Influence of Skew Angles on Box Type Bridge

Nasir Ali, Himanshu Guleria, Himanshu Sharma

Abstract: In the present study, modeling and analysis of a three-lane three-span box bridge has been carried out by using finite element software STAAD pro v8i. The study has been executed to find the effect of skew angle on all bridge slabs (top slab, bottom slab, outer walls, inner walls) under various loads (dead load, live load, surfacing load, earth pressure, temperature and live load surcharge) and their combinations using IRC 6:2016. Skew angles taken for study ranges from 0\(^0\) to 70\(^0\) with an interval of 10\(^0\). Parameters that are mainly examined are longitudinal moments, transverse moments, torsional moments, shear forces and displacements. It has been observed that with the increase of skew angle all the parameters increases with the increase of skew angles in all slabs.

Keywords: Skew bridge, skew angle, moments, force, displacement

I. INTRODUCTION

In the present era, bridges can be attributed as life line of any country. With the availability of new techniques, there is a growing demand for skew bridges. The reason behind this surge are less availability of space especially in the urban areas, complex intersections at the places where roads cross obstructions like rivers, railway crossings, etc. at an angle other than 90\(^0\). Skew bridges are useful at the places where road alignment changes are not feasible and at the places where roads are constructed in the areas having different terrains [3]. Skew bridges help to maintain the alignment of the modern highways by negotiating the sharp curves which in turn makes the road construction economical and increases safety to the fast-moving vehicles.

The skew angle can be defined as the angle between the centerline of the traffic and abutments. Due to the presence of skew angle, both longitudinal, as well as transverse length increases in proportion to cosec \( \Theta \) where \( \Theta \) is the skew angle [3] (Figure 1).

Skew bridges up to an angle of 20\(^0\) show somewhat same behavior as that of normal bridges but the problem arises when the skew angle is more than 20\(^0\) various parameters like longitudinal moments, transverse moments, torsional moments, shear forces, etc. show different behavior. In the present study, behavior of three-lane box type skew bridge having skew angle ranging from 0\(^0\) to 70\(^0\) under different loads and combinations (dead load, superimposed dead load, surfacing, earth pressure, temperature load, live load, live load surcharge) as per IRC 6:2016 has been studied.

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Figure 1 Plan of skew bridge

II. MODELLING ON STAAD PRO

2.1 Software and its features

STAAD pro is a software developed by the research engineers international in 1997 and later brought by Bentley. The software is worldwide used for the design and analysis of structures like buildings, bridges, towers, and water plants for materials like concrete, steel, timber, and aluminum as it supports various codes of design. Both 2D and 3D structures can be analyzed and designed. It provides parameters like bending moment, shear force, torsional moment, deflection of any structure and variation of such parameters can show in post-processing.

2.2 Geometric dimensions of a bridge

For present study, the span of each box is 8 m and the width of the bridge is decided as per IRC 6:2016. Final plan and data of bridge model is shown in figure 2 and Table 1.2 respectively.
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Figure 2(a) Final plan of bridge

Figure 2(b) Transverse section of bridge

Table 1.2 Dimensions of bridge model

<table>
<thead>
<tr>
<th>S.NO</th>
<th>Parameters</th>
<th>Dimensions</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Thickness of top slab</td>
<td>0.7 m</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Thickness of bottom slab</td>
<td>0.75 m</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Thickness of outer walls</td>
<td>0.4 m</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Thickness of inner walls</td>
<td>0.35 m</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Clear span of boxes</td>
<td>8 m</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Number of boxes</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Clear height</td>
<td>5.025 m</td>
<td></td>
</tr>
</tbody>
</table>

2.3 Stepwise procedure to prepare model on Staadpro.v8i

- Double click on STAADpro.v8i icon
- A window will appear select new project
- Select space (as it is a 3D modal)
- Give file name and location of folder where you want to save
- Select length unit (m) and force unit (kN) and then click next
- New window will appear click add beam or add plate option and then click finish
- A window with data bar, tool bar, menu bar, text bar etc. will appear
- Select a node and then go to translational repeat, select the axis and give dimensions according to your modal and then ok repeat the process till your model is completed as shown in Figure 3 and 4.

III. STUDY OF LOADING

Code of practice for roads and bridges IRC 6:2016 provides following values for various loads [15]:

3.1 Dead load
Density of concrete for bridge members is taken as 25 kN/m³
Density of bitumen is taken as 22 kN/m³
Dead load calculations
Self-weight of structure is assumed as 1 with the density of 25 kN/m³
Weight of bitumen layer on bridge = density of bitumen X thickness of bitumen layer = 22 X 0.070 = 1.534 kN/m²

3.2 Earth pressure load
E.P = K₀γZ
Where
K₀ = coefficient of earth pressure at rest
γ = density of soil
Z = height of wall
E.P = 0.5 X 20 X 6.75 = 6.45 kN/m²

3.3 Live load surcharge
ΔP = Kₑγhₑq
Where
k = Coefficient of lateral earth pressure
γ = Density of soil
hₑq = Equivalent height of soil for vehicular loading 1.2 m
ΔP = 0.5 X 20 X 1.2
ΔP = 12 kN/m²

3.4 Live loads

Figure 5 Wheel spacing for 70R wheeled vehicle
Figure 6 70R wheeled vehicle

Figure 7 Class A train of vehicles

Figure 8 SV class vehicle with typical axle arrangement

Figure 9 Transverse wheel spacing of special vehicle

IV. RESULTS

In the present work, 8 models of three lane box type skew bridge are prepared on STAAD PRO V8i with skew angle ranging from 0° to 70° with an increment of 10°. Under different loads dead load, superimposed dead load, surfacing, earth pressure, temperature, surcharge and live load and their combinations, results are obtained for longitudinal moments, transverse moments, torsional moments and shear force.

4.1 Contours of maximum torsion in top slabs for all skew angles.

Figure 10 Typical top slab contour of max torsion for 0° skew

Figure 11 Typical top slab contour of max torsion for 10° skew

Figure 12 Typical top slab contour of max torsion for 20° skew

Figure 13 Typical top slab contour of max torsion for 30° skew

Figure 14 Typical top slab contour of max torsion for 40° skew
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4.2 Results of models for all slabs and their variation with skew angle

- Shear forces in all slabs

- Moments in top slab

- Moments in bottom slab

- Moments in right outerwall

- Moments in right innerwall

- Right outer wall moments vs skew angle

- Right inner wall moments vs skew angle
Chart 6: Left inner wall moments v/s skew angle

Chart 7: Left outer wall moments v/s skew angle

Chart 8: Top slab displacements v/s skew angle

Chart 9: Bottom slab displacements v/s skew angle

Chart 10: Right outer wall displacements v/s skew angle

Chart 11: Right inner wall displacements v/s skew angle

Chart 12: Left inner wall displacements v/s skew angle
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Chart-13: Left outer wall displacements v/s skew angle
- From the charts (Chart 1), it is observed that shear force in all the slabs increases with the increase of skew angle.
- It is clearly indicate from charts that longitudinal moments and transverse moments both sagging and hogging in all slabs increase with the increase of skew angle.
- From torsional charts (Chart 2 to Chart 7), it can be concluded that torsional moments in all slabs increases with the increase of skew angle.
- From displacement charts (Chart 8 to Chart 13), it is observed that displacement increases in all slabs with the increase of skew angle.

V. CONCLUSION
- From the above results, it can be concluded that the behavior of box type bridge changes at lower skew angles also which is not seen in other type of bridges.
- In box type bridges parameters like longitudinal moments, transverse moments, torsional moments, shear forces and displacements in all slabs of bridge increases with the increase of skew angle.
- So, utmost care should be taken in the design of box type skew bridge even at lower skew angles.

REFERENCES