EFFECT OF SKEW ON THE BEHAVIOUR OF RC GIRDER BRIDGES

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ABSTRACT

Many bridges are skewed and their behaviour and corresponding analysis need to be furthered to fully accomplish analysis objectives. This project has used an approach of detailed finite element analysis to understand the behaviour of different skew bridges. This project focused on the effect of skew on the behaviour of girder bridges. Investigation of effect of skewness on the design parameters i.e. bending moment, shear force and Torsion, study the effect of skew angle, span and type of load on girder bridges. Dead load and live load (class A and class 70R) were applied as per IRC guidelines. The skew angles were taken as $\theta=0^0$, 15^0, 30^0, 45^0 and 60^0 and span were used 25m. The skew bridge has been performed in CSiBridge software, total five models are analyzed. Bridges with skew angle less than or equal to 15^0 be analyzed by non-skew bridges. For all the five models, study the variation of maximum bending moment, shear force and Torsion. The finite element analysis results for skew bridges compared with non-skew bridges for both dead load and live loads. The effect of skew was observed for dead load and live load on skew bridges. Analysis results for bending moment decreases with increase in skew angle also increase in shear force and Torsion with increase in skew angle up to 45^0 and after it decreases. The use of providing girder at ends of abutment is to decrease in maximum bending moment and Torsional moment.

Keywords: *Bridges,Skew angle, FEM, span length, Girders and Live loads.*

1. INTRODUCTION

Bridge is a structure resting on two supports over a depression, obstruction and crossing of a river or valley. Reinforced concrete skew bridge have been widely constructed in hilly regions, it consist of RCC precast I girders, bearings, abutments or piers, cast in situ deck slab and crash barrier. The girders are provided between the deck slab and abutments. Bearings are provided at the junction of slabs and the top of pier and abutment to transmit the load coming from super structure to the sub structure. These structural elements increase the strength and bear heavy load on the bridge.

Many studies have been carried out in the field of skew bridges. Depending on the geometry, the use of skew bridges has increased considerably in the recent days, in the recent years for highways and railways to meet several requirements mainly the natural and man-made obstacles and various intersections in mountainous terrains.

The skew angle is defined as the angle of inclination between the centre line of bridge and abutment. In this thesis an attempt has been made to study the effect of skew angle on the behaviour of RCC precast I girder Bridges. The study also focuses the effect of skew in design parameters such as bending moment ,shear forces and Torsion in simply supported 3-lane precast I girder bridges. The skew bridge analysis has been performed in using the latest CSiBridge software. As the span and skew angle increases, the design parameters such as maximum bending moment, shear force and torsion also increase. This poses a real challenge to the designers.

The effect of skew bridges is observed on maximum live load bending moment, maximum live load shear force and torsion at critical locations. The spans selected were 25m, 28.2m, 31.92m, 37m and 45.8m and the skew angles were taken as 0^0, 15^0, 30^0, 45^0 and 60^0. If the skew angle is less than 20^0, it doesn't effect on bending moments, shear forces and torsional values. And can be considered as non-skew bridges.

2. OBJECTIVES AND SCOPE

1) To study the effect of skewness directly on design parameters i.e. bending moment, Shear force and torsion.
2) To study behaviour of RCC precast I girder bridges considering skew effect
3) To study the behaviour of cast in situ deck slab bridges
4) To study the effect various types of loads.
5) To observe the effect of skew on maximum live load bending moment, live load shear force at critical locations.
6) To check the deflection characteristic of and behaviour of RCC precast I girder bridges.
7) To study the effect of varying skew angles.
8) To compare the analysis with other available conventional methods.
9) To develop exact design tools that can help engineers to handle skew bridges easily.

3. AIM AND SCOPE OF THE WORK

The present analytical work focuses on the study of effect of skew on the behaviour of reinforced concrete precast I girder bridges.The effect of skewness directly effects the design parameters such as bending moment, shear force and torsion, which influences the behaviour. An effort is made to formulate an acceptable and reliable method of analysis.

4. METHODOLOGY

This thesis reports the behaviour of skew bridges analysed and tabulated using CSiBridge software. Five different cases of models with skew angles 0^0, 15^0, 30^0, 45^0, 60^0 and span of 25m and 12m width are considered. Precast I girder bridges are selected for model generation. The dimensions of girder are depth 1750m, breadth of the flange at top 1200mm, bottom width 600mm and depth of flange at top 150mm, at bottom 325mm and thickness of web 300mm. The different parameters defined are diaphragms, bearings and crash barriers.

Analysis is performed for dead load and live load on skew bridges. The results have contributed to understanding the behaviour of skew bridges based on the maximum loads. The results are extracted in excel and further used for plotting the graph such as skew angle versus bending moment, shear force and torsion. Comparison is made for all the models and a comprehensive conclusion is drawn.

Table 1: Span and skew angles

Sl No	Angle (degree)	Span (m)
1	0°	25
2	15°	25
3	30°	25
4	45°	25
5	60°	25

5. FINITE ELEMENT MODELLING

FEA is the most versatile method, which can be used to develop any type of structure with varying size, shape and boundary conditions. Physical measurements are important before creation of a model, which after analysis are checked and resized if required and are further used to calibrate numerical model for validation. The finite element based CSiBridge software is used to model the bridge superstructure, subjected to dead load and live loads. Modelling consist of primarily selecting the structural elements to simulate the superstructure.

6. RESULTS AND DISCUSSIONS

In this chapter analysis is performed to evaluate the effect of skew on the behaviour of precast I girder bridges, from the analysis the results are obtained and presented in terms of structural parameters such as bending moment, shear force and torsion. These parameters occur in the girder bridges due to applied dead load and live load. Bridges of span 25m and 12m wide were analysed for skew angles of 0^0, 15^0, 30^0, 45^0 and 60^0. From the analysis bending moment, shear force and torsion diagrams are as follows.

6.1 Analysed parameters diagrams

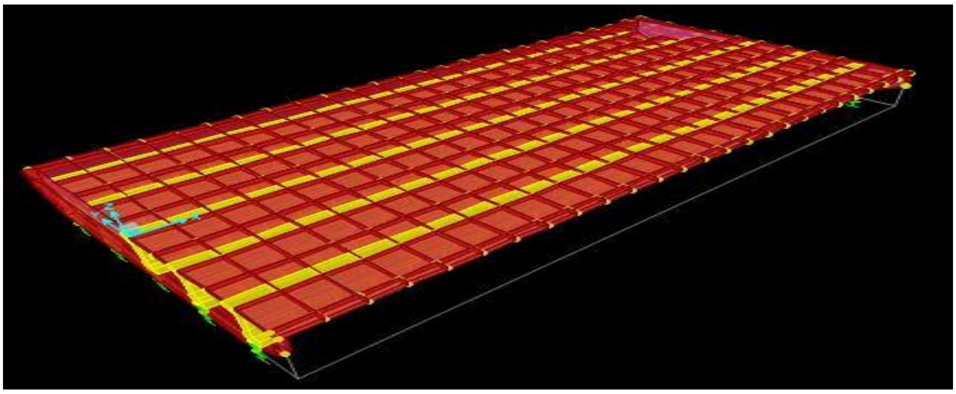

Figure 1: plan for skew bridge $\theta=0^0$

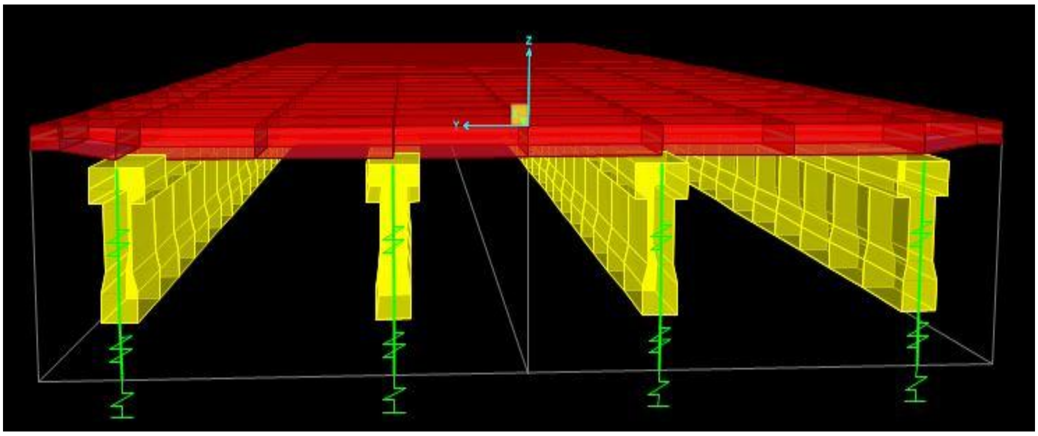

Figure 2: cross section of bridge

6.2 Bending moment

Table 2 Bending moment (DL+LL)

Skew angles	DL BM	CLASS A	CLASS 70R
0	15613.5	6075.25	8896
15	15450	6037.03	9018.745
30	14962.6	5871.05	6563.533
45	13943.5	473.528	8081.306
60	12765.1	4732.91	7740.544

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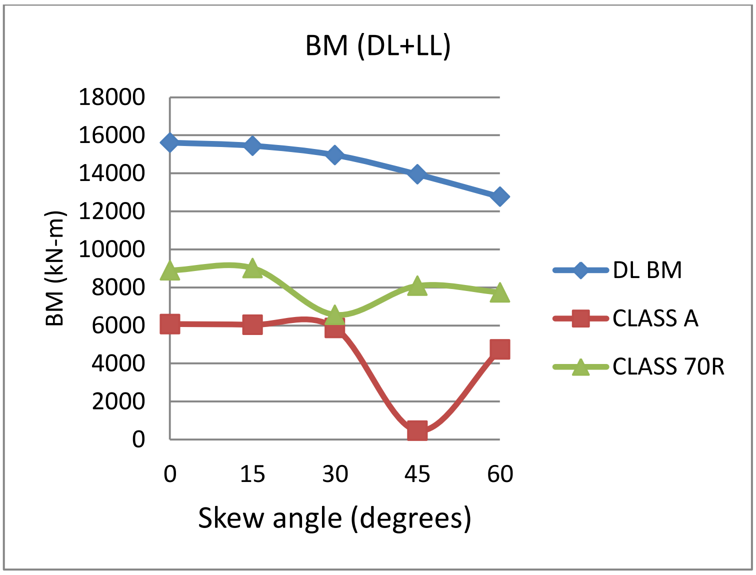

Figure 3: Skew angle vs bending moment

The variation of bending moment is presented in figure 3 for dead load and live load. The maximum bending moment is observed during increment in skew bridges. Also increase in span length will effect the bending moment on bridges. The bending moment for Skew angle between 0^0 to 15^0 is constant, as the skew angle increases the maximum bending moment decreases. It can be concluded that considering 0^0 to 15^0 skew can be termed as straight bridges because there is no significant effect on girder bridges. Dead load bending moment is maximum for 0^0 skew,as theskew angle increases the dead load bending moment decreases gradually. Also live load bending moment for class A and class 70R loadings decreases as the skew angle increases.

6.3 Shear force

Table 3: Shear force (DL+LL)

Skew angles	DL SF	CLASS A	CLASS 70R
0	-2484.9	0	0
15	-2478.9	0	0
30	-2478.9	14.436	12.9849
45	-2478.9	44.9085	78.8219
60	-2752.6	104.429	281.2376

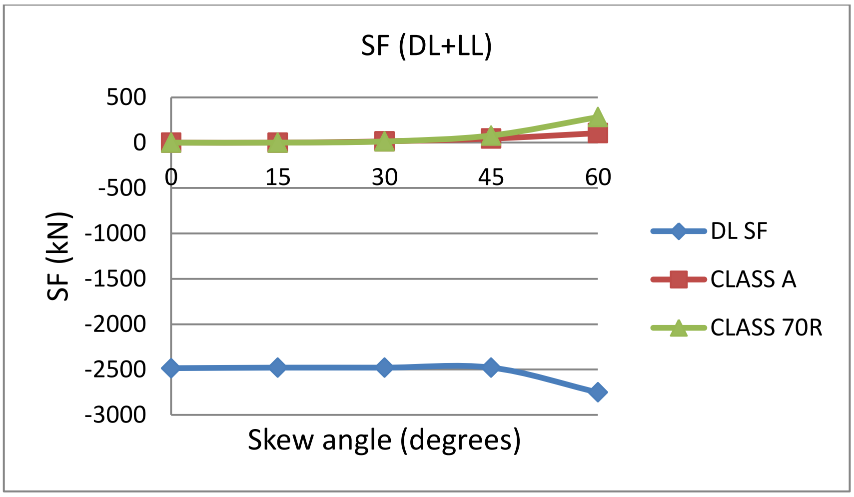

Figure 4: Skew angle vs Shear force

6.4 Torsion

The variation of torsional moment is as shown in figure 5. As skew angle increases torsional moment in skew bridge increases, but it increases to a certain limit and it decreases thereafter and can be concluded that it depends on span and skew angle.

Table 4: Torsion (DL+LL)

Skew Angles	DL Torsion	CLASS A	CLASS 70R
0	-0.0223	1.51E-02	493.7647
15	-341.22	233.058	473.8718
30	-2070.7	444.967	627.5738
45	1062.75	5406.63	901.1165
60	-3343.7	1550.22	2398.626

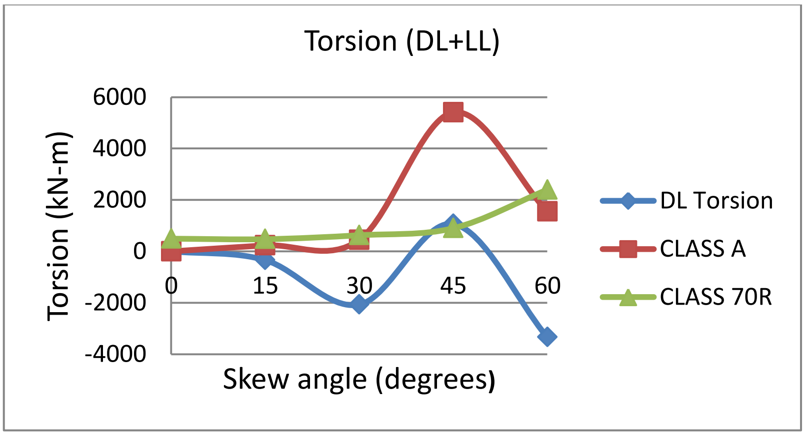

Figure 5: Skew angle vs Torsion

For dead load and live load case, there is almost less torsion moment in bridge but increases abruptly to 30 and its increment rate slows down at 45^0 and 60^0. The torsional moment decreases with the provision of girders for both dead load and live load.

6.5 Live load bending moment

Table 5: Live load bending moment

Skew Angles	CLASS A	CLASS 70R
0	6075.25	8896
15	6037.03	9018.745
30	5871.05	6563.533
45	473.528	8081.306
60	4732.91	7740.544

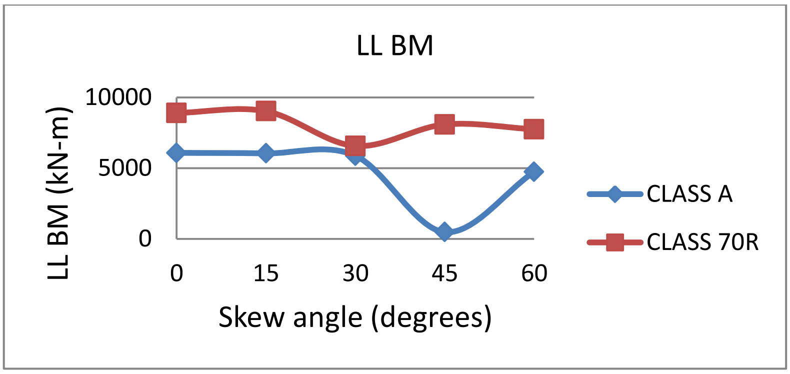

Figure 6: Skew angle vs Live load bending moment

Skew angle vs live load bending moments are presented in figure 6. Class A and class 70R loadings bending moment increases up to 30^0 and it decreases when skew angle reaches to 45^0 and 60^0.

6.6 Live load shear force

Table 6: Live load Shear force

Skew Angles	CLASS A	CLASS 70R
0	0	0
15	0	0
30	14.436	12.9849
45	44.9085	78.8219
60	104.429	281.2376

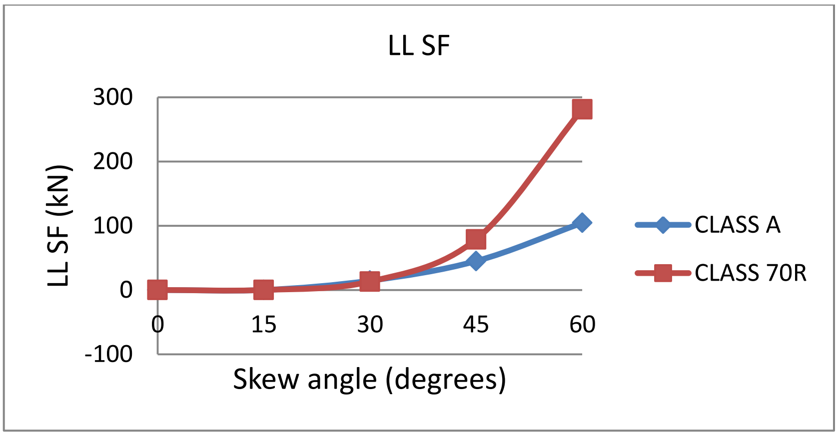

Figure 7: Skew angle vs Live load shear force

From figure 7 live load shear force increases as the skew angle increases in girder bridges.

6.7 Live load torsion

Table 7: Live load torsion

Skew Angles	CLASS A	CLASS 70R
0	1.51E-02	493.7647
15	233.058	473.8718
30	444.967	627.5738
45	5406.63	901.1165
60	1550.22	2398.626

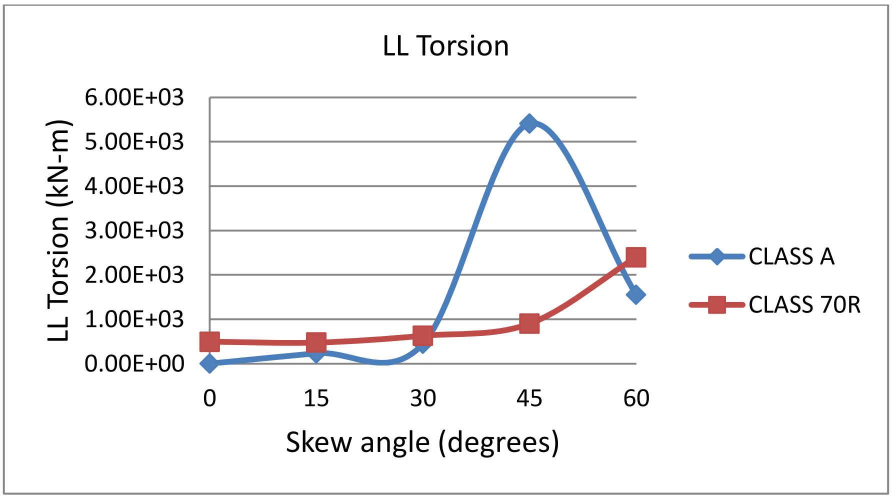

Figure 8: skew angle vs Live load torsion

Table 8: Dead load bending moment

Skew Angles	Left Exterior girder	Interior girder 1	Interior girder 2	Interior girder 3	Right Exterior girder
0	3.44E+03	2935.833	2877.908	2930.164	3419.185
15	3266.721	2832.784	2860.634	2981.403	3545.955
30	3077.002	2671.627	2771.368	2975.737	3635.213
45	2852.894	2450.337	2567.387	2830.317	3618.137
60	2642.658	2067.693	2126.528	2497.408	3696.049

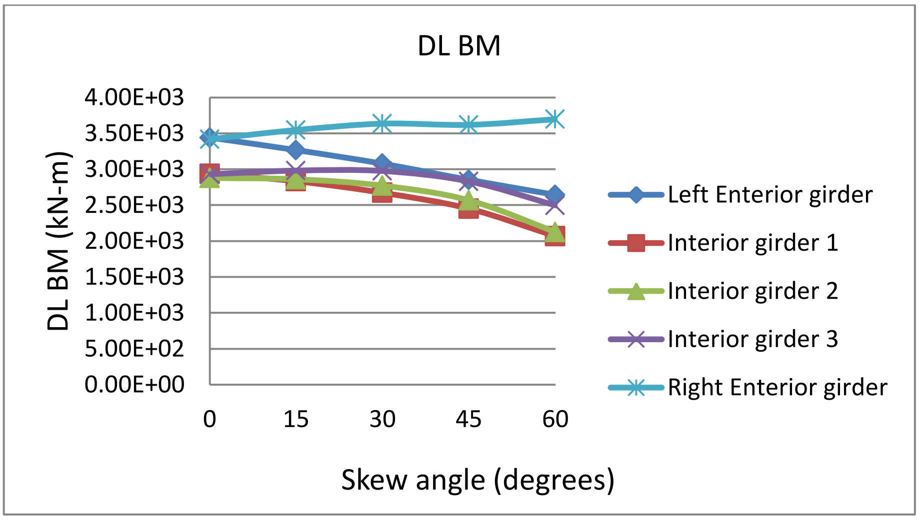

Figure 9: Skew angle vs Dead load bending moment

The different curves as seen in figure 9 are due to dead load on the skew bridge, it is seen that bending moment decreases as skew angle increases and it depends on span and skew angle. There is no effect of right exterior girder bridges and for dead load left exterior girder and interior girder 1, 2, 3 it changes, which in turn affect the behaviour of skew bridges.

Table 9: Dead load shear force

Skew Angles	Left Exterior girder	Interior girder 1	Interior girder 2	Interior girder 3	Right Exterior girder
0	-6.03E+02	-402.2814	-401.733	-402.636	-634.83
15	-678.188	-407.897	-402.423	-395.157	-592.426
30	-727.054	-415.037	-402.472	-394.626	-539.055
45	-785.2797	-426.6223	-389.2847	-383.8136	-493.9343
60	-1435.74	-403.678	-630.042	-385.872	-488.65

Shear force at support is plotted in figure 10 for dead load on all on bridges. Shear force increases with increase in skew angle, but for interior girder 1, 2, 3 it is almost same and does not effect on bridges. The shear force in left exterior girder and right exterior girder may change due to dead load and live load on bridges. Shear force is maximum at 45^0 and 60^0 for both left and right exterior girder.

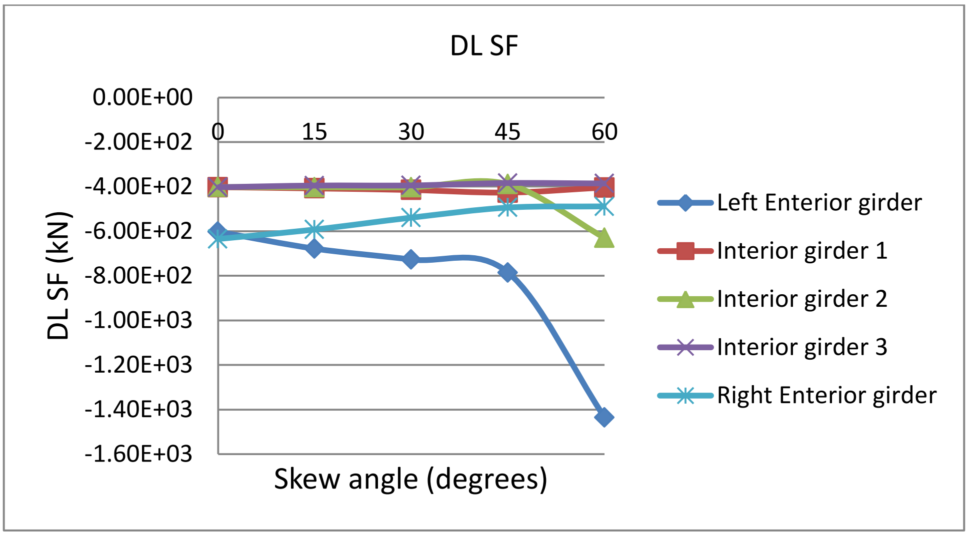

Figure 10: Skew angle vs Dead load shear force

Table 10: Dead load torsion

Skew Angles	Left Exterior girder	Interior girder 1	Interior girder 2	Interior girder 3	Right Exterior girder
0	-2.49E+01	-3.11E+01	-4.67E-01	3.00E+01	-2.42E+01
15	-44.7535	-80.1771	-60.7351	-19.9714	3.0478
30	-68.9783	-141.789	84.8982	-80.7304	-26.2148
45	-96.5687	-210.766	-221.029	-175.152	-81.9331
60	-99.0379	-287.497	-288.23	-215.554	-96.8964

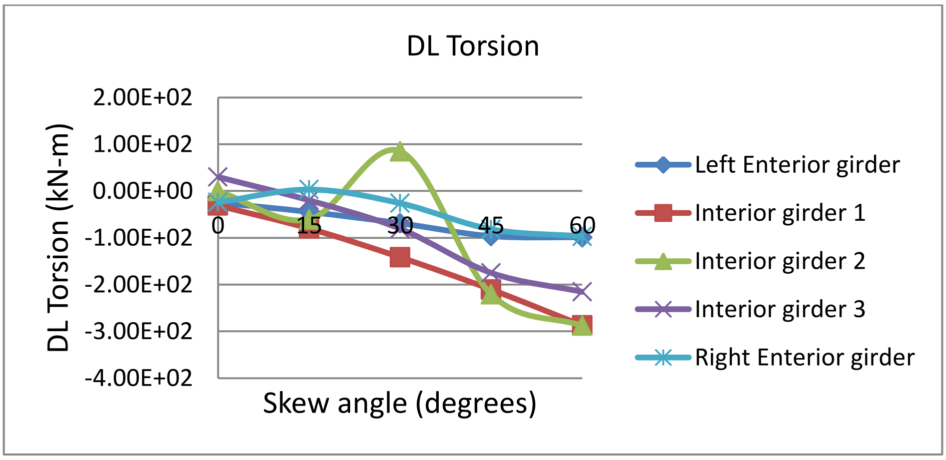

Figure 11: Skew angle vs dead load Torsion

Table 11: live load bending moment

Skew Angles	Left Exterior girder	Interior girder 1	Interior girder 2	Interior girder 3	Right Exterior girder
0	3.35E+03	2.90E+03	2.58E+03	2.88E+03	3.34E+03
15	3231.017	2827.044	2562.8	2933.171	3449.821
30	2078.354	2011.198	2114.844	2687.716	3327.042
45	2712.881	2371.3955	2202.3931	2635.9178	3274.209
60	2442.441	1949.189	1766.241	2141.713	2960.909

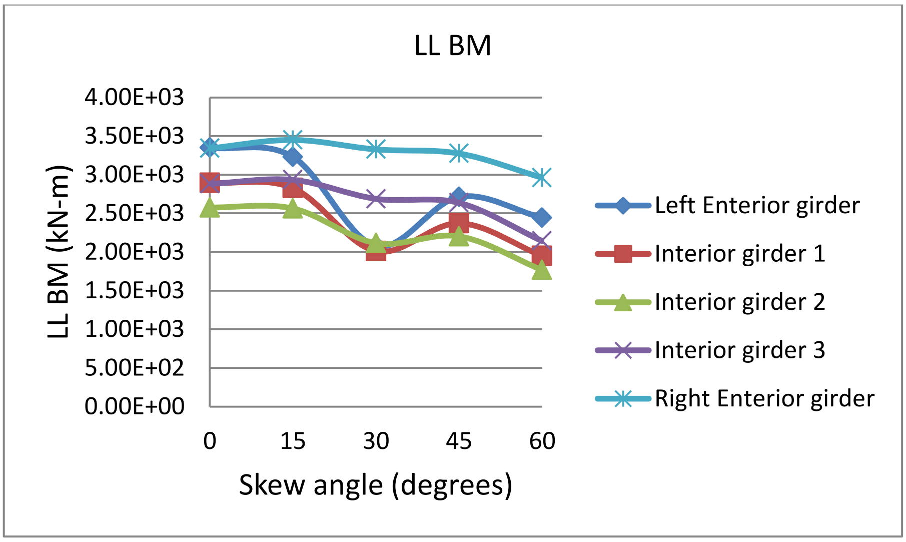

Figure 12: Skew angle vs live load bending moment

Table 12: Live load shear force

Skew Angles	Left Exterior girder	Interior girder 1	Interior girder 2	Interior girder 3	Right Exterior girder
0	1.11E+01	1.42E+00	0.0401	1.42E+00	0.00E+00
15	0	0	0	0	0
30	82.9238	17.7749	5.5012	0.2231	0.7914
45	212.2353	33.1514	4.4108	0	0
60	658.4864	47.3209	5.3166	0	22.0969

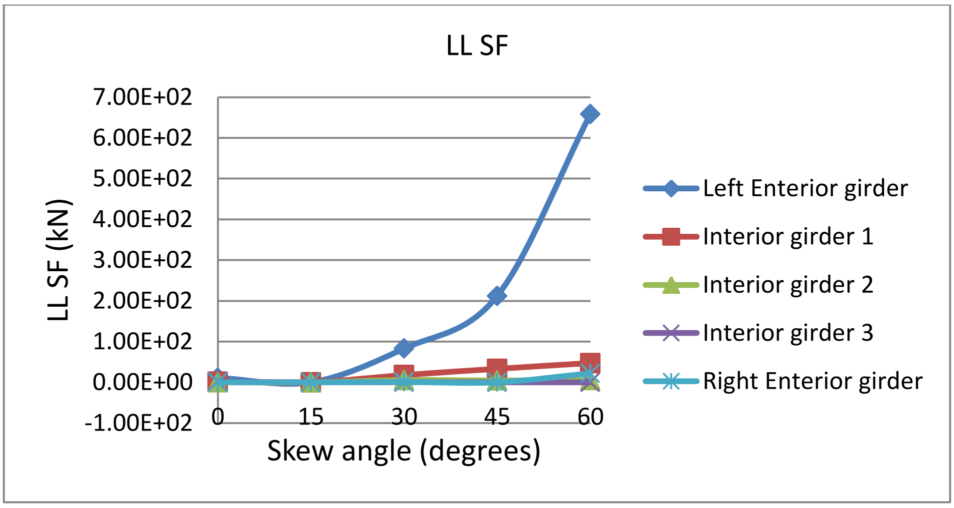

Figure 13: Skew angle vs live load shear force

Table 13: Live load Torsion

Skew Angles	Left Exterior girder	Interior girder 1	Interior girder 2	Interior girder 3	Right Exterior girder
0	3.99E+00	1.26E+01	2.61E+01	8.13E+01	3.37E+01
15	18.1164	28.8282	25.5036	58.0043	29.4462
30	85.5294	68.7639	57.0177	63.7144	55.6945
45	177.3805	107.5894	71.0518	49.0096	156.625
60	275.9403	201.038	178.9942	141.694	315.8783

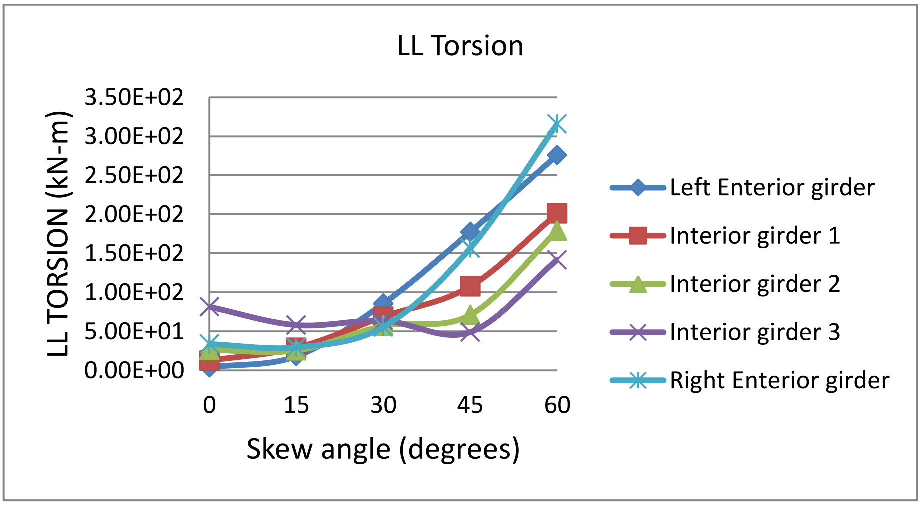

Figure 14: skew angle vs live load torsion

The variation of torsional moment is as shown in figure 14, as skew angle increases effect of torsional moment comes into account. The class 70R and class A loadings are placed centrally and moved over the span in this study. Live load torsional moment increases with the increase in skew angle. It can be concluded that the maximum torsion in I-girder skew bridge is noticed compared to that of straight bridges as the skew angle increases.

7. CONCLUSIONS

This summarizes the conclusion of this study on effect of skew on the behaviour of girder bridge analysis. Scope for future work also suggested in this chapter.

Following are the major conclusions

1) A literature review was completed in this project to summarize the behaviour of skew bridges, analysis and research. The research is mainly focused on the bending moment, shear force and Torsion analysis in skew bridges.
2) Analysis results have played a critical role in the FEA modelling to development of analysis guidelines for the design of the girder in particular and bridge in as a whole.
3) The maximum bending moment decreases with increase in skew angle for dead load cases and maximum moment due to live load increases as the skew angle increases.
4) The torsional forces will be maximum as the skew angle increases and this will affect the design of the girder as compared to the girder in non-skew bridge.
5) The finite element analysis of the skew bridge predicts the very accurate behaviour which we may not get when the analysis using any other standard method do.

8. SCOPE FOR FURTHER WORK

1) The design of the girder considering the skew effect can be taken up using the present limit state method.
2) The design of the Cast-in-situ deck slab can be taken up considering the skew effect using the resent limit state method.
3) Also the substructure design for the skew bridges can be taken up.
4) Study of the Skew effect on the design box girder bridges may also be consider

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