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STUDY OF TORSION AND DISPLACEMENT ON SKEW GIRDER BRIDGES

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ABSTRACT:*The presence of skewness in a bridge makes the analysis and design of bridge decks complex one. The angle of skew has a considerable effect on the behavior of the bridge. Therefore, there is a need for more research to study the effect of skew angle on the performance of skew bridges.Several models have been made with varying skew angles and the effect of skew angle is studied using CSI bridge software. This paper summarizes the result of series of loading applied on skew girder bridges as per IRC 6:2000guidelines to access peculiar aspects in maximum torsional moment and maximum displacement. For this study the skew angles have 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, Torsion, Displacement*

1. INTRODUCTION

With the rapid rate 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.Skew bridges are common at highways, river crossing and other extreme grade changes when skewed geometry is necessary due to limitations in space. 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. 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. For bridges with small skew angle, it is frequently considered safe to ignore the angle of skew and analyze the bridge as a right bridge. However, bridges with large angle of skew can have a considerable effect on the behavior of the bridge especially in the short to medium range of spans.

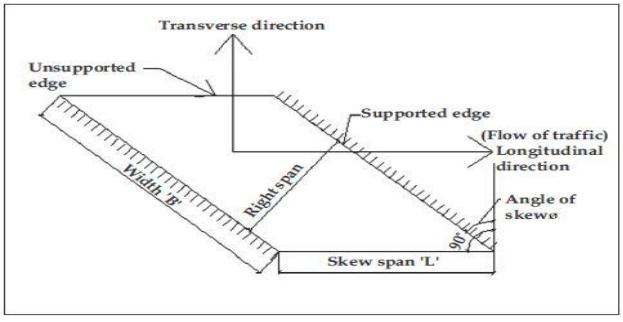


Figure1- Skew Bridge Model View

2. SCOPE OF THE 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.

3. OBJECTIVE OF THE STUDY

The main objective of this study is to develop practical and reasonably accurate design guidelines for estimating the variation of the skew angle for vehicular loads. This study also investigates the behavior of skew girder bridge, on design parameters such as maximum torsional moments and maximum displacements 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 CSI Bridge software. The results are demonstrated and compared with straight bridge using graph.

4. LITERATURE REVIEW

Khaleel et al., (1990) evaluated a method for determining moments in continuous normal and skew slab-and-girder bridges due to live loads. **Menassa et al. (2007)** compared the effect of skew angle with reference to straight bridge and reported that the bridges with skew angle less than 20°can be designed as non skew as the moments are almost same for both. **VikashKhatri et al. (2012)** compared grillage method and finite element method of analysis and recommended the use of FEM because of closes agreement with the exact solution. **Patrick Theoret et al., (2012)** studied the bending moments and shear forces, required to design skewed concrete slab bridges. **Sindhu B.V et al. (2013)** performed his research study on effect 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.

5. MODELLING

a) Geometrical Properties:

A four lane RC girder bridge deck is considered. The span of the bridge is 72 m with a slab thickness of 200mm.The size of the abutment is 4m by depth and 2m by width. Height of the pier is 8m with a diameter of 1.6m. 4 nos. of bents of size 2m×1.6 m are provided at a c/c distance of 14.6m from the abutment. For each model, the model configuration is kept same, only skew angle is changed from 10° to 50°. The bridge deck is analyzed for Dead load as well as live load i.e. IRC AA wheeled loading.

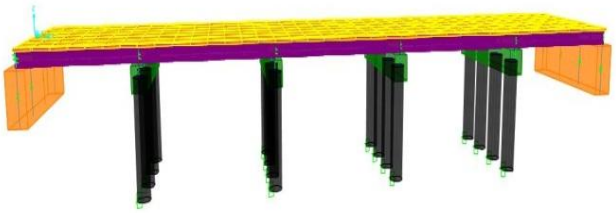


Figure2- Model View

b) Material Properties:

The material property of concrete and steel are tabulated in table 1.

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

Table1- Material property

c) Girder Dimension:

Precast I girder is used for this study. The salient dimensions of the girders of the bridge are shown in figure3.

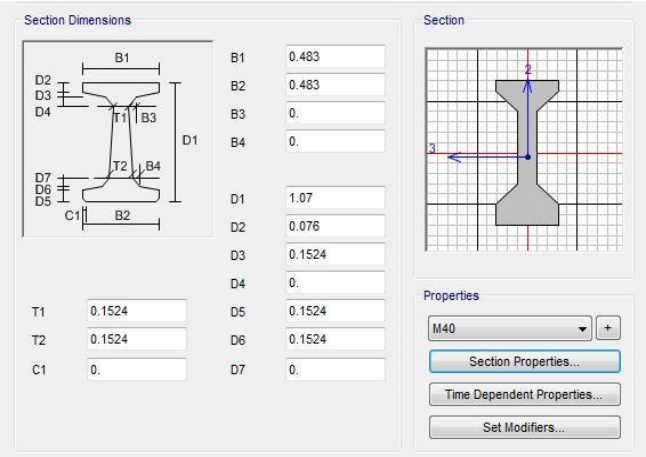


Figure3- Girder dimesion

d) Model Section Views:

The model section views in figures 4 to 9, display the variation of skewness from 0° to 50°.

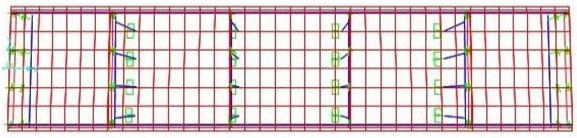


Figure4- Straight Bridge Section

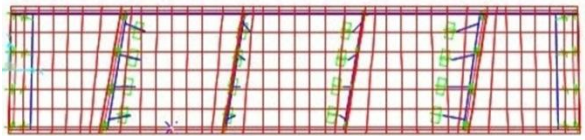


Figure5- 10° Skew bridge section

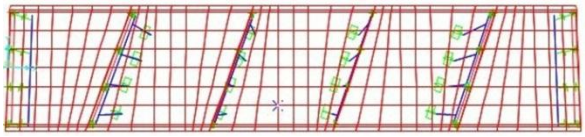


Figure6- 20° Skew bridge section

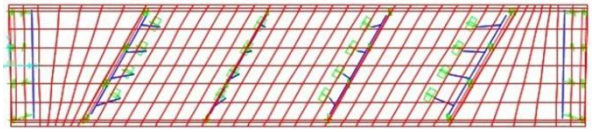


Figure7- 30° Skew bridge section

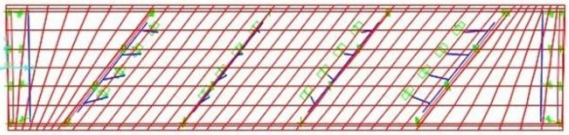


Figure8- 40° Skew bridge section

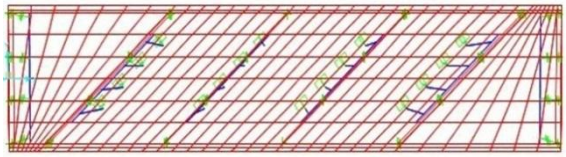
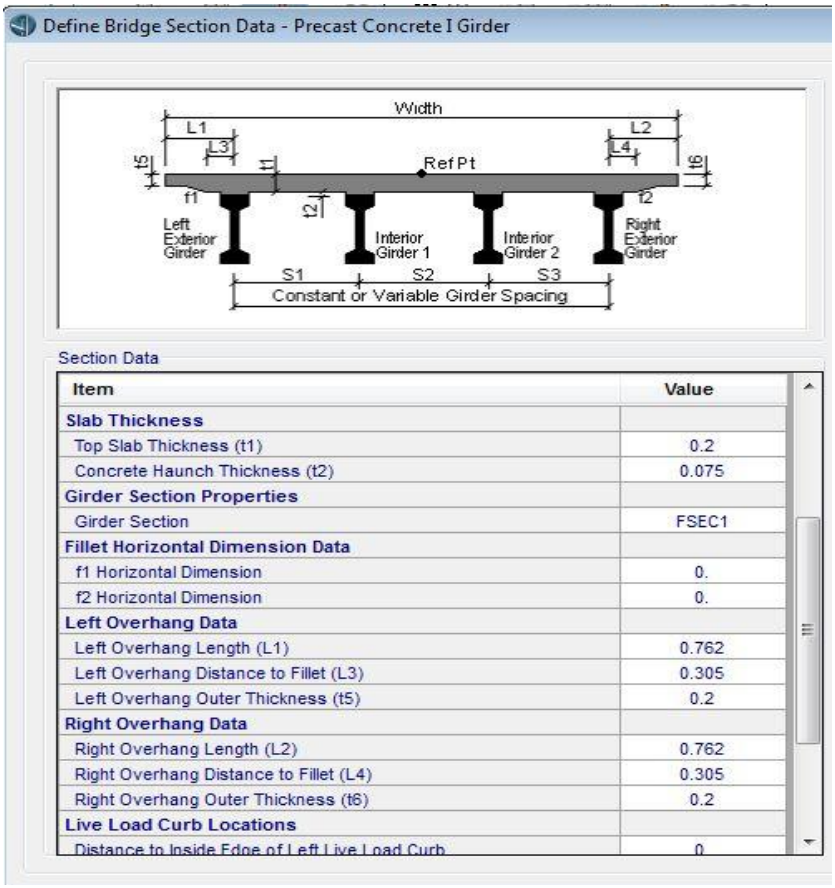


Figure9- 50° Skew bridge section

e) Bridge Section Data:

The details of bridge section data are shown in figure 10.



Item	Value
Slab Thickness	
Top Slab Thickness (t1)	0.2
Concrete Haunch Thickness (t2)	0.075
Girder Section Properties	
Girder Section	FSEC1
Fillet Horizontal Dimension Data	
f1 Horizontal Dimension	0.
f2 Horizontal Dimension	0.
Left Overhang Data	
Left Overhang Length (L1)	0.762
Left Overhang Distance to Fillet (L3)	0.305
Left Overhang Outer Thickness (t5)	0.2
Right Overhang Data	
Right Overhang Length (L2)	0.762
Right Overhang Distance to Fillet (L4)	0.305
Right Overhang Outer Thickness (t6)	0.2
Live Load Curb Locations	
Distance to Inside Edge of Left Live Load Curb	0

Figure10- Bridge Section Data

f) Load On Bridge Deck Models:

The vehicular live load consisting of a wheel load of class IRC AA wheeled is considered for analysis. 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.

6. RESULTS AND DISCUSSION

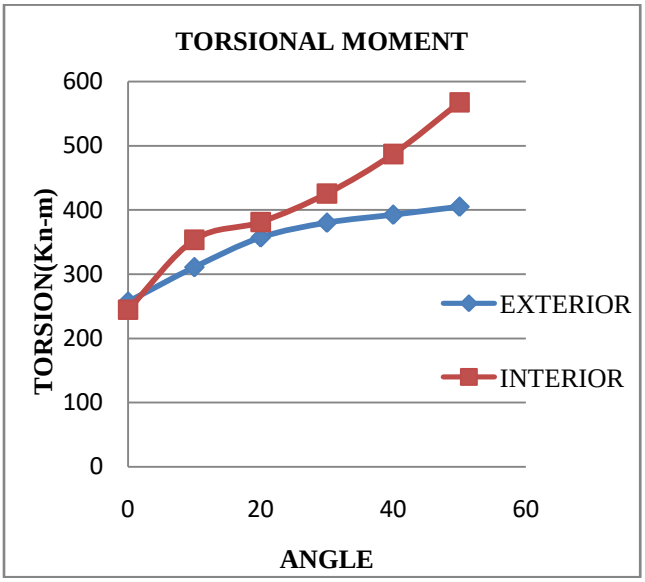
The results are obtained and presented in terms of critical structural response parameter such as torsional moment and transverse displacement in the bridge deck models due to the applied wheel load. The parametric study to know torsional moment andtransverse displacement& in case of all models is performed here. The results are shown in table 2 to 5& in graph 1 to 2 which are listed below. In Table 2 and graph 1, it is observed that as the skew angle increases the torsional momenthas also increased in both exterior and interior girder. From Table 3 and graph 2, the vertical shear is started increasing with varying angle on both exterior and interior girder. Table 4 and Table 5shows the percentage increase in torsional moment andtransverse displacement for exterior and interior girder at different skew angles with respect to the straight bridge.

a) Torsional Moment:

The variation oftorsional moment for both exterior and interior girder due to skewness of the bridge are shown in table 2 and graph 1.

ANGLE	TORSIONAL MOMENT (KN-m)	
	EXTERIOR GIRDER	INTERIOR GIRDER
0°	257.1159	244.7926
10°	310.8394	353.616
20°	357.1472	381.2755
30°	380.1518	425.7226
40°	392.5695	487.2637
50°	405.0487	567.6181

Table2- Torsional Moment On Exterior & Interior Girder For Different Skew Angles



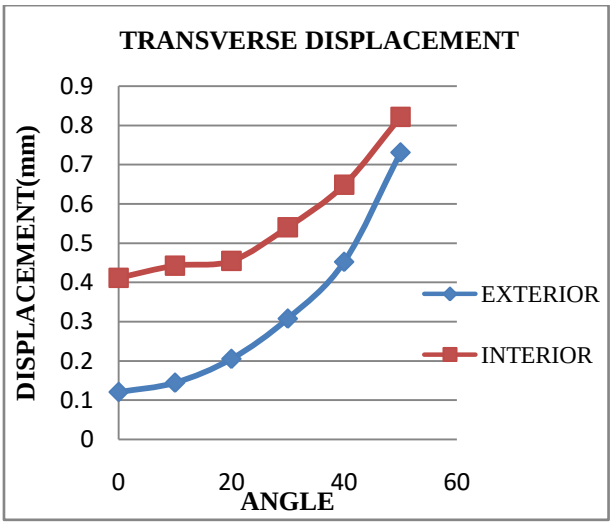
Graph1- Torsional MomentOn Exterior & Interior Girder For Different Skew Angles

b) Transverse displacement:

The variation of transverse displacement for both exterior and interior girder due to skewness of the bridge are shown in table3 and graph 2.

ANGLE	TRANSVERSE DISPLACEMENT (mm)	
	EXTERIOR GIRDER	INTERIOR GIRDER
0°	0.121208	0.411833
10°	0.145013	0.442787
20°	0.205688	0.454777
30°	0.308239	0.540976
40°	0.452867	0.649029
50°	0.733065	0.822204

Table3*- Transverse displacement *On Exterior & Interior Girder For Different Skew Angles



Graph2- Transverse Displacement On Exterior & Interior Girder For Different Skew Angles

c) Deformed Shape Of The Models:

The deformed shape of the modelsare displayed below from figures 11 to 16, for skew angle varies from 0° to 50°.

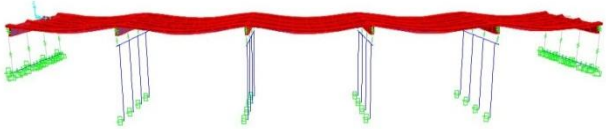


Figure11- 0° Skew bridge deformed shape

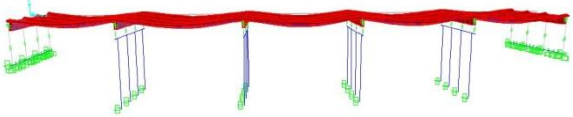


Figure12- 10° Skew bridge deformed shape

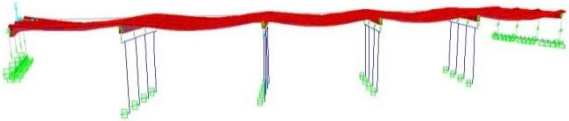


Figure13- 20° Skew bridge deformed shape

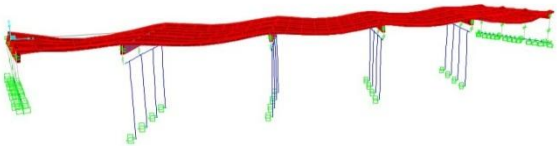


Figure14- 30° Skew bridge deformed shape

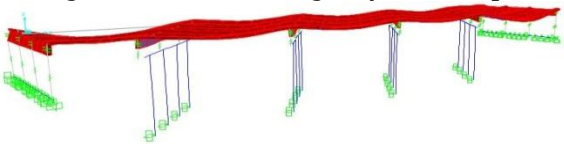


Figure15- 40° Skew bridge deformed shape

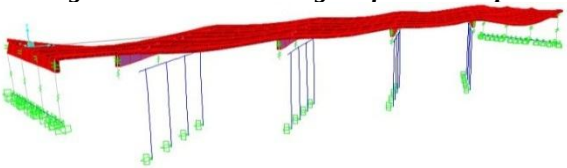


Figure16- 50° Skew bridge deformed shape

d) Percentage Increase In Torsional Moment On Exterior & Interior Girder For Different Angles:

The percentage increase in torsional moment for different angles on exterior and interior girder are shown in table4.

ANGLE	% INCREASE IN TORSIONAL MOMENT	
	EXTERIOR	INTERIOR
0°	----	----
10°	20.895	44.46
20°	38.905	55.75
30°	47.852	73.91
40°	52.682	99.05
50°	57.535	131.9

Table4- Percentage Increase In Torsional Moment

e) Percentage Increase In Transverse Displacement On Exterior & Interior Girder For Different Angles:

The percentage increase in transverse displacementfor different angles on exterior and interior girder are shown in table5.

ANGLE	% INCREASE IN TRANSVERSE DISPLACEMENT	
	EXTERIOR	INTERIOR
0°	----	----
10°	19.64	7.516153
20°	69.698	10.42753
30°	154.31	31.3581
40°	273.63	57.59519
50°	503.62	99.645

Table5- Percentage Increase InTransverse Displacement

7. CONCLUSION

Hence from the obtained results we conclude that the effect of torsional moment and transverse displacement are more in case of skew bridges which is analyzed using CSI bridge software.Presence of skew angle in the bridge influences more torsional moment and displacement. The values increase with increase in angle. The behavior of a girder bridge of constant length is analyzed using CSI bridge software and studied for varying skewangles. Parameters like torsional moments and transverse displacement 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:

a) Torsional moment increases for both exterior and interior girders, as the skew angle increases under dead load and moving load. Thus, due to net effect, maximum torsional moment in interior girder is more than the exterior girder.
b) The value of maximum transverse displacement in both girders increases with increase in skew angle. Considerable variations are observed in results for skew angles more than 20°.
c) The percentage increase in torsional moment on exterior and interior girder for 50° skew angle are 57.535% and 131.9% respectively.
d) The value of maximum transverse displacement in both exterior and interior girder increases with increase in skew angle. Considerable variations are observed in results for skew angles more than 20°.
e) The percentage increase in transverse displacement on exterior and interior girder for 50° skew angle are 503.62% and 99.645% respectively.
f) The percentage increase in torsional moment and transverse displacement with respect to straight bridge is less up to 20 degree skew angle. At higher skew angle sharp increase is observed.
g) 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.
h) It is observed that both torsional moment and transverse displacement follows the same trend i.e value of torsional moment& transverse displacementt increases as the skew angle is increased.

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