International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 10 Issue: 07 | Jul 2023 www.irjet.net p-ISSN: 2395-0072

ANALYSIS OF SKEWED COMPOSITE BRIDGES

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Abstract - *Bridges are the important components of the Highway and Railway Transportation System. Failure of Bridges due to natural and manmade hazards may cause significant disruption to the transportation system and may affect its performance. Thus it results in major economic losses. Thus Safety and Serviceability of bridges have always been a great concern to Civil Engineering Profession. Bridges are a very special type of Structure. They are characterized by Simplicity in Geometry and Loading Condition. The Reinforced Concrete Bridges are usually subjected to Uniformly Distributed Dead Load, Vehicular Live Loads, and transfers same to the support through flexure, Shear, and Torsion. Newly Designed Bridge Structures are often Skewed Structures and they are often used in highly congested Urban Areas where there is Space Constraint or in mountainous terrain areas. If a Road alignment crosses the river or any other obstructions at an angle other than 90 degrees then Skewed Bridge Structure is necessary as they are Economical and most prominent Structures in such conditions. However, force flow in Skewed Structure is much more complicated than Conventional Bridge Structure. Various Promising methodologies like Grillage analysis, Finite Element Method, or Load Distribution Method are available. But Finite Element Method is considered the most suitable and precise methodology of analysis. This technique requires high precision in Data Collection, Modelling, and analysis of Skewed Structure and interpretation of results. In this research, an attempt has been made to study variations of various parameters like Bending Moment, Shear Force, and Torsional Moment with different skew angles ranging between 0 Degrees to 70 Degrees at an increment of 10 Degrees each. For our study, we have taken into consideration four major Loading Conditions i.e. 3Class A Loading Condition, Class A+70R Far, Class A + Class 70 R Near, and Fatigue Loading Condition as per IRC Guidelines. For in-depth analysis of the Skewed Bridge structure, 7 models for each loading condition i.e. overall 28 models were developed in MIDAS CIVIL for our analysis purpose.*

1. INTRODUCTION

This article gives us a brief idea about Skewed Bridges. Generally, due to complex intersections at various places such as Highways, Railway Crossings, and River Crossing, there is a continuously growing demand for such Skewed Bridges to distribute entire traffic without Congestion. Skewed Bridges for the angle between 0 degrees and 30 degrees are considered Straight Bridges as variation in parameter like Shear Force, Bending Moment and Torsional Moment is very small beyond 30 degrees there is a huge variation in parameters. The main Motive of our research is to determine the most Critical angle i.e. The angles at which there is a sharp increment or decrement in Shear Force, Bending Moment, and Torsional Moment. Generally, these are the points or skew angles at which Design must be carried out more precisely and rigorously to avoid any type of failure. For our analysis, we have made use of MIDAS CIVIL Software.

1.1 Software and its features

MIDAS Civil is a Finite Element Analysis Software developed by MIDASoft used for bridge analysis and design. MIDAS Civil Combines powerful pre and post-processing features with an extremely fast solver, which makes bridge modeling and analysis simples,quick and effective. Also, there are several easy parameter modification tools available that can be used for parametric analysis leading to optimized and economical design.

1.2 Features

- MIDAS Civil provides the user with unlimited and efficient modeling methods for any type of project.
- MIDAS Civil provides the user with various analysis functions for any type of analysis. It is used for linear analysis but is also capable of carrying out geometric nonlinear analysis.
- Gets detailed design reports. Design features provide detailed and clear calculation histories, enabling checking the capacity of selected sections for moment shear and torsion.

2. Identify, Research and Collect Ideas

- From the study of various literature papers, it was found that very limited study has been carried over skewed bridges and even it doesn't hold much relevance in Indian Perspective due to differences in design Live Load Standards, and type of bridges built here.

- Thus it doesn't provide any help to designers regarding quick estimation of the Bending Moment, Shear Force, and Torsional Moment which are of prime interest.

- While designing skewed Bridges most tedious job is to identify the most critical skew angle.

- But to identify a critical angle the most important task is to design Skewed Bridges for different loading Conditions as per IRC Standards.

- None of the researchers have carried out detailed studies regarding identifying critical angles as per Indian Standard.

- The Advantage of identifying a Critical angle is that while designing we can consider necessary precautions to avoid failure of bridge structures.

- The Detailed Methodology that we have adopted to identify the Critical skew angle is discussed in the methodology mentioned below.

3. METHODOLOGY

- The most important task was to select the appropriate dimensions of our skewed structure. So the Literature study and studying various journals and various books helped in selecting the appropriate dimensions of our structure. One of the books that helped me a lot in my entire work is **"Design of Bridges by N.Krishnaraju".**

- After the selection of appropriate dimensions, we started modeling our skewed structures with different skewed angles in **MIDAS Civil.** But only modeling the bridges with different skew angles would not give us a clear idea regarding the performance and effect of Skewed Bridges. Also, it would not give us a clear idea regarding the most critical angle at which sufficient safety precautions are necessary.

- So to overcome all the above situations and get a clear picture regarding performance, impacts, and locate the most critical skew angle which is the primary focus of our research we modeled Skewed Bridges with skew angles starting from 0 Degrees to 70 Degrees increasing by 10 Degrees.

- Also, we have considered different IRC Loading Conditions i.e. 3 Class A, Class A + 70 R Near, Class A+ 70R Far, and Fatigue Loading Condition for in-depth analysis and to get a clear idea regarding performance and impacts of skewed Bridge Structure.

- So for each loading condition, we designed 7 models. Thus overall 28 models were developed for in-depth analysis of a skewed structure which helped us to identify the most critical Skewed angles.

4. MODELLING AND ANALYSIS:

Consider a Simply Supported Bridge of span 36 meters and Total width of the bridge is 12 meters which is analyzed using MIDAS Civil Software. Detailed information about our model is provided below: The thickness of the Deck Slab is 220 mm, the Clear Carriageway width is 11 meters, End Barriers are 0.5 meters on each side.The thickness of the wearing course is 100 mm, Weight Density of the wearing course is 22 KN/M3.

Girder Details:

Consists of 5 girders with 2.5-meter center-to-center spacing in Transverse Directions. Girders are provided with Diagonal Bracings. Width of Top Flange: 400mm, Width of Bottom Flange: 850mm, Thickness of Top and Bottom Flange: 25mm.Height of web: 2045mm, Thickness of web: 12mm.

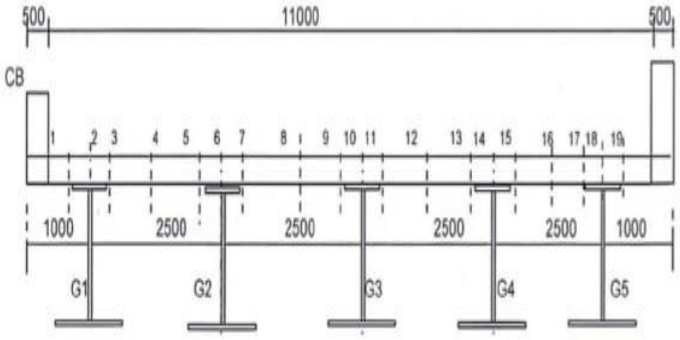


FIG 1) CROSS SECTION OF BRIDGE LAYOUT

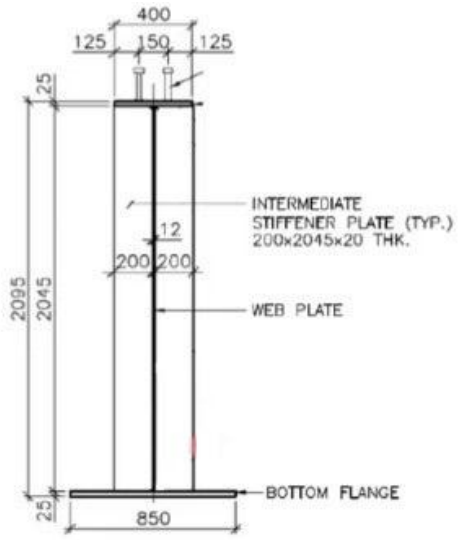


FIG 1) DETAILS OF GIRDER

STEPS TO BE FOLLOWED WHILE MODELING IN MIDAS CIVIL:

1. Define Material Properties
2. Define Time Dependent Properties.
3. Defining Section Properties.
4. Modeling of structure in MIDAS Civil
5. Specifying loading conditions as per Indian Standards.
6. Specifying Different conditions of the lane.
7. Specifying Construction Stages which majorly includes two stages
    a) Girder only Stage.
    b) Composite Stage
8. Construction Stage Analysis.
9. Run analysis.
10. Computation of results.

5. ANALYSIS AND RESULTS:

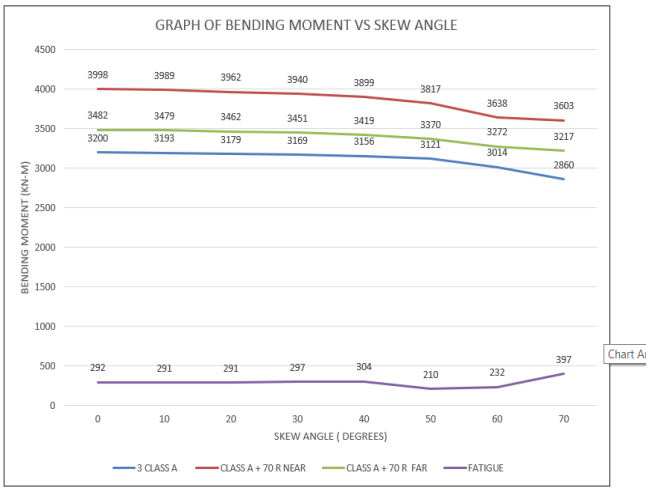
Analysis of 28 m long and 12 m wide Bridge for different skew angles ranging from 0 degrees to 70 degrees with increment @10 degrees was done by using MIDAS Civil Software which is based on Finite Element Approach. For our analysis purpose total of 28 models were designed by taking into consideration of Dead Load and Live Load as per IRC 6:2017. For our entire analysis we have taken into consideration Four Loading Condition 3 CLASS A, CLASS A+70 R NEAR, CLASS A + 70 R FAR, Fatigue Loading Condition. The main motive of our entire work is to estimate Critical Skew angles which if proper necessary measures are not taken may lead to the failure of the structure. Critical Skew angles are the locations at which there is a sudden change in Bending Moment, Shear Force, and Torsional Moment.

5.1. RESULTS:

5.1.1. Results of Bending Moment (KN-M) for 3 CLASS A, CLASS A +70R NEAR, CLASS A + 70R FAR, Fatigue Loading Conditions.

SR.NO	SKEW ANGLE	3 CLASS A	CLASSA+70R NEAR	CLASS A +70 R FAR	FATIGUE
1	0	3200	3998	3482	291
2	10	3193	3989	3479	291
3	20	3179	3962	3462	291
4	30	3169	3940	3451	297
5	40	3156	3899	3419	304
6	50	3121	3817	3370	210
7	60	3014	3638	3272	232
8	70	2860	3603	3217	397

TABLE 1: DATA REPRESENTING BENDING MOMENT FOR VARIOUS LOADING CONDITIONS IN KN-M



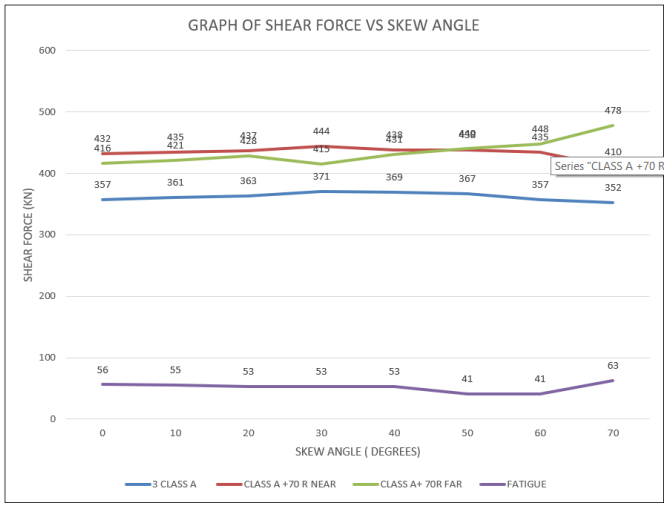
GRAPH 1: THE GRAPH REPRESENTS THE VARIATION OF BENDING MOMENT AGAINST THE SKEW ANGLE

5.1.2. Results of Shear Force (KN) for 3 CLASS A, CLASS A+ 70R NEAR, CLASS A +70R FAR & Fatigue Loading Condition.

SR. NO	SKEW ANGLE	3 CLASS A	CLASS A+ 70R NEAR	CLASS A +70R FAR	FATIGUE
1	0	357	432	416	56
2	10	361	435	421	55
3	20	363	437	428	53
4	30	371	444	415	53
5	40	369	438	431	53

6	50	367	438	440	41
7	60	357	435	448	41
8	70	352	410	478	63

TABLE 2: TABLE REPRESENTS SHEAR FORCE DATA FOR VARIOUS LOADING CONDITION

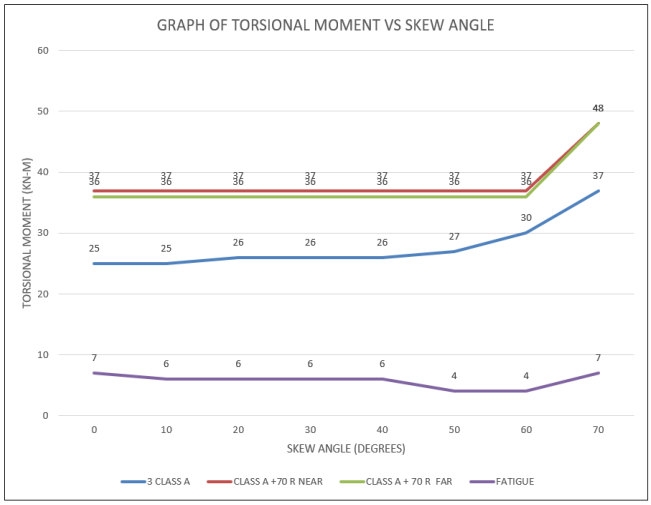


GRAPH 2: THE GRAPH REPRESENTS THE VARIATION OF SHEAR FORCE AGAINST SKEW ANGLE.

5.1.3. Results of Torsional Moment (KN-M) for 3 CLASS A, CLASS A + 70R NEAR, CLASS A+ 70R FAR, and Fatigue Loading Condition.

SR. NO	SKEW ANGLE	3 CLASS A	CLASS A+ 70R NEAR	CLASS A +70R FAR	FATIGUE
1	0	25	37	36	7
2	10	25	37	36	6
3	20	26	37	36	6
4	30	26	37	36	6
5	40	26	37	36	6
6	50	27	37	36	4
7	60	30	37	36	4
8	70	37	48.13	48	7

TABLE 3: TABLE REPRESENTS TORSIONAL MOMENT DATA FOR VARIOUS LOADING CONDITION



GRAPH 3: THE GRAPH REPRESENTS THE VARIATION OF TORSIONAL MOMENT AGAINST THE SKEW ANGLE.

6. CONCLUSIONS:

1. For 3 Class A loading conditions it was found that the Bending moment decreases linearly up to 60 degrees but above 60 degrees there is a sharp decrease in the Bending moment.

2. For 3 Class A loading conditions it was found that Shear force increases up to 30 degrees and then between 30 to 60 degrees it decreases and above 60 degrees there is a Sharp decrease.

3. From the study, it was found that for Class A+70R Near loading condition Bending Moment decreases Linearly between 0 degrees and 60 degrees skew angle above 60 degrees there is a sharp decrease.

4. From the study it was found that for Class A+70R Near loading condition Shear Force increases linearly between 0 degrees and 30 degrees skew angle for 40 degrees to 60 degrees shear force decreases linearly above 60 degrees skew angle there is a sharp decrease.

5. From the study, it was found that for Class A+70R Far loading condition Bending Moment decreases Linearly between 0 degrees and 60 degrees skew angle above 60 degrees there is a sharp decrease.

6. From the study it was found that for Class A+70R Far loading condition Shear Force increases linearly between 0 degrees and 20 degrees skew angle for 30 degrees there is a sharp decrease again from 40 degrees to 60 degrees it increases linearly above 60 degrees there is a sharp rise.

7. From the study it was found that for Fatigue loading condition Bending Moment increases linearly upto 40 degrees skew angle above 40 degrees skew angle, there is a sharp decrease and it increases linearly up to 60 degrees, and above 60 degrees there is a sharp increase

8. From the study it was found that for Fatigue loading condition Shear Force decreases linearly between 0 degrees and 40 degrees skew angle and above 40 degrees there is a sharp decrease again for 40 degrees to 60 degrees it increases linearly above 60 degrees there is a sharp rise.

7. RECOMMENDATIONS:

1. From all the above Conclusions we can suggest that the most critical angle is 30 Degrees and 60 Degrees. So while designing the Bridges for those specific skew angles necessary preventive measures must be taken into consideration from a safety and economic consideration point of view.

2. From the study, it is recommended that the maximum skew angle must be less than 30 degrees as far as possible from a safety and economic consideration point of view. While Designing Skew Bridges for angles more than 30 degrees, Designers should be concerned about Torsion and take all necessary steps for safe and economical design.

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