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ANALYSIS AND BEHAVIOUR OF SKEWED BOX GIRDER BRIDGE

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Abstract:

Box girder bridge is different from bridges which differ in reliability, economy and aesthetic appearance. Box Girder Bridge has excellent strength and torsional rigidity. Box girders are used for most long spans. This study shows the forces and moments of other results from 0 to 60-degree skew angles. The effect of the same span with a skew angle of 0 to 60 degrees is different. In this study the span is 31 m long and the effective span 30 m. A 2-cell box girder with a width of 9.5 m and a depth of 2.5 m. In this study, different IRC codes are used for the load. The STAAD PRO V8i software are used for the analysis of grillage models. Models are simply supported. Interestingly, the torsion was more exaggerated than the bending moment and deflection. The effects of reaction and torsion angle are mainly observed at obtuse corner rather than acute corner. The shear forces for the permanent load of each support are different and gradually increase and decrease from the LHS side to the RHS side. The Vertical force alternating with the Pier& abutment increases as the angle of inclination(Skew) increases.

Keywords—**Box Girder Bridge, Grillage model, skew angle zero degree to 60 degrees, bending moment, shear force, deflection, and torsion, Pier & abutment, Vertical forces, STAAD Pro.**

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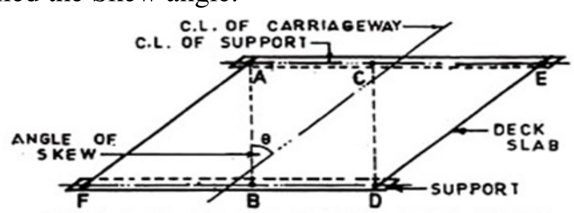
I. INTRODUCTION

Transportation must meet the demand for infrastructure construction covering the shortest route of the street. These short circuits must cross several obstacles. The bridge structure is the only way to solve this problem The structural function of a box girder bridge deck is more complex than that of a girder bridge deck and therefore requires analysis and design. The forces acting on the deck cause the interaction of longitudinal, transverse, as well as longitudinal and transverse bends. In general, this can be understood as the ratio of the longitudinal structure in the deformation profile of the plank and the bearing capacity of the plank. For river bridges, the slope of the centreline of movement relative to the centreline of the river is called the Skew angle.



II. LITERATURE SURVEY

Papers on Analysis & behaviour of skewed box girder bridge.

S. Madavi, *et al.* (2018)Presents a Comparison of Skew Bridges with Different Skew Angles. Based on the behavior of 20m equal-length T-shaped beams, various inclination angles are analysed and researched. According to the obtained research, the bending moment of the longitudinal beam increases by 35% to 40% with the increase of the skew angle, the shear force acting on the beam increases by 96% to 100% with the increase of the skew angle, and the torsion on the beam is increases with increase in skew angle.

M.Sharma, *et al.* (2017)Introduced Behaviour of reinforced concrete skew slab: A review. Based on the retrospective research, an analysis method is also proposed for determining the corner forces of the straight & skew bridge. It is recommended to provide a shear reinforcement along the free edge of the slab to withstand the high vertical shear stress generated near the free edge.

Ashwini, *et al.* (2017) presents analysis of box girder bridges under IRC loading. The analysis of the box bridge under IRC loading is shown. Single-cell and multi-cell box beams for analysis. The results obtained show that the bending moment of the single cell box girder is maximum compared to the 4 cell box girder. From this comparative study, it is clear that the single cell girder bridge is cheaper than the four cell girder bridge.

D.Patil, *et al.* (2016) Presents Influence of Moving Load on the Behaviour of Skewed and Curved Rectangular Box Girder Bridges. The analysis of the box girder model is carried out in SAP2000. According to analysis, the shear stress for skew box girder and curved box girder is directly proportional to the skew angle and inversely proportional to the radius of curvature. The shear stress at a skew angle of 20 degrees increases by 0.5%, the shear stress at a skew angle of 40 degrees increases by 3.75%, and the shear stress at a skew angle of 60 degrees increases by 14.37%.

P. Theoret, *et al.* (2012) Present the Analysis and Design of Straight and Skewed Slab Bridges. Test results are shown to determine the bending moments and shear forces required for the design of skewed concrete bridges. Finite element analysis confirmed that a significant reaction force was generated at the corners of the slab. Studies have shown that AASHTO's moment reduction factor is accurate for skew angles up to 30 °, but is very modest at higher skew angles.

S. Tanvir, *et al.* (1984) presents Comparative structural behaviour of Straight, Curved & skew RC box girder bridge models. In this study, the theoretical and experimental values of selected structural quantities (e.g. reaction forces, deflections and moments) are compared. The volume of steel reinforcement is much smaller for the skew model than straight & curved model. When point loads are applied in the mid-span, the planar model i.e. straight & curve model resembles the bend pattern, but the skew bridge are different and are highly dependent on the lateral position of the applied point loads.

III. OBJECTIVE

1) To Carry the analysis of Concrete box girder bridge deck with different skew angle from zero degree to 60 degrees 2) analyses the parameter used in the investigation for maximum deflections, maximum Bending, maximum Support reaction & maximum Torsion moment of the box girders for different angle i.e. from zero degree to 60 degrees.
3) To understand the behaviour of shear force on outer & inner web 4) To understand the behaviour of torsion & the corresponding shear.

IV. PROBLEM STATEMENT

A two lane national highway bridge is analysed for this purpose. The first stage involves detailed analysis of the zero-degree angle bridge using the software STAAD.Pro. The span of the bridge is 31.00 m in the direction of the traffic. overall width of the deck is 9.5 m including anti-crash barrier of width 0.5 m on either side.

A box girder bridge consists of a top and bottom slab connected by vertical webs to form a cellular or box-like structure. Thickness of the web is 300 mm and 750 mm for running section and support section respectively.

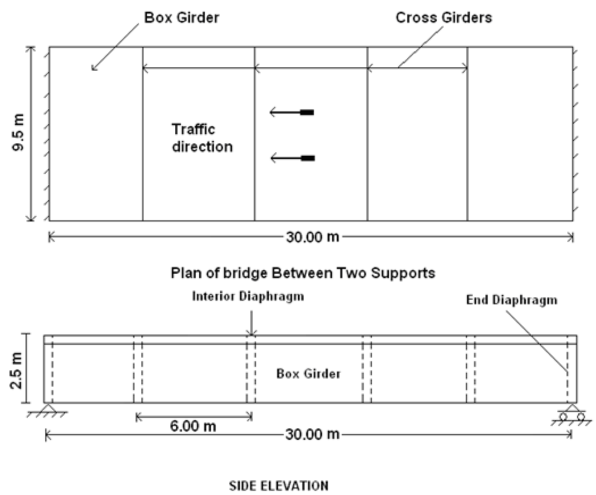


Fig 1.1: Plan & elevation of Box Girder.

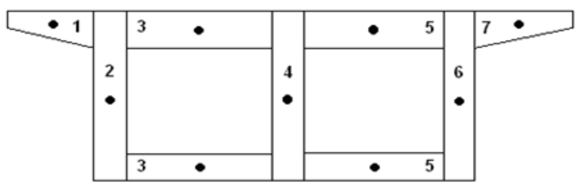


Fig 1.2: Various Elements of Box girders.

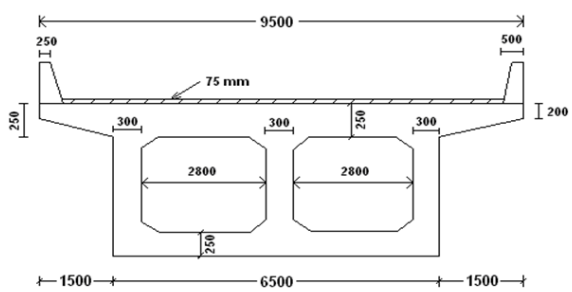


Fig 1.3: Mid-Section

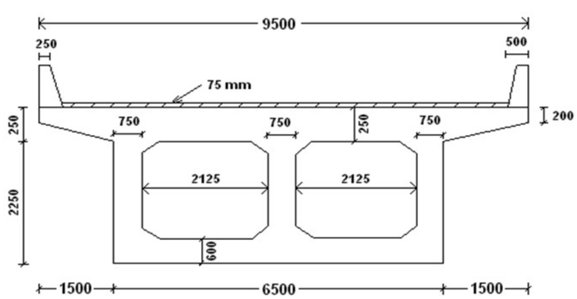


Fig 1.4: Support Section

The analysis is carried out using Staad pro with grillage model with 2 lanes live load loading. Grade of Steel= Fe500 and Grade of Concrete=M40, Density of Concrete= 25 kN/m3. The length is mentioned in Meter (m), deflection mentioned in millimetre (mm), the forces are mentioned in the Kilo newton (Kn) & the Moments are mentioned in the Kilo newton-meter (Kn-m).

The DL, SIDL & LL loading are taken for analysis the deck slab. The 2L loading of Class A & 70R are taken for live load loading as per IRC 6-2010.

The live load checks for maximum Forces & moments

V. METHODOLOGY AND ANALYSIS

In the present study of analysis is used to perform under the guideline of IRC 6:2010 & the using STAAD pro Software.

- The models are for different skew angles i.e. zero degree to 60 degrees with same width & length.
- The structure is simply supported.
- The analysis has been carried out for the above mentioned loading & the results of longitudinal analysis Bending moment, deflection, torsion & reaction has been studied.
- After this preliminary study a parametric study of different angles from zero degree to 60 degrees will do to obtained final results for comparison of the structures

VI. RESULT AND DISCUSSION

1. Comparison between the zero degree to 60 degrees

Loads	Support Reaction			Bending Moment			Torsion Moment			Deflection		
	Zero Deg	Skew (15 Deg)	Diff	Zero Deg	Skew (15 Deg)	Diff	Zero Deg	Skew (15 Deg)	Diff	Zero Deg	Skew (15 Deg)	Diff
	(Kn)	(Kn)	(%)	(Kn-m)	(Kn-m)	(%)	(Kn-m)	(Kn-m)	(%)	(mm)	(mm)	(%)
DL	1092.22	1108.1	**1.444**	6518.6	6524.7	**0.095**	5.116	38.455	**153**	50.485	50.280	**0.407**
SIDL	182.029	195.65	**7.215**	1145.9	1139.5	**0.565**	16.237	20.393	**22.69**	8.83	8.732	**1.117**
70R	433.846	489.76	**12.11**	2047.9	1876.9	**8.714**	27.687	12.733	**73.99**	14.56	13.211	**9.716**
Class A	346.153	373.16	**7.509**	1962.8	1769.4	**10.37**	46.912	52.544	**11.33**	14.04	13.025	**7.501**

Loading	Support Reaction			Bending Moment			Torsion Moment			Deflection		
	Zero Deg	Skew (30 Deg)	Diff	Zero Deg	Skew (30 Deg)	Diff	Zero Deg	Skew (30 Deg)	Diff	Zero Deg	Skew (30 Deg)	Diff
	(Kn)	(Kn)	(%)	(Kn-m)	(Kn-m)	(%)	(Kn-m)	(Kn-m)	(%)	(mm)	(mm)	(%)
DL	1092.22	1170.3	**6.904**	6518.6	6547.1	**0.437**	5.116	80.264	**176**	50.485	50.279	**0.409**
SIDL	182.029	208.17	**13.4**	1145.9	1113.4	**2.878**	16.237	23.935	**38.33**	8.83	8.541	**3.328**
70R	433.846	565.56	**26.36**	2047.9	1841.3	**10.62**	27.687	26.067	**6.028**	14.56	12.924	**11.91**
Class A	346.153	395.25	**13.25**	1962.8	1726.1	**12.84**	46.912	51.737	**9.783**	14.04	12.676	**10.21**

Loading	Support Reaction			Bending Moment			Torsion Moment			Deflection		
	Zero Deg	Skew (45 Deg)	Diff	Zero Deg	Skew (45 Deg)	Diff	Zero Deg	Skew (45 Deg)	Diff	Zero Deg	Skew (45 Deg)	Diff
	(Kn)	(Kn)	(%)	(Kn-m)	(Kn-m)	(%)	(Kn-m)	(Kn-m)	(%)	(mm)	(mm)	(%)
DL	1092.22	1307.1	**17.91**	6518.6	6567.2	**0.744**	5.116	136.07	**185.5**	50.485	49.964	**1.038**
SIDL	182.029	223.5	**20.45**	1145.9	1064.3	**7.39**	16.237	28.535	**54.94**	8.83	8.104	**8.575**
70R	433.846	539.88	**21.78**	2047.9	1766.3	**14.77**	27.687	42.068	**41.23**	14.56	12.259	**17.16**
Class A	346.153	603.65	**54.22**	1962.8	1639.7	**17.94**	46.912	50.614	**7.592**	14.04	11.904	**16.47**

Loading	Support Reaction			Bending Moment			Torsion Moment			Deflection		
	Zero Deg	Skew (60 Deg)	Diff	Zero Deg	Skew (60 Deg)	Diff	Zero Deg	Skew (60 Deg)	Diff	Zero Deg	Skew (60 Deg)	Diff
	(Kn)	(Kn)	(%)	(Kn-m)	(Kn-m)	(%)	(Kn-m)	(Kn-m)	(%)	(mm)	(mm)	(%)
DL	1092.22	1545.2	**34.35**	6518.6	6460.6	**0.894**	5.116	224.36	**191.1**	50.485	47.944	**5.164**
SIDL	182.029	244.12	**29.14**	1145.9	946.52	**19.06**	16.237	38.156	**80.6**	8.83	7.116	**21.5**
70R	433.846	619.66	**35.28**	2047.9	1561.1	**26.98**	27.687	54.628	**65.46**	14.56	10.734	**30.25**
Class A	346.153	722.41	**70.42**	1962.8	1441.4	**30.63**	46.912	60.443	**25.21**	14.04	10.093	**32.71**

The above comparison is between zero degree to 60 degrees.
It is shown that the difference in percentage in between the zero degree to skew angles (15^0 ,30^0 ,45^0& 60^0)

Maximum Support reaction

		DL	SIDL	70R	Class A
0	**max Fy**	1092.221	182.029	433.846	346.153
15	**max Fy**	1108.103	195.653	489.756	373.156
30	**max Fy**	1170.323	208.172	565.559	395.25
45	**max Fy**	1307.067	223.496	539.884	603.649
60	**max Fy**	1545.228	244.123	619.662	722.412

Maximum Deflection

		DL	SIDL	70R	Class A
0	**Y**	50.485	8.830	14.560	14.040
15	**Y**	50.270	8.732	13.211	13.025
30	**Y**	50.287	8.541	12.924	12.676
45	**Y**	49.964	8.104	12.259	11.904
60	**Y**	47.944	7.116	10.734	10.093

Maximum Bending Moment

		DL	SIDL	70R	Class A
0	**MZ**	6518.584	1145.909	2047.859	1962.83
15	**MZ**	6524.734	1139.462	1876.872	1769.385
30	**MZ**	6547.11	1113.403	1841.278	1726.061
45	**MZ**	6567.237	1064.25	1766.257	1639.656
60	**MZ**	6460.626	946.523	1561.097	1441.422

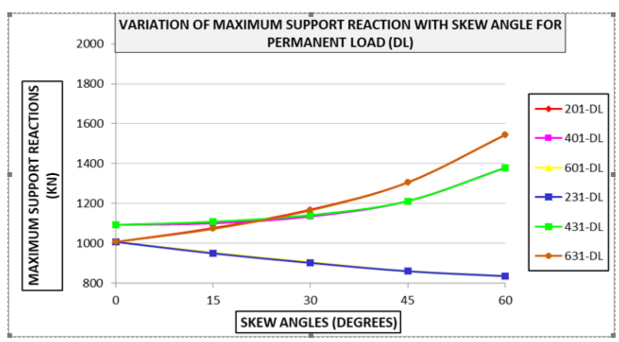
Maximum Torsion Moment

		DL	SIDL	70R	Class A
0	**MX**	5.116	16.237	27.687	46.912
15	**MX**	38.455	20.393	12.733	52.544
30	**MX**	80.264	23.935	26.067	51.737
45	**MX**	136.074	28.535	42.068	50.614
60	**MX**	224.361	38.156	54.628	60.443

The above results showing variation in forces & moments for different angles. The forces & moments are increased in some cases & decrease in some cases

2. Maximum Shear Force on each node for Permanent load (DL) from the zero-degree to 60 degrees

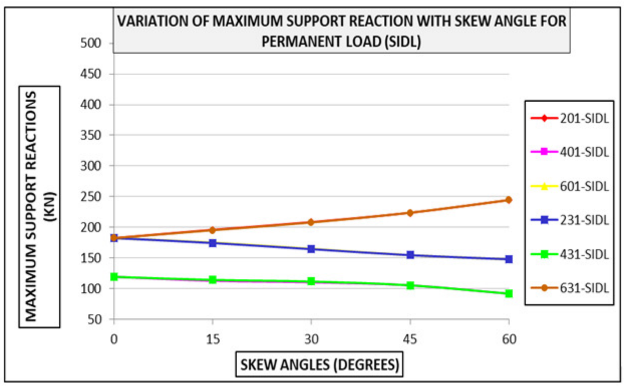
	DL	DL	DL	DL	DL	DL
Node no.	201	401	601	231	431	631
0	1008.597	1092.221	1008.596	1008.6	1092.221	1008.596
15	1078.075	1099.833	954.218	950.15	1108.103	1074.075
30	1170.323	1134.198	905.221	901.82	1141.066	1166.902
45	1307.062	1211.532	859.429	859.43	1211.521	1307.067
60	1545.226	1378.232	834.405	834.41	1378.228	1545.228



The DL decreases at LHS from 42.026 % to 18.903% & On RHS side it is increases from 18.903 % to 42.026 %. It Means high reactions are observed near the obtuse corner. Comparatively low reactions are observed near the acute corner.

3.Maximum Shear Force on each node for Permanent load (SIDL) from the zero-degree to 60 degrees

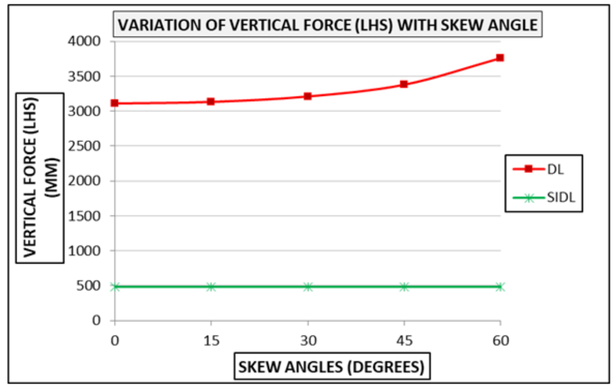
	SIDL	SIDL	SIDL	SIDL	SIDL	SIDL
Node no.	201	401	601	231	431	631
0	182.029	119.692	182.029	182.03	119.692	182.029
15	195.653	113.22	174.88	174.17	114.635	194.942
30	208.172	110.7	164.876	164.3	111.848	207.6
45	223.50	105.57	154.68	154.68	105.57	223.50
60	244.123	91.612	148.015	148.02	91.611	244.123

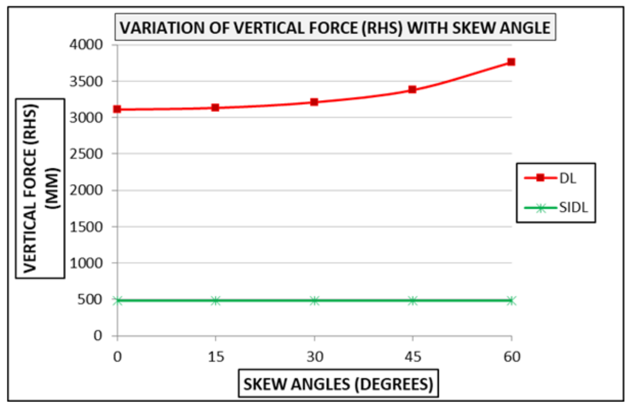


The SIDL at LHS to RHS for outer web is from 29.142 % to 20.612%, for Middle web is constant 13.55% & for Inner web is 20.612% to 29.142%. It Means high reactions are observed near the obtuse corner. Comparatively low reactions are observed near the acute corner

4.Vertical Forces due to permanent load on Pier / Abutment

LHS	FY (KN)	DL	SIDL	RHS	FY (KN)	DL	SIDL
Right	201+401+601	3109.41	483.75		231+431+631	3109.414	483.75
15	201+401+601	3132.13	483.75		231+431+631	3132.323	483.746
30	201+401+601	3209.74	483.75		231+431+631	3209.786	483.752
45	201+401+601	3378.02	483.75		231+431+631	3378.02	483.75
60	201+401+601	3757.86	483.75		231+431+631	3757.863	483.75





The dead load are increases with increasing skew angle. On the LHS & RHS side it is same vertical force due to simply supported span. The SIDL is independent & not changing with skew angle.

VII. CONCLUSION

The effect on slab of DL, SIDL & LL i.e. Class A & 70R loading are different for skew angle zero degree to 60 degrees

1. Graphical representation shows that the maximum values of the structural responses like deflections, bending moments, Support reactions and torsional moments increase with the increase in skew angles from 0^0 to 60^0.
2. In the comparative study, the maximum support reaction for the DL Increases by 1.444 % to 34.35%, SIDL increases by 7.215 % to 29.14 %. The live load is

varying load so; the results are also varying. For 70R loading reaction is maximum i.e. 35.28 % & minimum 12.107 % & for Class A loading reaction is maximum 70.42 % & minimum 7.509 % for the skew angle from zero degree to 60 degrees.

3. In the comparative study, the maximum Deflection for the DL decreases by 0.407 % to 5.164%, SIDL decreases by 1.117 % to 21.5%, 70R decreases by 9.716 % to 30.25% & Class A decreases by 7.501 % to 32.71% for skew angle from zero degree to 60 degrees.
4. In the comparative study, the maximum Bending moment for the DL decreases by 0.095 % to 0.894%, SIDL decreases by 0.565 % to 19.058 %, 70R decreases by 8.714 % to 26.976 % & Class A decreases by 10.367 % to 30.633% for skew angle from zero degree to 60 degrees.
5. In the comparative study, the maximum Torsion moment for the DL Increases by 153 % to 191.1%, SIDL increases by 22.69 % to 80.6 %. The live load is varying load so; the results are also varying. For 70R loading reaction is maximum 73.99 % & minimum 6.028 % & for Class A loading reaction is maximum 25.21 % & minimum 7.592 % for the skew angle from zero degree to 60 degrees.
6. High reactions are observed near the obtuse corner. Comparatively low reactions are observed near the acute corner.
7. It is of interest to note that torsion is affected to a greater extent than deflections and bending moments for increased skew angle, and even 15^0 of skew produces results which differ appreciably from results obtained by analyzing zero-degree angle deck.

FUTURE SCOPE

Future aspects that can be considered in the study are: -

- Different type of bridges
- Change in support reaction
- Change in material of structure e.g. Steel
- Using different software

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