: 09 Issue: 07, pp. 2781-2784.
- [5] Vasu Shekhar Tanwar, Sagar Jamle, (2018), "Analysis of Box Culvert to Reduce Stress Values". International Journal of Advanced Engineering Research and Science (ISSN: 2349-6495(P) | 2456-1908(O)), vol. 5, no. 5, pp.103-105 AI Publications, doi:10.22161/ijaers.5.5.14.
- [6] Ibrahim S. I. Harba, (2011), "Effect Of Skew Angle On Behavior Of Simply Supported R. C. T-Beam Bridge Decks", ARPN Journal of Engineering and Applied Sciences, ISSN 1819-6608, Vol. 6, No. 8, pp. 1-14.



- [7] Kishan Gautam, Shashikant Shrivastava, (2020), "Skew Bridge Analysis using "ANSYS"", International Journal of Engineering Research & Technology (IJERT), Vol. 9, Issue 06, pp. 870-875.
- [8] Kristine Djuve et. al. (2019), "Analysis Of Varying Skew Angle In A Single Span Reinforced Concrete Plate Bridge", Conference Paper; University of Stavanger.
- [9] L.A. Abozaid, Ahmed Hassanet. al. (2014), "Nonlinear Behaviour of a Skew Slab Bridge under Traffic Loads", World Applied Sciences Journal, ISSN 1818-4952, Vol. 30, Issue 11, pp. 1479-1493.
- [10] Lakavath Ramesh, B. Ravi Kumar, (2017), "Finite Element Modeling Of Reinforced Cement Concrete Skew Bridge And Dynamic Analysis", Anveshana's International Journal Of Research In Engineering And Applied Sciences, ISSN-2455-6300, Vol. 2, Issue 1, pp. 210-215.
- [11] Lucia Moya, Eva O. L. Lantsoght, (2021), "Parametric Study on the Applicability of AASHTO LRFD for Simply Supported Reinforced Concrete Skewed Slab Bridges", infrastructures, Vol. 6, Issue 88, pp. 1-23.
- [12] Muthanna Abbu, Talha Ekmekyapar, Mustafa Özakça, (2013), "3D FE modelling of composite box Girder Bridge", 2nd International Balkans Conference on Challenges of Civil Engineering, BCCCE, pp. 487-494.
- [13] Nasir, Himanshu Guleria, (2019), "Review On Skew Slab Bridges", International Research Journal of Engineering and Technology (IRJET), ISSN: 2395-0056, Vol. 06, Issue 12, pp. 1559-1561.
- [14] Nikhil V. Deshmukh, Dr. U. P. Waghe, (2015), "Analysis and Design of Skew Bridges", International Journal of Science and Research (IJSR), ISSN: 2319-7064, Vol. 4, Issue 4, pp. 399-402.
- [15] Pavankumar Naik, K Gourav, (2023), "Analysis Of Skew Bridge-Slab Under IRC Vehicle Loading", IOP Conf. Series: Earth and Environmental Science, ITSCMSI-2022.
- [16] Roshan Patel, Sagar Jamle, (2019), "Analysis and Design of Box Culvert: A Review", International Journal for Research in Engineering Application & Management (IJREAM), ISSN-2454-9150, Vol. 5, Issue 1, pp. 266-270.
- [17] Pinkal Gohel, Patel Sweta, Pandey Vipul, Nikunj Patel, (2017), "Analysis & Design of Deck Slab under Different Types of Loading as per is Code by STAAD Pro Software", IJSRD - International Journal for Scientific Research & Development, ISSN: 2321-0613, Vol. 5, Issue 08, pp.361-364.
- [18] R. Javanmardi, B. Ahmadi-Nedushan, (2021), "Cost Optimization Of Steel-Concrete Composite I-girder Bridges With Skew Angle And Longitudinal Slope, Using The SM Toolbox And The Parallel Pattern Search Algorithm", International Journal Of Optimization In Civil Engineering, Int. J. Optim. Civil Eng., Vol. 11, Issue 3, pp. 357-382.
- [19] R. Shreedhar, Spurti Mamadapur, (2012), "Analysis of T-beam Bridge Using Finite Element Method", International Journal of Engineering and Innovative Technology (IJEIT), ISSN: 2277-3754, Vol. 2, Issue 3, pp. 340-346.
- [20] Vasu Shekhar Tanwar, Dr. M. P. Verma, Sagar Jamle, (2018), "Analytic Study of Box Culvert to Reduce Bending Moment and Displacement Values", International Journal of Current Engineering and Technology, IJCET, Vol. 8, no. 3, pp. 762-764, DOI: <https://doi.org/10.14741/ijcet/v.8.3.33>
- [21] Roshan Patel, Sagar Jamle, (2019), "Analysis and Design of Box Culvert: A Manual Approach", International Journal of Advanced Engineering Research and Science (IJAERS), ISSN: 2349-6495, Vol. 6, Issue 3, pp. 286-291.
- [22] Rahna Sajeeb, Adithya Viswambharan, (2021), "Finite Element Modelling and Dynamic Analysis of Skew Bridge using Staad. Pro", International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Special Issue – 2021, Vol. 9, Issue 9, pp. 102-105.





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