EFFECT OF SKEW ON THE BEHAVIOUR OF STEEL-CONCRETE I-GIRDER BRIDGE

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***Abstract** - Numerous bridges are skewed due to geometry and geography and their performance and conforming analysis has to be advanced to absolutely complete analysis objectives. This work has used a tactic of comprehensive finite element analysis to comprehend the performance of skew bridges. This thesis engrossed on the effect of skew on the behaviour of composite girder bridges. To study the Bending moment, Shear force and Torsional impact on skew bridge. The skew angles considered were 0°, 20° and 40° with span length of 36m. The skew bridges have been modelled and analysed through CSIBridge software. Results of skew bridges are compared with non-skew bridges. Ultimate limit state design is carried out in the design process referring to IRC codes.*

Keywords: Analysis, Bridges, Composite, Design, Finite Element, Models, Skew, Dead loads, Live loads, Girders.

1. INTRODUCTION

A bridge is a structure built on two or more supports over physical obstacles such as obstruction due to hills or important structures, depression and crossing water body or valley or road for the purpose of providing a passage over the obstacles. Steel-concrete composite skew bridge is a bridge structure in which the deck slab (cast-in-situ) is laid over the steel plate girders / box girders and shear connectors/shear studs are provided so as to provide integral action between deck slab and steel girders. Thus the composite action takes between concrete and steel girders. The steel and concrete act together in reducing deflections and increasing the strength and stiffness.

Several researches have been carried out experimentally as well as analytically to study the behaviour of skew bridges subjected to various type of loadings. Due to typical site conditions, skew bridges have become necessary to be studied and designed. In recent decades, to meet several requirements (such as natural and man-made obstacles and various intersections in mountain terrains) of highways and railways, skew bridges have been proposed.

The term 'skew angle' or 'angle of skew' is the difference between the alignments of end or intermediate support and the line square to longitudinal axis of the bridge. Or, the angle between line normal to center line of the bridge and the center line of the support (pier or abutment). This study focuses on the skew effect for the design parameters such as bending moment, shear force and torsion in a simply supported, 3-lane, steel-concrete composite I-girder bridge. As per bridge span and skew angle varies, the design parameters such as bending moment, shear force and torsion also varies. This poses a great challenge to structural designers.

In this study, the effect of skew angle is studied on maximum bending moment, maximum shear force and torsion at critical sections. The span selected was 36 m for the skew angles 0°, 20° and 40° respectively. Skew angle 0° is considered to be a non-skew bridge i.e., a straight bridge.

2. OBJECTIVES AND SCOPE

1) To study the various kinds of loads and load patterns.
2) To study the skew behaviour of steel-concrete composite I-girder bridge.
3) To study the deflection characteristic behaviour of the composite bridge.
4) To study bending moment, shear force and torsional effects due to the skew idea of extension of the bridges.
5) To compare effect of skew angles (0°, 20° and 40°) on the bridges.
6) To create design tools that help bridge designers to handle skew composite bridges effortlessly.
7) To propose a reasonable and effective finite element model.

3. AIM AND SCOPE OF WORK

This analytical study emphasizes on the study of skew effect on steel-concrete composite bridge which affects the bending moment, shear force and torsion. An attempt is made to articulate an adequate method of analysis. The present analytical effort is carried out to study the effect of skew angles on steel-concrete composite bridge performance.

4. METHODOLOGY

This proposition accounts for the behaviour of skew composite bridges are analysed and the results of CSI Bridge model subjecting it to various loads are tabulated. Three distinct instances of models with skew angles 0°, 20° and 40° with 36m span length and 12.9m width of composite section were considered.
The bridge structure was analysed for live loads and dead loads and the results have added to a remarkable conduct of skew angles based on ultimate loading conditions. The results were transferred to excel and additionally used in plotting charts of skew angle versus maximum and ultimate values of bending moment, shear force and torsion.

5. FINITE ELEMENT MODELLING

Finite element modelling is a technique of meshing a network of line elements connected by nodes within a material continuum. Finite element modelling is based on finite element method. Finite element analysis is the most adaptable method that can be used to model and analyse any structure (regular and irregular) of varying dimensions, any type of loadings and higher order elements.
FEM can be applied to various fields apart from structural engineering such as mechanical and aerospace engineer for heat transfers, liquid and aero-mechanic, electromagnetism, etc. FEM is useful for analyzing complicated structures such as bridges, buildings and other complicated structures subjected to both static and dynamic loadings

6. RESULTS AND DISCUSSIONS

This is the pace in which the analysis is performed to evaluate the effect of skew on the behaviour of steel-concrete I-girder Bridge, from the analysed model the results are obtained and presented in terms of structural parameters such as bending moment, shear force and torsion due to dead loads and live loads. Bridges of span 36m is analysed for skew angles 0°, 20° and 40°. From the analysis, bending moment, shear force and torsion diagrams are as follows.

6.1 ANALYSED MODELS

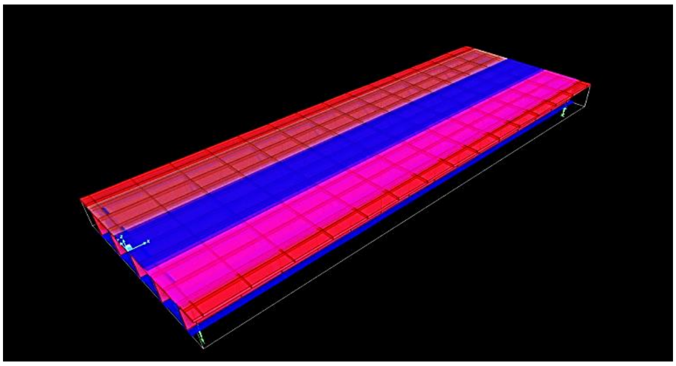

Fig -1: 3D model of 0° skew bridge

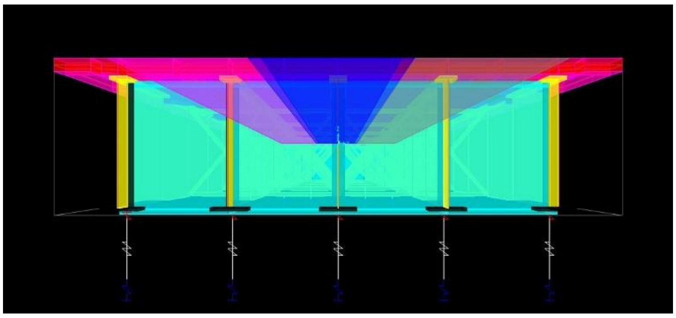

Fig -1: Cross-section of 0° skew bridge

6.2 Bending moment due to dead load

Table -1: Dead Load Bending Moment

Loading condition	Skew angles		
	0°	20°	40°
Dead load bending moment	1891.6238	1665.0318	1093.5824

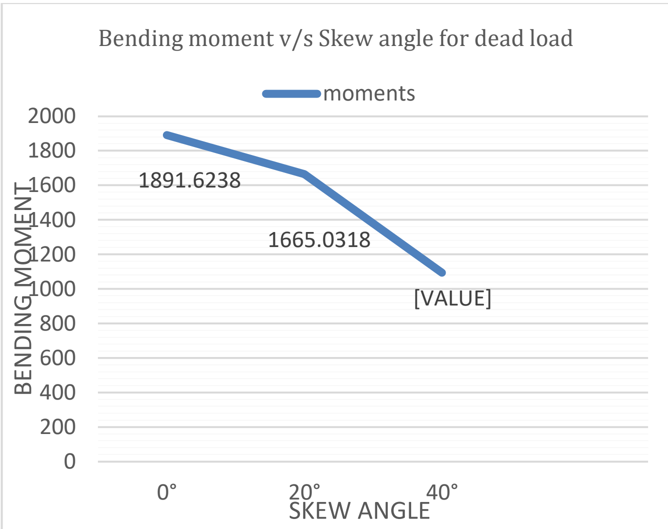

Chart -1: Dead load Bending Moment v/s Skew angle

The variation of dead load bending moment for varying skew angles of 0°, 20° and 40° are represented in chart-

1.It can be seen that as the skew angle builds, dead load bending moment will diminish. The dead load bending moment will also depend on the span of the bridge.

6.3 Bending Moment due to Live Load

Table -2: Live Load Bending Moment

Vehicular live loads	Skew angles		
	0°	20°	40°
3 CLASS A	1033.098	959.1523	689.3017
CLASS A + CLASS 70R	1051.985	977.4887	728.8977
Special vehicle	1800	1602.784	1047.516

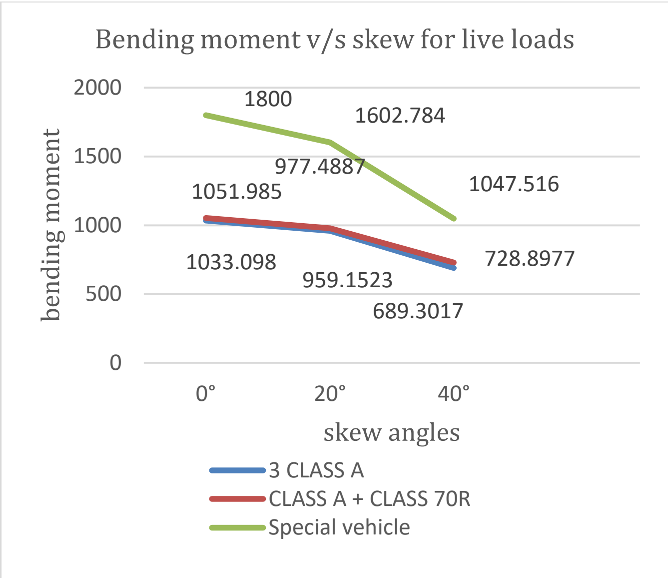

Chart -2: Live load Bending Moment v/s Skew angle

The variation of live load bending moment for varying skew angles of 0°, 20° and 40° for different vehicular classes are represented in figure 5.7 and tabulated in chart-2. It can be seen that as the skew angle inclines, live load bending moment will decline. The live load bending moment will decrease from 0° to 20° steadily (or nearly same) but at 40°, the max bending moment reduces quickly compared to other two cases. This is due to the skew effect.

6.4 Shear force due to Dead load

Table -3: Dead Load Shear Force

Loading condition	Skew angles		
	0°	20°	40°
Dead load shear force	216.0125	202.826	162.316

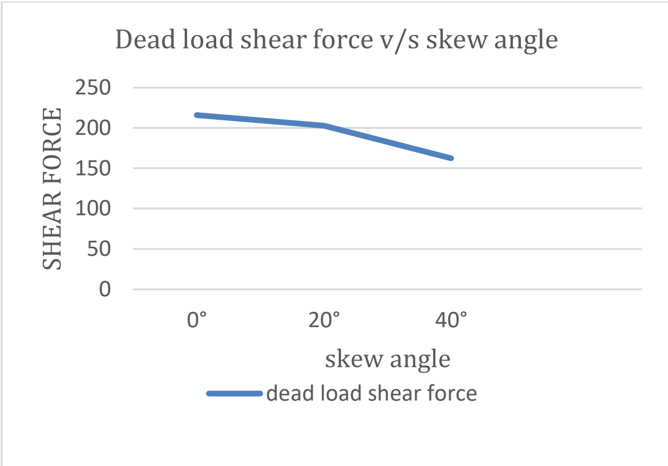

Chart -3: Dead load Shear Force v/s Skew angle

Chart-3 represents the effect of skew angle on dead load shear force of the bridge. As the skew angle increases, dead load shear force decreases. The shear force was found to be maximum for 0°. The values are tabulated in table-3.

6.5 Shear Force due to Live Load

Table -4: Live Load Shear Force

Vehicular live loads	Skew angles		
	0°	20°	40°
3 CLASS A	118.261	111.358	97.757
CLASS A + CLASS 70R	114.629	106.376	96.009
Special vehicle	204.325	189.221	155.017

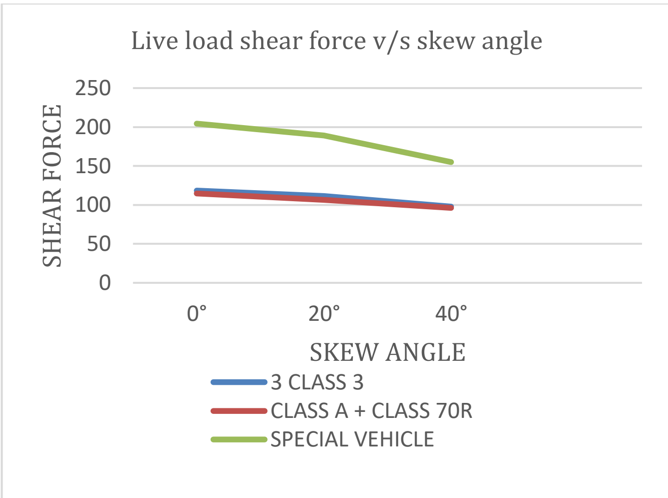

Chart -4: Live load Shear Force v/s Skew angle

Variation of live load shear force with varying skew angles and for different skew angles are tabulated in table -4 and represented using graphs in chart -4. As the skew angle increases from 0° to 40°, maximum live load shear force decreases.

6.6 Torsion due to Dead load

Table -5: Dead Load Torsion

Loading condition	Skew angles		
	0°	20°	40°
Dead load torsion	0	1.785	5.346

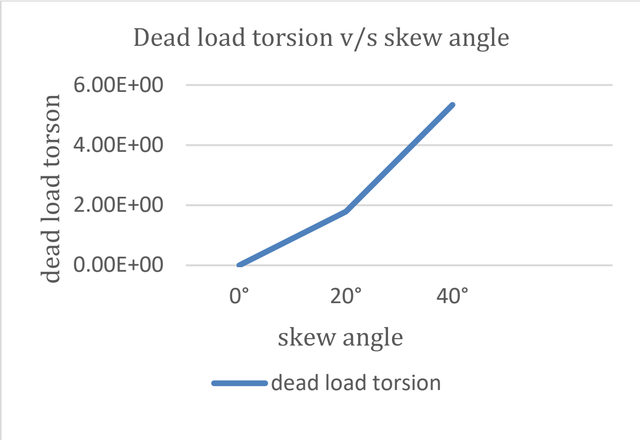

Chart -5: Dead load Torsion v/s Skew angle

The effect of skew angle on dead load torsion is represented using a graph in chart -5 from the tabulated values from table -5. Dead load Torsion increases as skew angle increases. It can be seen from the values that at 0°, the torsion is negligible. And increases for a very small value for 20° and 40°.

6.7 Torsion due to Live load

Table -6: Live Load Torsion

Vehicular live loads	Skew angles		
	0°	20°	40°
3 CLASS A	0	18.849	52.62
CLASS A + CLASS 70R	131.45	129.76	149.25
Special vehicle	61.31	65.27	149.25

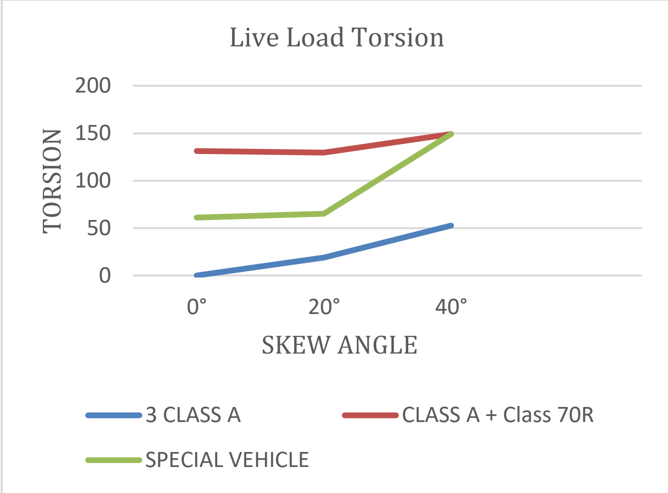

Chart -6: Live load Torsion v/s Skew angle

The variation of skew angle for varying skew angles is tabulated in table-6 and represented using a graph in chart-6. It can be seen that maximum live load torsion increase with increasing skew angle. The variation is nearly linear in case of 3 CLASS A vehicle and CLASS A + CLASS 70R combination. But for special vehicle, from 20° to 40° the torsion suddenly increases from 65.27 KN to 149.25 KN. The torsion due to live load was found to be maximum in case of CLASS A + CLASS 70R.

6.8 Ultimate bending moment v/s skew angle

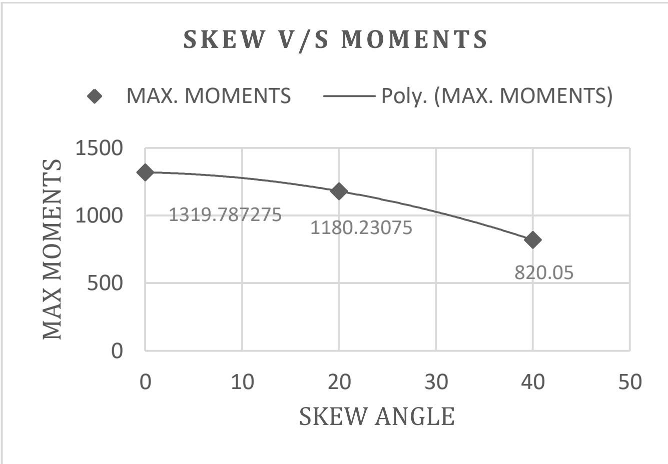

Chart -7: Ultimate Bending Moment v/s Skew angle

The effect of skew angle on ultimate bending moment due to the combined dead load and live load is represented in the plot of chart-7. The plot shows that the ultimate bending moment drops as skew angle increases in a parabolic form. The values obtained are – 1319.78 KN-m for 0° skew, 1180.23 KN-m for 20° skew and 820.05 KN-m for 40° skew.

6.9 Ultimate shear force v/s skew angle

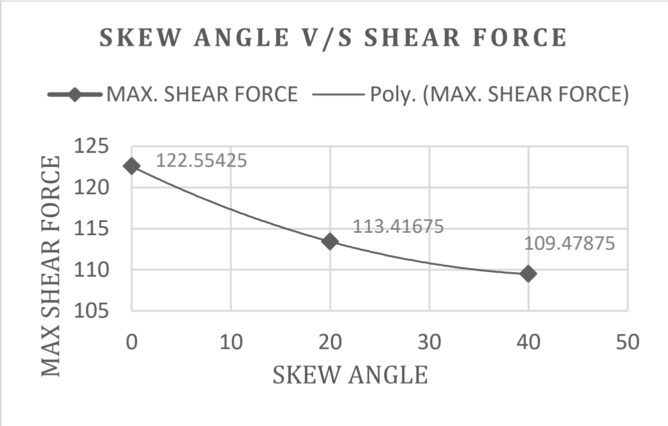

Chart -8: Ultimate Shear force v/s Skew angle

The effect of skew angle on ultimate shear force due to the combined dead load and live load is represented in the chart-8. The plot shows that the ultimate shear force value shrinks as skew angle value expands. The obtained values are – 122.55 KN for 0° skew, 113.41 KN for 20° skew and 109.47 KN for 40° skew.

6.10 Ultimate Torsion v/s skew angle

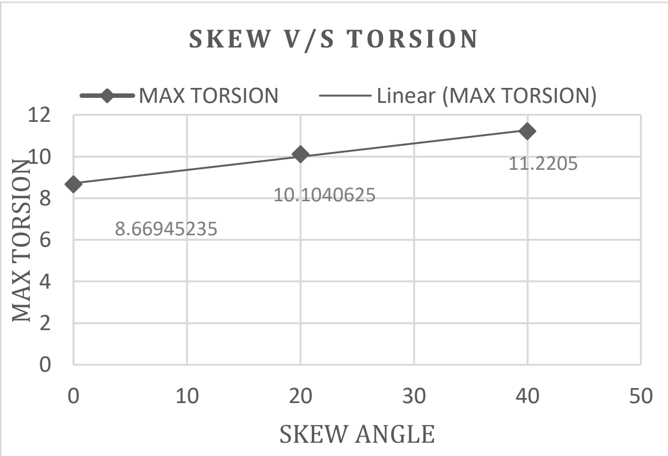

Chart -9: Ultimate Torsion v/s Skew angle

The effect of skew angle on ultimate torsional moment due to the combined dead load and live load is represented in the chart-9. The plot shows that the ultimate torsional moment builds up linearly as skew angle value rises. The obtained values are – 8.66 KN-m for 0° skew, 10.10 KN-m for 20° skew and 11.22 KN-m for 40° skew.

7. CONCLUSION

The main conclusions drawn from this study of the effect of skew angle on bending moment, shear force & torsion with various loading condition as per IRC: 6-2016 are explained below:

1) This study primarily concentrated on appraisal of ultimate values of bending moment, shear force and torsion in bridges of varying skew angles at critical sections.
2) The analysis results obtained have confirmed that the role of finite element model (FEM) in studying the effect due to skew angles in bridges and the design of I-Girder is an important process.
3) In general, Bending moment & Shear force for dead & live loading conditions decreased with increasing skew angle.
4) But the value of torsion increased with the increase in skew angle of the bridge. Hence, this is an important phenomena which cannot be neglected and it governs design.
5) The accuracy of the analysis of skew bridges using finite element analysis may not be obtained from conventional methods. From the analysis results, it is found that the values are very accurate and the use of FEM analysis is justified.

8. SCOPE OF FURTHER STUDY

1) The study can be further studied for various girder sections such as – concrete box girder, precast concrete 'I' and 'U' girders, steel 'U' girder, concrete tee beam and concrete solid girder.
2) Also for continuous bridges and cantilever portions of the bridge, the study can be taken up as a separate study.
3) Design of sub-structure and foundation related to such bridges can also be taken up.
4) The design procedure can also be studied for serviceability method including fatigue analysis.

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