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EFFECT OF SKEWNESS ON GIRDER BRIDGES

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ABSTRACT: *With the rapidrate of urbanization and infrastructure growth in India, the need for complex transportation systems has also increased. There are many situations where it is necessary to provide skew bridges on highways.The effect of force flow produced in skew bridges due to various loadings such as vehicular load, wind load etc.is more complex than in the straight bridges.This paper aims to analyze thebehavioral aspects of skew bridges using CSIbridge software. Severalmodels have been made with varying skew angles and the effect of skew angle is studied on various design parameters such as maximum bending moment and maximum shear force, obtained by applying loads as per IRC 6:2000guidelines. For this study the skew angleshave been varied from 0°to 50° at intervals of 10° and the result obtained are compared with straight bridge model.*

Keywords:*Bridge, Skew Bridge, Skew Angle, IRC AA Wheeled, CSI Bridge Software, Bending Moment, Shear*

I. INTRODUCTION

Skewed bridges are often encountered in highway design when the geometry cannot accommodate straight bridges.A skew bridge is one whose longitudinal axis i.e the direction of flow of traffic is not perpendicular to the axis of the support or abutment. The skew angle can be defined as the angle between the normal to the centerline of the bridge and the centerline of the abutment or pier cap.The effect of force flow produced in skew bridges due to various loadings such as vehicular load, wind load etc. is more complex than in the straight bridges.

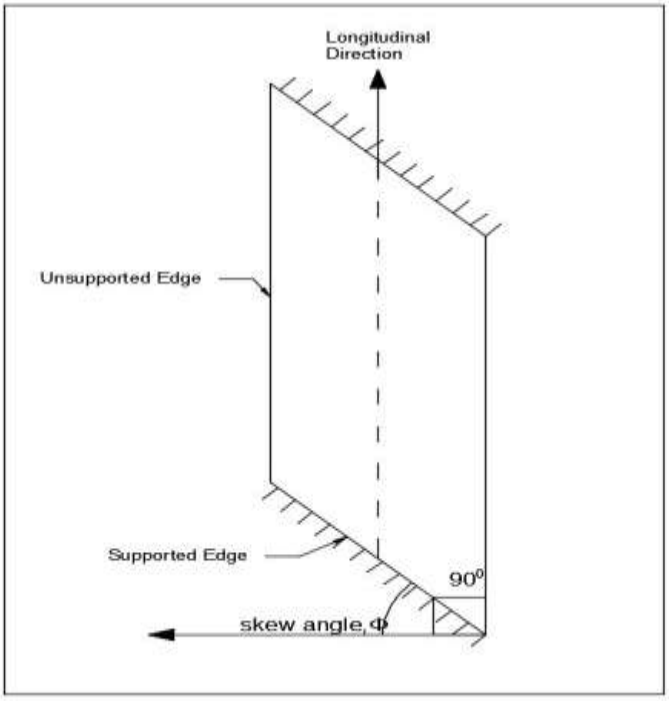


Figure1- Sketch of Skew Bridge

II. SCOPE OF THE PRESENT STUDY

Skew bridges are common at highways; the analysis and design of skew bridges are much more complicated than those for a right bridge. There are no detailed guidelines addressing the performance of skewed highway bridges. Therefore, there is a need for more research to study the effect of skew angle on the performance of highway bridges.

III. OBJECTIVE OF THE PRESENT STUDY

The present work is carried out tostudy the behavior of skew girder bridge, on design parameters such as maximum bending moments and maximum shear forces by considering IRC class AA Wheeled loading. Several models have been made with varying angle skew angle varied from 0° to 50° at an interval of 10° using CSIBridge software. The results are demonstrated and compared with straight bridge using graph.

IV. LITERATURE REVIEW

Khaleel et al., (1990) evaluated a method for determiningmoments in continuous normal and skew slab-and-girderbridges due to live loads. **Menassa et al. (2007)** compared theeffect of skew angle with reference to straight bridge andreported that the bridges with skew angle less than 20°can be designed as non skew as the moments are almost samefor both. **VikashKhatri et al. (2012)** compared grillagemethod and finite element method of analysis andrecommended the use of FEM because of closes agreementwith the exact solution. **Patrick Theoret et al., (2012)** studiedthe bending moments and shear forces, required to designskewed concrete slab bridges.**Sindhu B.V et al. (2013)** performed his research study oneffect of skew angle on static behavior of reinforced concrete slab bridge decks where he conclude that For right bridge deck slabs (0° skew), maximum torsional moments are located near all corner regions and as skew angle increases torsional moments have also increased gradually.

V. MODELLING

5.1 Geometrical Properties:

A four lane RC girder bridge deck is considered. The span of the bridge is 72 m and skew angle is varied from 0° to 50° at 10° interval is considered.The bridge deck is analyzed for Dead load as well as live load i.e. IRC AA wheeled loading.

Size of abutment	4m(depth)x2m(width)
Size of bent	2m(depth)x1.6m(width)
Height of pier	8m
Diameter of pier	1.6m
Thickness of slab	200 mm

Table1- Geometrical property

5.2 Material Properties:

The material property of concrete and steel are tabulated in table 2.

Concrete Grade	M40
Steel Grade	Fe415
7Density Of Concrete	25 KN/m^3
Young's Modulus (Conc.)	31622.777 N/mm^2
Young's Modulus (Steel)	200000 N/mm^2

Table2- Material property

5.3 Girder Dimension:

Precast I girder is used for this study. The salient dimensions of the girders of the bridge are shown in figure 2.

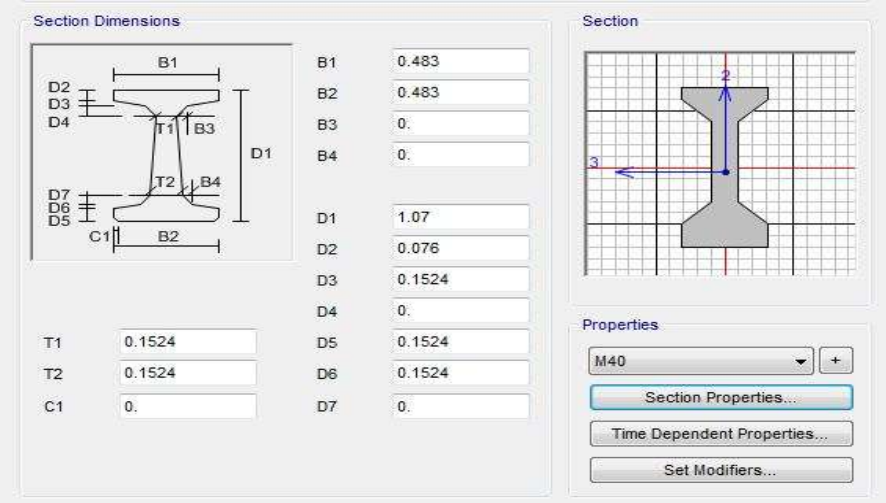


Figure2- Girder dimesion

5.4 ModelSection Views:

The model section views in figures 3 to 8, display the variation of skewness from 0° to 50°.

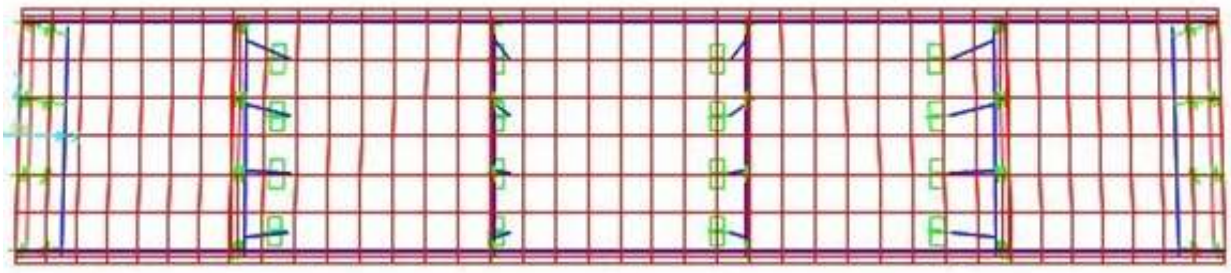


Figure3- Straight Bridge Section

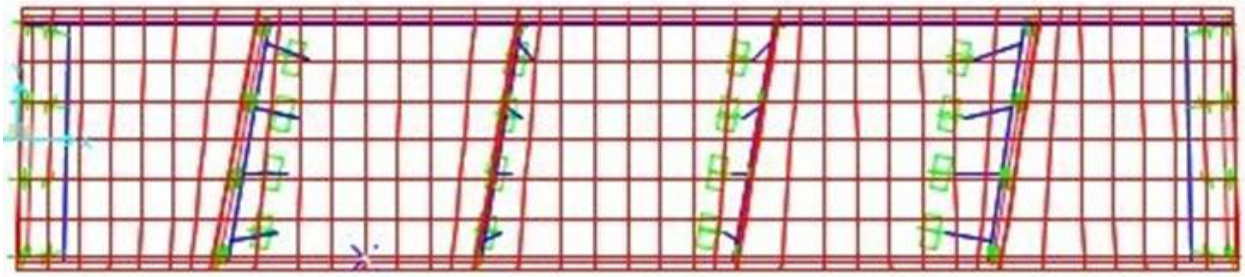


Figure4- 10° Skew bridge section

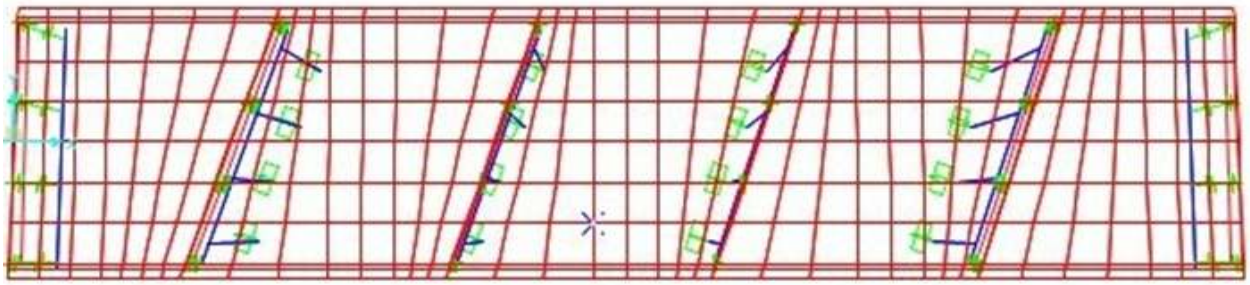


Figure5- 20° Skew bridge section

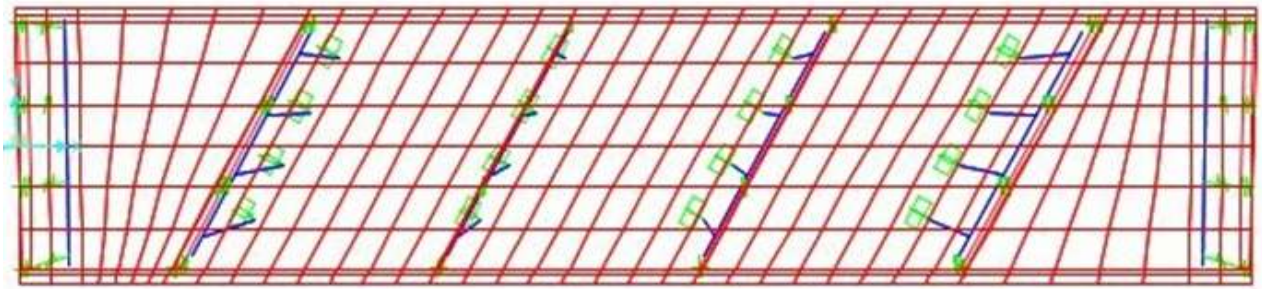


Figure6- 30° Skew bridge section

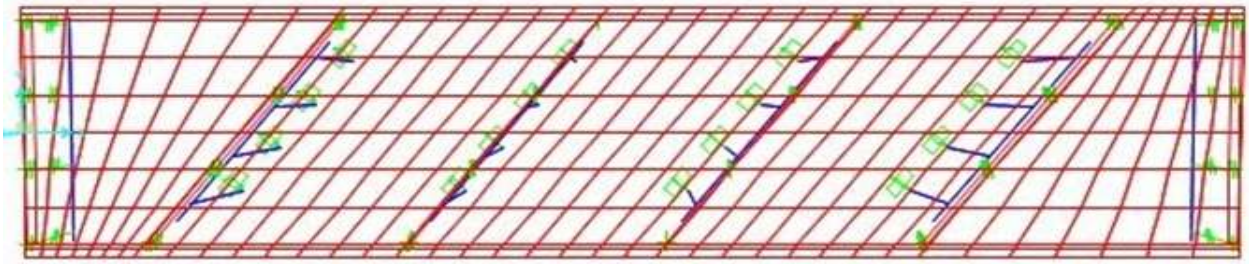


Figure7- 40° Skew bridge section

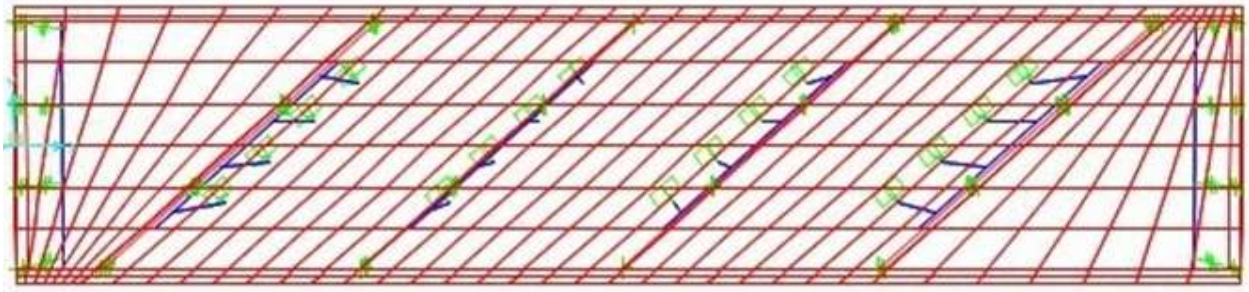


Figure8- 50° Skew bridge section

5.6 Bridge Section Data:

The details of bridgesection data areshown in figure 9.

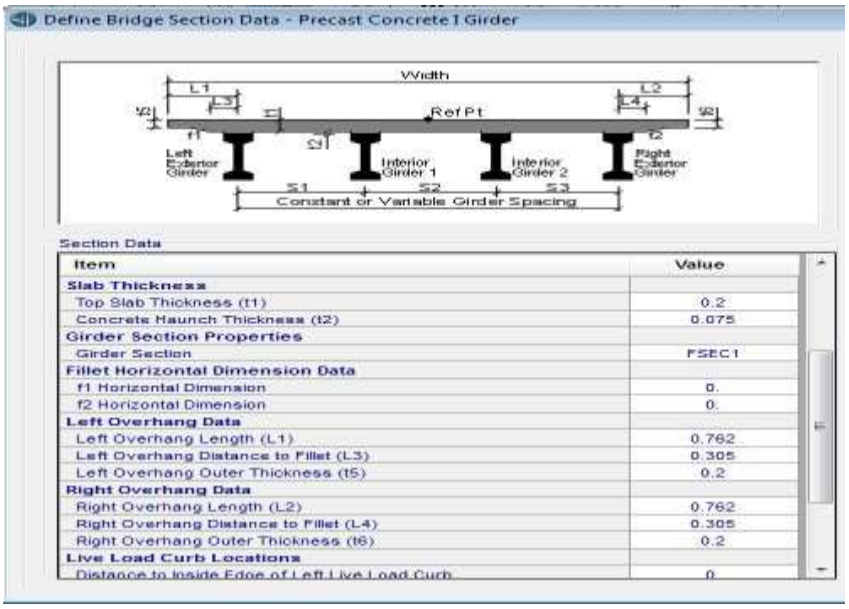


Figure9- Bridge Section Data

5.7 Load On Bridge Deck Models:

The vehicular live load consisting of a wheel load of class IRC AA wheeled is considered for analysis. The peak values of critical structural response parameter such as bending moment, and vertical shear are analyzed. Different load combination as per code:

- 1.35D.L+1.5M.L
- 1.05D.L+1.5M.L
- 1D.L+0.2M.L
- 1D.L+0.75M.L
- 1D.L+1.5M.L
- 1D.L+1M.L

For this present study, load combination of (1.35D.L+1.5M.L) has been taken due to the maximum value of different parameters.

VI. RESULTS AND DISCUSSION

The results are obtained and presented in terms of critical structural response parameter such as bending moment about horizontal axis and vertical shear in the bridge deck models due to the applied wheel load. The variations of the critical structural response parameter due to changes in skew angle are shown in table 3 to 6 and graph 1 to 2.

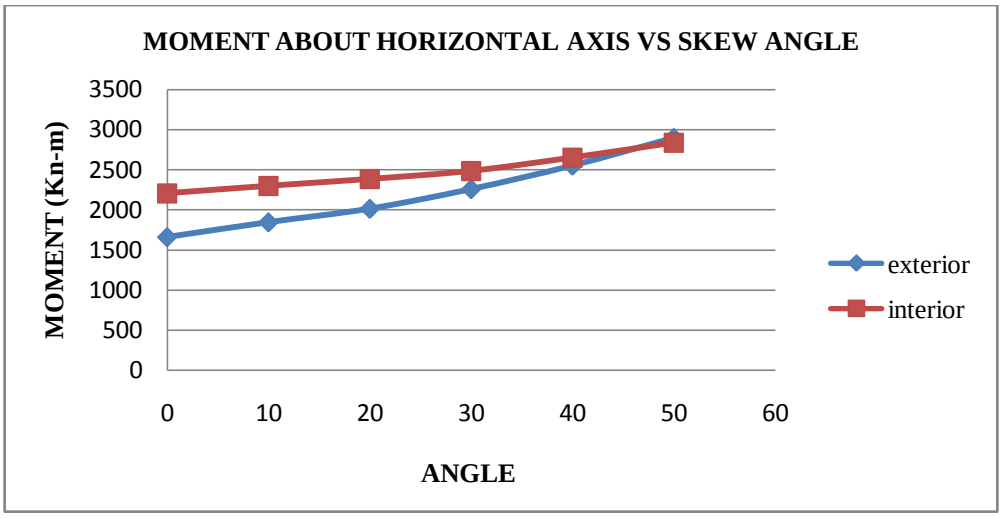
Variation of bending moment about horizontal axis and vertical shear:
The parametric study to know bending moment about horizontal axis and vertical shear & in case of all models is performedhere. The results are shown in table 3 to 6& in graph 1 to 2 which are listed below. In Table 3 and graph 1, it is observed that as the skew angle increases the B.M has also increased in both exterior and interior girder. From Table 4 and graph 2, the vertical shear is started increasing with varying angle on both exterior and interior girder. Table 5 and Table 6 shows the percentage increase in B.M and vertical shear for exterior and interior girder at different skew angles with respect to the straight bridge.

6.1 Bending Moment:

The variation of bending moment about horizontal axis for both exterior and interior girder due toskewness of the bridge are shown in table 3 and graph 1.

ANGLE	MOMENT ABOUT HORIZONTAL AXIS (KN-m)	
	EXTERIOR GIRDER	INTERIOR GIRDER
0°	1661.63	2206.462
10°	1846.211	2299.175
20°	2014.427	2384.896
30°	2258.626	2486.161
40°	2551.666	2652.695
50°	2896.282	2838.554

Table3- Bending Moment On Exterior & Interior Girder For Different Skew Angles



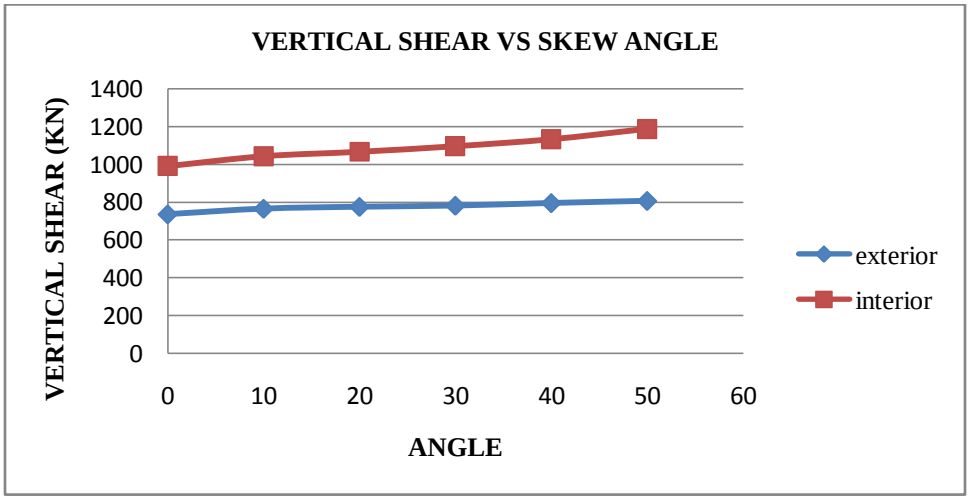
Graph1- Bending Moment On Exterior & Interior Girder For Different Skew Angles

6.2 Vertical Shear:

The variation of vertical shear for both exterior and interior girder dueto skewness of the bridge are shown in table 4 and graph 2.

ANGLE	VERTICAL SHEAR (KN)	
	EXTERIOR GIRDER	INTERIOR GIRDER
0°	734.694	990.753
10°	764.382	1042.512
20°	774.272	1065.832
30°	780.608	1095.054
40°	794.494	1131.545
50°	805.999	1186.132

Table4- Vertical Shear OnExterior & Interior Girder For Different Skew Angles



Graph2- Vertical Shear On Exterior & Interior Girder For Different Skew Angles

6.3 Percentage Increase In Bending Moment On Exterior & Interior Girder For Different Angles:

The percentage increase in bending moment for different angles on exterior and interior girder are shown in table5.

ANGLE	% INCREASE IN BENDING MOMENT	
	EXTERIOR	INTERIOR
0°	----	----
10°	11.1084	4.20185
20°	21.232	8.08688
30°	35.9284	12.6764
40°	53.564	20.2239
50°	74.3036	28.6473

Table5- Percentage Increase In Moment

6.4 Percentage Increase In Vertical Shear On Exterior & Interior Girder For Different Angles:

The percentage increase in vertical shear for different angles on exterior and interior girder are shown in table6.

ANGLE	% INCREASE IN VERTICAL SHEAR	
	EXTERIOR	INTERIOR
0°	----	----
10°	4.04	5.22
20°	5.39	7.58
30°	6.25	10.5
40°	8.14	14.2
50°	9.71	19.7

Table6- Percentage Increase In Vertical Shear

VII. CONCLUSION

1) The behavior of a girder bridge of constant length is analyzed using CSI bridge software and studied for varying skewangles. Parameters like Shear force and horizontal bending moments on exterior and interior girders along with the percentage increase with respect to straight bridge are investigated. The analysis of bridges and comparisons of the results of different skew angles have led to the following conclusions.
2) Bending moment increases for both exterior and interior girders, as the skew angle increases from 0° to 50° under dead load and moving load. Thus, due to net effect, maximum horizontal bending moment in interior girder is more than the exterior girder as we increase the skew angle.
3) The percentage increase in bending moment on exterior and interior girder for 50° skew angle are 74.3036% and 28.6473% respectively.
4) The value of maximum vertical shear in both exterior and interior girder increases with increase in skew angle. Considerable variations are observed in results for skew angles more than 20°.
5) The percentage increase in bending moment on exterior and interior girder for 50° skew angle are 9.71% and 19.7% respectively.

6) The percentage increase in BM and vertical shear with respect to straight bridge is less up to 20 degree skew angle. At higher skew angle sharp increase is observed.
7) It is also observed that, skew angle up to 20° do not affect the design values considerably for skew bridges. For higher skew angles, analysis results must be taken into account while designing skew bridges.
8) It is observed that both vertical shear and horizontal bending moment follows the same trend i.e value of shear and bending moment increases as the skew angle is increased.

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