ANALYSIS AND BEHAVIOUR OF SKEW BRIDGES WITH DIFFERENT SKEW ANGLE

Ajay D. Shahu[1], S.V. Joshi[2], P. D. Pachpor[3]
Shri. Ramdeobaba College of Engineering and Management, Nagpur, India
Email: pachporpd@rknec.edu[3]

Abstract
The paper includes different techniques and the related work that has been done for skew angle on skew bridges. Work has been done to understand the effect of skew angle in skew bridges and is primarily focused on IRC Loadings. Paper has shown the intervals of skew angle taken for analysis are 10º, 15º, 20º and 30º. To optimize the result interpretation and variation in values of parameters for different skew angle, the interval of skew angle is kept as 5º. Therefore skew angle increases from0º to 60oat an interval of 5º. This would help to understand the variation in result for different parameter more precisely. Also, when we plot a graph; say, max Bending Moment value for each skew angle versus skew angle value would reflect smooth variation. Paper provides the Detailed study of normal and skewed reinforced cement concrete bridges, various loading criteria on bridges as per Indian Road Congress (IRC) 6 and amendments made recently, different parameters like bending moment, twisting moment, shear force under different skew angles from 0^0 to 60^0 at an interval of 5^0.

Keywords: skew bridges, skew angle, shear force, bending moment, and torsional moment, etc.

I. INTRODUCTION

Due to the complex intersection at various places such as highways, river crossing, railway crossing, there is a continuous growing demand of bridges to distribute the traffic without any congestion. Skew bridges are useful to cater high speed vehicle as highway alignments are kept straight as far as possible. Moreover, congestion of traffics also overcomes as alignment of road and bridge kept straight. These have leaded the provision of number of skew bridges.

In small skew angle bridges say up-to 20o, bridges are considered straight and are typically designed as normal right angle bridges with no considerable modification. Up-to skew angle 20o, there is no considerable variation in values of parameters like bending moment, shear force and torsional moment. However, if the skew angle increases beyond 20o, then there could be considerable variation in terms of shear force, bending moment, and torsional moment. Thus, these would lead variation in Equivalent Bending Moment, and Equivalent Shear Force Shear force due to torsion. Thus, there is a scope of more research to study the effect of skew angle on parameters of analysis in skew bridges

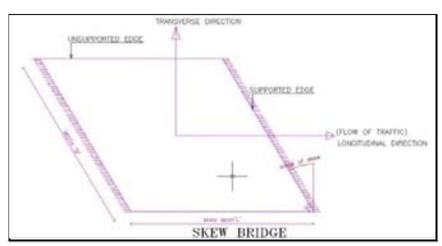


Figure 1.1Diagrammaticrepresentation of skew angle

II. REINFORCED CONCRETE BRIDGE MODELWITH MESH SLAB

A. *Software and its features*

STAADpro.v8i stands for Structural Analysis and Design. It is software developed by Research Engineers for analysis of complex structures.STAAD*Pro.v8i* can be used for the analysis and design of steel, concrete, composite, timber, aluminum and cold-formed steel structures as it support various codes of design. Complex models can be quickly and easily generated through powerful graphics, text and spreadsheet interfaces that provide true interactive model generation, editing, and analysis. Analysis of 2-D, 3-D Plane Frame and Truss Structures with different load combinations using Global Stiffness Matrix Method. It calculates Stress, Shear Forces, Bending Moments, deflection and other parameters of analysis for different elements and can show the stress variations on the element in the Diagrammatic Representation in the Post Analysis Mode.

B. *Preliminary model prepared on staadpro.v8i and corrected.*

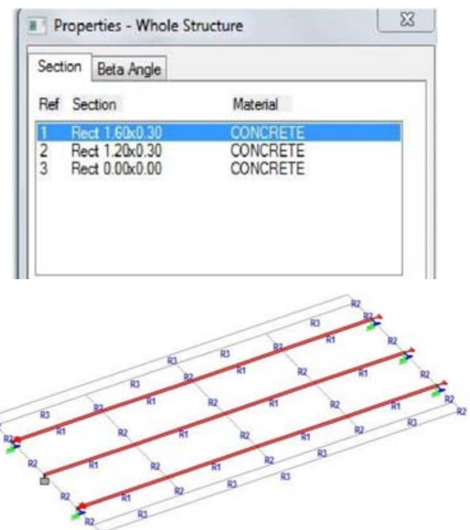


Figure 1.3Model property

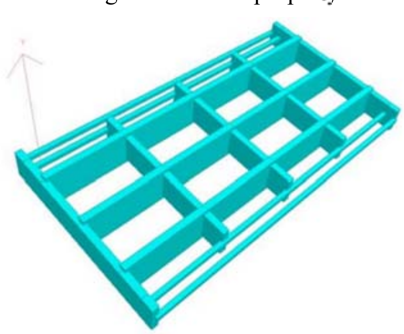
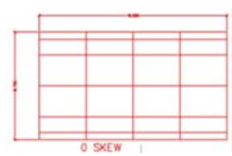
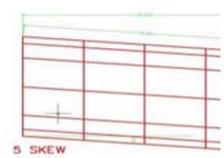
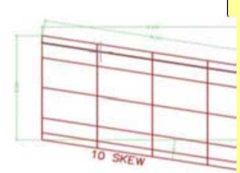
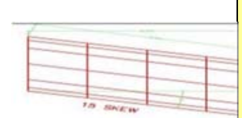


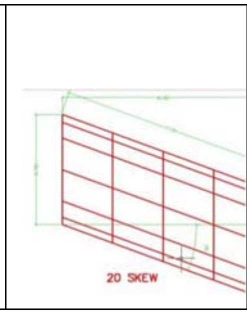
Figure 1.4 Rendered view

C. *Model with skew angle and skew length*

While preparing model with skew angle, it is observed that the length of the span increases with the increase in skew angle. Thus, it would be impossible to compare the result obtained from these models as the span length has increased from 16m to 32 m. some of the variations with respect to skew angle can be observed below.

TABLE 1.1 SHOWS SKEW LENGTH WITH SKEW ANGLE

Sr. no.	**Image**	**Skew angle**	**c/c length in m**	**Skew length in m**
1		0°	16	**16.000**
2		5°	16	**16.061**
3		10°	16	**16.246**
4		15°	16	**16.564**

5		20º	16	**17.026**

D. Geometric dimensions of bridge

As we know, it is a reinforced concrete bridge. Therefore span is selected and restricted to 16m. For the longer spans, the self weight of the girder becomes too heavy. Therefore, pre-stressed concrete bridge decks are most commonly used. The width of the Bridge is decided from IRC 6, which say that for two lane bridges carriage width ranges from 5.3m to 9.6m.

TABLE 5.2 CARRIAGE WIDTH FOR NUMBER OF LANES

Table 2 Live Load Combination

Sl. No.	Carriageway Width (CW)	Number of Lanes for Design Purposes	Load Combination
1)	Less than 5.3	1	One lane of Class A considered to occupy 2.3m. The remaining width of carriageway shall be loaded with 500 kg/m²
2)	5.3m and above but less than 9.6m	2	One lane of Class 70R OR two lanes for Class A
3)	9.6m and above but less than 13.1	3	One lane of Class 70R for every two lanes with one lanes of Class A on the remaining lane OR 3 lanes of
4)	13.1m and above but less than 16.6m	4	One lane of Class 70R for every two lanes with one lane of Class A for the remaining lanes, if any, OR one lane of Class A for each lane.
5)	16.6m and above but less than 20.1	5	
6)	20.1m and above but less than 23.6	6	

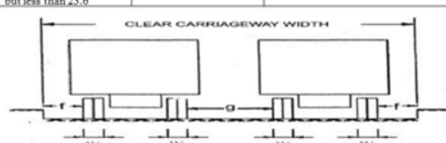


Figure 15 Diagrammatic representations to calculate carriage width

E. Final plan and data of the bridge model

Final data required to prepare a model on staadpro.v8i are as under:-

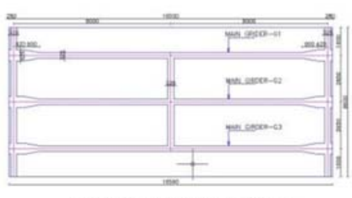


Figure 1.6 Final Layout plan of bridge

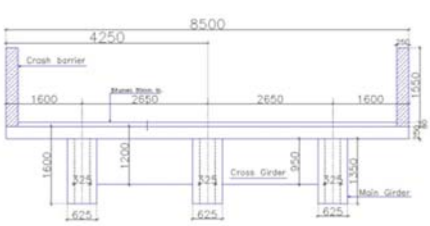


Figure 1.7 Transverse section of bridge

F. Stepwise procedure in brief to prepare model on staadpro.v8i

- Double click on icon of Staadpro.v8i that appears on window after installation.
- Window will appear, Select Indian design code option under the heading of License Configuration
- Select option-New Project that appears under the heading of Project tasks
- New window will appear, in which
- Select-Space (as it is a 3-d model)
- Assign-File name
- Select location or folder to save the Staad file
- Select unit-m and kN
- Select next key option
- New window appears in which
- Select option-Add beams
- Select Finish option
- New window appears which includes
- Main window,
- Data area, □ Menu bar,
- Tool bar, and
- Page control which is described as below:-

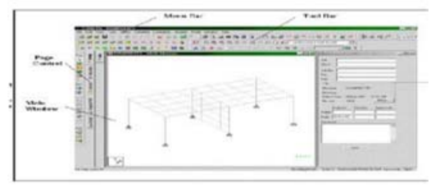


Figure 1.8 staadpro.v8i window

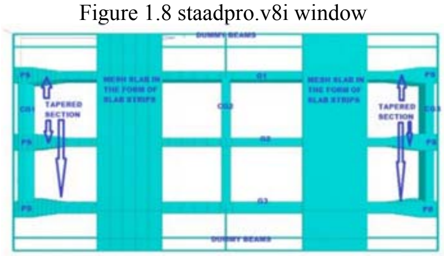


Figure1.9 Rendered 3-D model of bridge

III. STUDY OF LOADING

A. Dead load from codes

Code of practice of design loads other than seismic load for buildings and structures IS 875 gives the density of concrete and asphaltic bitumen as below:-

- Density of concrete for structural member of bridge is taken as 25kN/m^3
- Density of asphalt bitumen surface layer on bridge slab is taken as 22kN/m^3

Code of practice for roads and bridgesIRC6:2010 gives the value for calculating weight of crash barrier in the following table.

TABLE 1.3 SPECIFICATION OF TYPE OF CRASH BARRIER

Sl. No.	Requirement	Types of Crash Barrier		
		P-1 In-situ/ Precast	P-2 In-situ/ Precast	P-3 In-situ
1)	Shape	Shape on traffic side to be as per IRC:5, or New Jersey (NJ) Type of 'F' Shape designated thus by AASHTO		
2)	Minimum grade of concrete	M-40	M-40	M-40
3)	Minimum thickness of R C wall (at top)	175 mm	175 mm	250 mm
4)	Minimum moment of resistance at base of the wall [see note (i)] for bending in vertical plane with reinforcement adjacent to the traffic face [see note (ii)]	15 kNm/m	7.5 kNm/m	100 kNm/m for end section and 75 kNm/m for intermediate section [see note (iii)]
5)	Minimummomentofresistance for bending in horizontal plane with reinforcement adjacent to outer face [see note (ii)]	7.5 kNm/m	3.75 kNm/m	40 kNm/m
6)	Minimum moment of resistance of anchorage at the base of a precast reinforced concrete panel	22.5 kNm/m	11.25 kNm/m	Not applicable
7)	Minimum transverse shear resistance at vertical joints between precast panels, or at vertical joints made between lengths of in-situ crash barrier.	44 kN/m of joint	22.5 kN/m of joint	Not applicable
8)	Minimum height	900 mm	900 mm	1550 mm

Footpath load

Code of practice for roads and bridgesIRC6:2010 gives the value for calculating weight of footpath in the following way:-

TABLE 1.4 FOOTPATH LOADING AS PER SPAN

Footpath loading	
EFFECTIVE SPAN	LOAD
• Effective span<7.5m • 7.5<Eff. span<30m • Effective span>30m	• 400 or 500kg/m² • P=p1-((40L-300)/9) • P=(p1-260-4800/L)x ((16.5-W)/L) Where, P1=400 or 500kg/m² L=Effective span W=width of footway

Code of practice for roads and bridgesIRC6:2010 gives the value for calculating weight of Impact load in the following way:-

TABLE 1.5 IMPACT LOADING CRITERIA

IMPACT LOADING(%)	
CLASS A AND B	CLASS AA AND 70R
• RCC BRIDGE= 4.5/(6+L) • STEEL= 9/(13.5+L)	• TECKED VEHICLE • SPAN<9M=25% UPTO 5M 10% FOR 5-9M • WHEELED VEHICLE • IMPACT LOAD=25%

Dead load Calculations

- Weight of reinforced concrete structure of bridge is assigned as self-weight=1 with the density $25kN/m^3$. It can be understood as
  Density of concrete X volume of section =self-weight of structure
- Weight of bitumen layer on bridge =density of bitumen X thickness of bitumen layer
  = 22 X 0.08
  $=1.76kN/m^2$ applied on carriage width
- Weight of crash barrier
  Minimum thickness from table above=250 mm forP-3 in situ
  Minimum height of crash barrier=1550 mm for P-3 in situ
  Weight of crash barrier =thickness x height x density of concrete = 0.25 x 1.55 x 25
  = 9.6875kN/m on both sides

B. Live load from codes

TABLE 1.6 LOADING CLASS IN IRC 6:2014

SR NO.	SEMESTER	LOAD	LENGTH
1	CLASS AA	70T	3.6m
2	CLASS A	55T	15.8m
3	CLASS B	33.2T	15.8M
4	CLASS 70RWHEELED	100T	13.4m
5	CLASS 70RTRACKED	70T	4.57m
6	CLASS 70RBOGGIE	40T	1.22m
7	SPECIAL VEHICLE	385T	38.5m

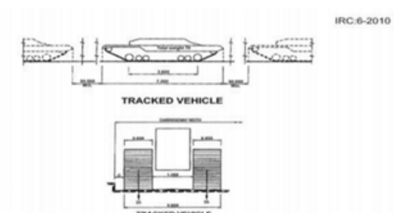


Figure 1.10 Class AA Tracked Vehicle

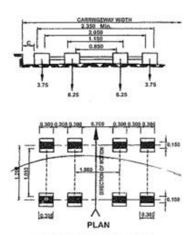
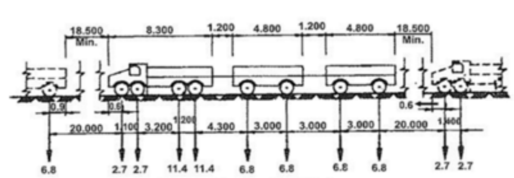


Fig. 1 Class AA Tracked and Wheeled Vehicles (Clause 204.1)

Figure 1.11 Class AA wheeled vehicle



Class A Train of Vehicles

Fig. 2 Class 'A' Train of Vehicles (Clause 204.1)

Figure 1.12 Class A Train of Vehicle

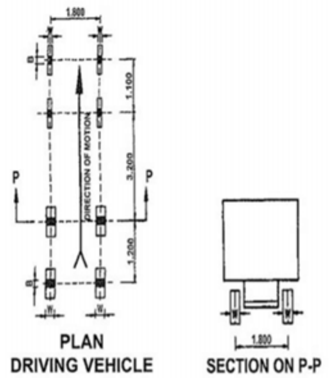


Figure 1.13 Plan of Class A Train of Vehicle

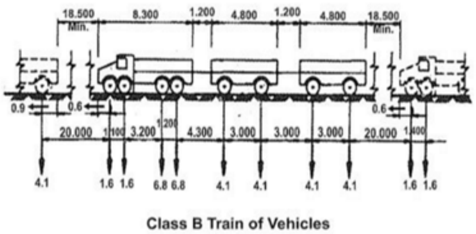


Figure 1.14 Class B Train of Vehicle

IV. RESULTS AND REVIEWS

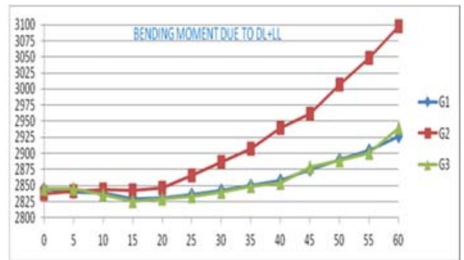
In the present work, 26 bridge models are prepared on staadpro.v8i, with the skew angle 0^0 to 60^0 with the increment of 5^0. Total 13 reinforced concrete T-beam bridge model for dead load and 13 reinforced concrete T-beam bridge model for live load having skew angle 0^o ,5^o ,10^o ,15^o ,20^o ,25^o ,30^o ,35^o ,40^o ,45^o ,50^o ,55^o ,60^o . These 26 models are simply supported.

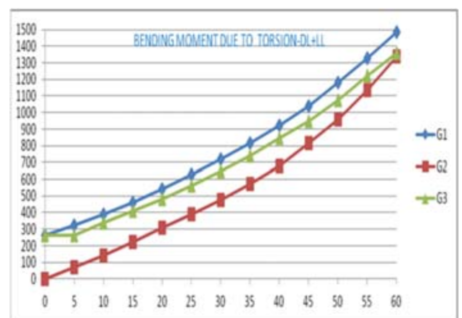
Figure 1.15 Main Girders and details

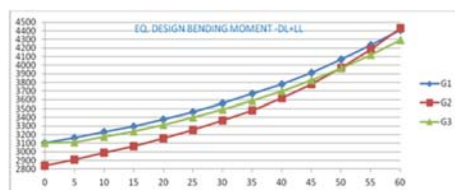
Under Dead load, Live load and combination of Dead + Live load, results obtained for all 26 models with skew angle 0^o to 60^o are axial force, shear, torsion and moment. These parameters are further interpreted to get maximum bending moment, maximum Shear force,Bending Moment due to Torsion, Design Equivalent Bending Moment, Shear Force due to Torsion, and Design Equivalent Bending Moment.

TABLE 1.8 RESULT CHART FOR DEAD LOAD+ LIVE LOAD

		DEAD LOAD+LIVE LOAD					
		BENDING MOMENT			SHEAR FORCE		
SKEW ANGLE	GIRDER	BENDING MOMENT	BENDING MOMENT DUE TO TORSION	DESIGN EQUIVALENT BENDING MOMENT	SHEAR FORCE	SHEAR FORCE DUE TO TORSION	DESIGN EQVALENT SHEAR FORCE
0^0	G1	2845.20	261.48	3106.67	676.27	604.30	1280.57
	G2	2837.58	0.00	2837.58	951.15	0.00	951.15
	G3	2845.20	261.48	3106.67	676.27	604.30	1280.57
5^0	G1	2840.07	324.54	3164.61	631.90	610.57	1242.48
	G2	2840.85	67.89	2908.74	934.24	35.54	969.78
	G3	2845.00	263.36	3108.37	678.91	656.33	1335.24
10^0	G1	2837.89	390.49	3228.38	635.69	647.82	1283.51
	G2	2843.31	143.35	2986.65	934.06	66.35	1000.41
	G3	2835.56	337.89	3173.45	677.15	692.31	1369.46
15^0	G1	2828.79	463.22	3292.01	635.88	688.78	1324.66
	G2	2842.53	220.85	3063.38	928.12	98.75	1026.87
	G3	2825.57	408.89	3234.46	680.26	735.54	1415.80
20^0	G1	2830.85	542.38	3373.22	637.84	731.36	1369.21
	G2	2846.08	307.68	3153.76	827.15	228.36	1055.51
	G3	2829.35	480.44	3309.79	684.22	781.09	1465.30
25^0	G1	2835.64	627.74	3463.38	640.24	777.06	1417.31
	G2	2865.03	390.08	3255.11	821.63	300.61	1122.24
	G3	2832.76	563.75	3396.51	689.27	830.94	1520.21
30^0	G1	2842.19	719.82	3562.01	452.18	1016.65	1468.83







V. CONCLUSIONS

- Torsional moment plays a major role for both equivalent bending moment and equivalent shear force observed during the analysis and design for varying skew angle both for the dead load and live load. As the skew angle increases, torsion moment increases. Thus, this increases the value of M_t which directly affect the value of Equivalent Bending and Equivalent Shear
- From the graphical observation for live load, bending moment decreases for all three girders, moment due to torsion for girder-G2 increases whereas moment due to torsion for girder-G1 and G3 decreases. Thus, due to

net effect, equivalent design bending moment increases gradually as we increase the skew angle from 0 to 60; but the considerable effect is due to torsional moment.

- For the combination of dead load and live load, it is observed that, bending moment, moment due to torsion, and equivalent design bending moment increases gradually as we increase the skew angle from 0 to 60 degree; and the considerable effect is due to torsional moment generated both for dead load and live load.
- From the graph, it is also observed for dead load that, there is a considerable decrease innormal shear force for girder G2 whereas increase innormal shear force for girder G1 and G3. Shear due to torsion for dead load increases for all three girders as skew angle increases. Thus, equivalent shear force also increases for all three girders as skew angle increases.
- The net effect due to dead load and live load shows that, shear force decreases for girders G1 and G2 whereas shear force increases for girders G3as the skew angle increases from 0^0 to 60^0.

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