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Skew Effect on the Design of Composite Super Structures in Bridges

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Abstract - *The presence of skew in a bridge makes the analysis and design of bridge complex. Design of bridges by considering skew angle is becoming more customary in the engineering community, so there is a need for more research to study effect of skew angle on the behaviour of skewed bridges such as bending moment, shear force, torsion and other parameters. This study mainly focuses on the effect of skew angle on the design of composite super structures in bridges. Six models have been developed and analyzed by using Finite element based software CSi Bridge 2015 (Advanced Version). Skew angles are taken as 0^0, 10^0, 20^0, 30^0, 40^0 and 50^0, and all models were subjected to IRC class A and IRC class 70R vehicle loading. Results for skewed bridges are compared to the straight or non-skewed bridges.*

Key Words: Bridges, Skew angle, FEM, Girders, Dead load and live load.

1. INTRODUCTION

Bridge is a structure which covers a gap, generally these structures will carry a road or railway over an obstacles such as natural or artificial obstacles like a canal, river or roadway or railway. Bridge is the most significant component of a transporting system and it is corresponding to the responsibilities in carrying a force flow of transport. These structures are classified on the basis of distribution of forces in the structure such as shear, compression, tension and moment.

1.1 Composite Bridge

Where a RC deck slab casted on top of several I-steel girders side by side and act as composite in them in bending. Composite action is developed by connecting shear connectors on top flange of the steel girder by welding. The deck slab cast around the shear connectors. The steel girders may be rolled sections, for short spans, or can be fabricated from plate. Girders are launched by providing stiffeners to web and resting on bearings. Effective span of these bridges about 25 meters to 150 meters are applied.

1.2 Skewed Bridges

The term angle of skew or skew angle is generally applied to the difference between the normal to the centreline of the bridge and the centreline of the abutment or pier cap. In earlier days, they used to prevent skew bridges as far as feasible due to lack of information about structural behaviour and construction difficulty. But in the recent days there is rising trend to provide skewed composite bridges compare to straight bridges.

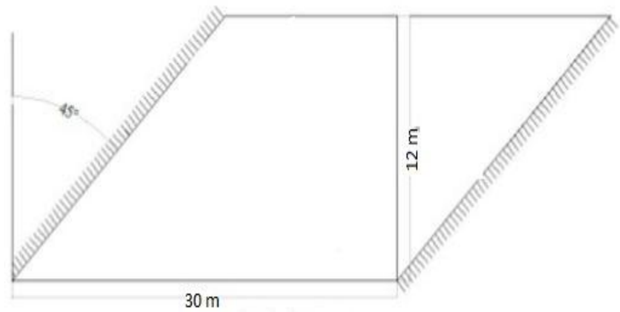
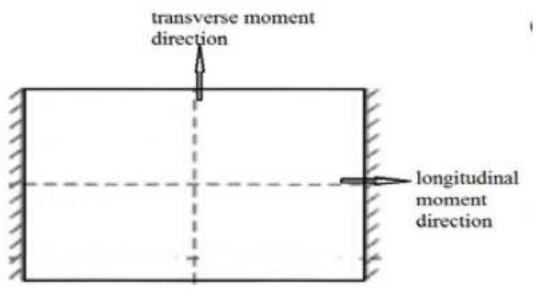


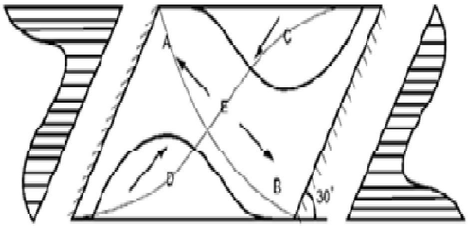
Figure 1 : Plan of skew bridge

1.4 behaviour of bridge decks

In straight bridges, the deck slab is perpendicular to the supports and the load path is straight towards the support shows in figure 1.2 (a) .Whereas in skewd bridges the load tends to take shortest path to the nearest supports as shown in figure 1.2 (b) and it is complicated problem because in which direction slab will span and the manner in which load will transfer to the supports due to skew in bridge.



(a)



(b)

Figure 2: Behaviour of bridge decks

1.4 Advantages

1) These bridges are encountered in highway design when the geometry of structure cannot accommodate straight bridges.
2) These bridges consumes less space compare to other straight bridges
3) Bridges can be constructed even in congested place if skew bridges are designed properly done.
4) Skew bridges are more efficient in urban areas because lack of space required constructing traditional non skewed bridges.

1.5 Disadvantages

1) In skew bridge the force flow is much more complicated as compared to normal straight bridges
2) Under service load and seismic load skew bridges makes their behaviour more complex

1.6 Objectives

1) The objective of analysis is to study on the behaviour on entire bridge section under different loading conditions such as dead load of whole structure, live load of IRC A and IRC 70R loading with the presence of skew angle in bridges section.

2) The objective is to study the structural behaviour in each individual girders of a bridge section under the various loading conditions such as IRC A loading and IRC 70R loading with varying in skew angles.

2. PARAMETRIC STUDY

A 3 lane, 3D bridge model of span 30 m, width 12 m and effective span 28.52m, has been taken. Total six bridge models are considered of steel I-beam girder with deck slab and various skew angles of 0^0.10^0, 20^0, 30^0, 40^0 and 50^0 to know the effect on the composite superstructure (i.e. steel girder and concrete deck slab) with presence of skew angle in the bridge. The number of longitudinal girders has been taken 4. End lifting beams provided to avoid the toppling of longitudinal girders. POT cum PTFE bearing are used, thickness of wearing course 50 mm and standard New Jersey crash barrier provided. All models were analyzed for dead load and two classes of live load i.e. IRC Class A and IRC Class 70R.

Table 2: Section details

I – Flange section	
Section Name : Longitudinal Main Girder	
Outside height	1.322 m
Top flange width	0.500 m
Top flange thickness	0.032 m
Web thickness	0.014 m
Bottom flange width	0.600 m
Bottom flange thickness	0.040 m
Section Name: End lifting beam	
Outside height	0.900 m
Top flange width	0.300 m
Top flange thickness	0.025 m
Web thickness	0.012 m
Bottom flange width	0.300 m
Bottom flange thickness	0.025 m
Section Name: X- Bracing ISMC 100	
Outside depth	0.100 m
Outside flange width	0.050 m
Flange thickness	0.0075 m
Web thickness	0.047 m

Table 3: Span items

Span	Diaphragm property	Distance in m	Location
Span 1	End lifting beam	0.000	All spaces
Span 1	X- Bracing	7.130	All spaces
Span 1	X- Bracing	14.260	All spaces
Span 1	X- Bracing	21.390	All spaces
Span 1	End lifting beam	28.520	All spaces

4. FINITE ELEMENT METHOD

It is a numerical technique for obtaining approximate solution of partial differential equation. FEM helps in producing stiffness and strength visualization, also to minimize the weight of material cost of the structure. FEM indicate the distribution of stress and strains and also it gives detailed visualization of a body.

Models were developed and analyzed by general Finite-Element Analysis using CSi Bridge 2015 (SAAP 2000) software, for the longitudinal girder we modeled two-noded 3-D elastic beam element with six degrees of freedom at each node. Concrete deck slab modeled using four-noded 3-D elastic shell element with six degrees of freedom at each node.

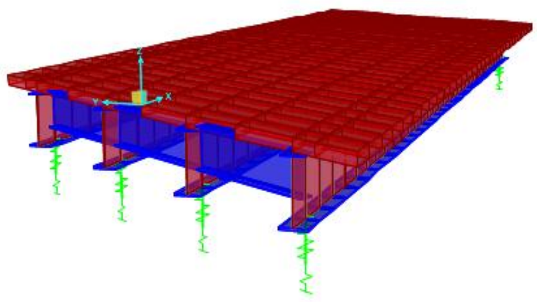


Figure 3: 3D view of composite bridge

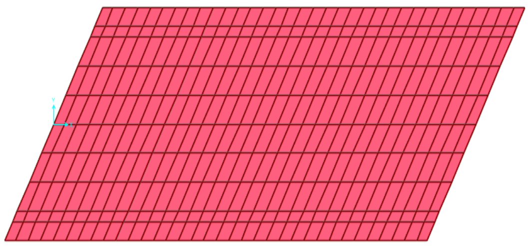


Figure 4: Plan of skewed bridge section

5. RESULTS AND DISCUSSIONS

The project work carried out to determine the skew effect on the design of composite super structure of a bridge. Total six models were modelled, bridge of span 0 m, 3.565m, 7.130m, 10.695m and 14.260m were analysed for skew angles of 0^0, 10^0, 20^0, 30^0, 40^0, and 50^0.

The FEA results are obtained and presented in term of structural response parameters such as longitudinal bending moment, Shear force and Torsional moment due to dead load of the structure and applied live load. The variations in behaviour of structure due to changes in skew angles are presented as follows.

Entire Bridge Section

Bending moment

Table 4: Bending moment due to DL and LL in kN-m

Skew angles in degrees	Dead load	Class A Loading	Class 70R Loading
0	11619.068	7480.228	5329.208
10	11590.805	7439.239	5567.771
20	11484.207	7393.680	5794.312
30	11241.128	7266.659	5837.264
40	10775.642	6917.342	5837.989
50	9964.306	6186.622	5458.091

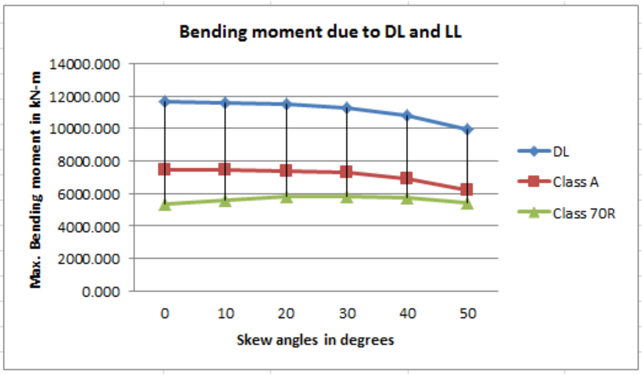


Figure 3: Skew angle vs bending moment

The maximum bending moment due to dead load is observed at 0^0 skew angle bridge, as increase in skew angle the bending moment also decreases. In case of class A loading also maximum bending is observed for 0^0 skew angle bridge. Whereas in case of class 70R loading, the bending moment is maximum at 30^0 skew angle bridge

Shear force

Table 5: Shear force due to DL and LL in kN

Skew angles in degrees	Dead load	Class A loading	Class 70R loading
0	1622.749	312.550	257.098
10	1622.822	314.155	245.005
20	1623.051	315.170	235.357
30	1623.479	295.221	219.208
40	1624.191	289.191	220.060
50	1625.386	234.181	199.495

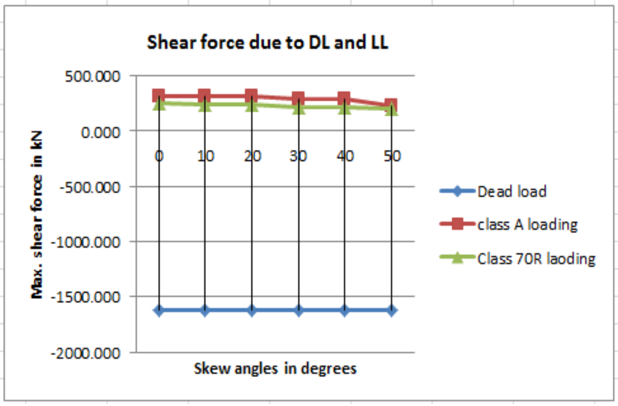


Figure 6: skew angle vs shear force

From figure 6, the maximum shear force due to dead load is almost same for all skewed bridges. Due to class A loading the shear force is maximum in 20^0 bridge, after 20^0 skew the shear force is decreasing gradually. In case of class 70R loading also shear force deceases due to increasing in skew angle.

Torsion

Table 5: Torsion due to DL and LL in kN-m

Skew angles in degrees	Dead load	Class A loading	Class 70R loading
0	0.000	0.000	3278.099
10	94.667	430.232	3186.950
20	218.717	704.623	3040.191
30	385.670	776.179	2834.579
40	589.864	718.708	2558.559
50	809.237	726.366	2193.439

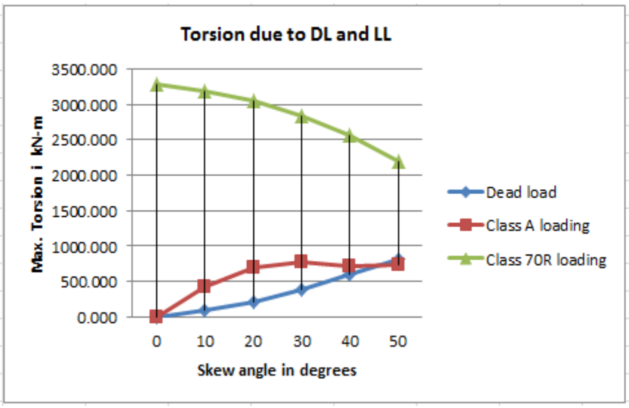


Figure 3: Skew angle vs bending moment

Torsion due to deal load and class A loading is zero in 0^0 skew in bridge, as skew angle increases torsion also increases for dead load and class A loading. In case of class 70R loading the torsion at 0^0 skew is maximum. As the skew angle increases it goes on decreasing.

Individual Girders for IRC class A loading

Bending moment

Table 6: Bending moment due to IRC class A loading

Skew angles in Degrees	Left Exterior girder	Interior girder 1	Interior girder 2	Right Exterior girder 2
0	1848.795	1891.358	1891.359	1848.795
10	1806.424	1873.951	1897.860	1889.164
20	1767.898	1846.095	1891.896	1916.715
30	1686.251	1811.554	1877.634	1921.566
40	1618.826	1731.932	1974.485	1846.322
50	1481.272	1583.199	1619.706	1746.405

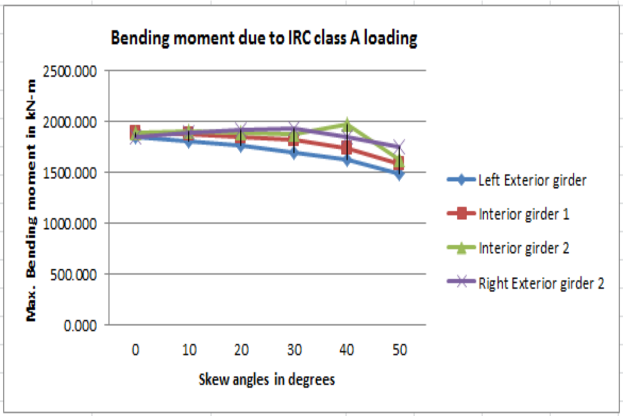


Figure 8: skew angle vs live load bending moment

It is observerd that from figure 8, the bending moment icreases upto in certain skew angle there after it decreases for large skew angle for Interior girder 1, 2 and right exterior girder. In left exterior as skew angles increases the bending moment is deacreasing.

Shear force

Table 7: Shear force due to IRC class A loading

Skew angles in Degrees	Left Exterior girder	Interfior girder 1	Interior girder 2	Right Exterior girder 2
0	83.227	84.580	90.190	85.143
10	72.156	83.756	90.295	88.279
20	61.345	81.960	96.511	81.017
30	61.345	81.960	96.511	81.017
40	46.092	83.203	87.092	91.527
50	23.743	76.813	96.075	87.715

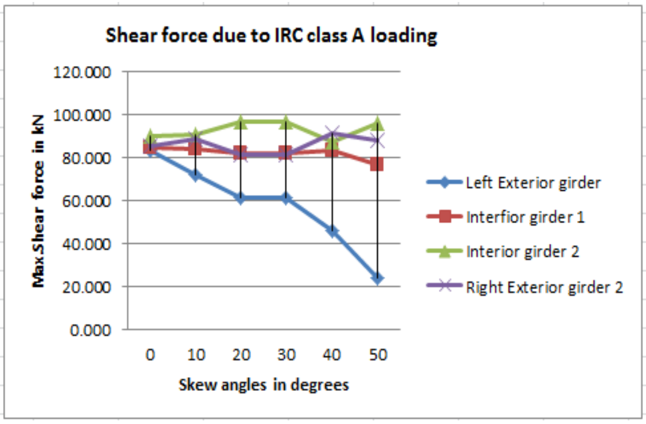


Figure 9: skew angle vs live load shear force

The shear force in each girder is varrying with respect to increase in skew angle. Interior girder 1, 2 and right exterior girder taking more shear force as shown in figure 9.

Torsion

Table 8: Torsion due to IRC class A loading

Skew angles in Degrees	Left Exterior girder	Interfior girder 1	Interior girder 2	Right Exterior girder 2
0	11.957	3.451	1.153	9.555
10	12.898	16.923	19.528	9.834
20	20.760	41.984	28.494	13.764
30	33.439	44.148	49.090	10.606
40	44.650	58.136	52.287	7.242
50	68.237	78.511	63.520	7.066

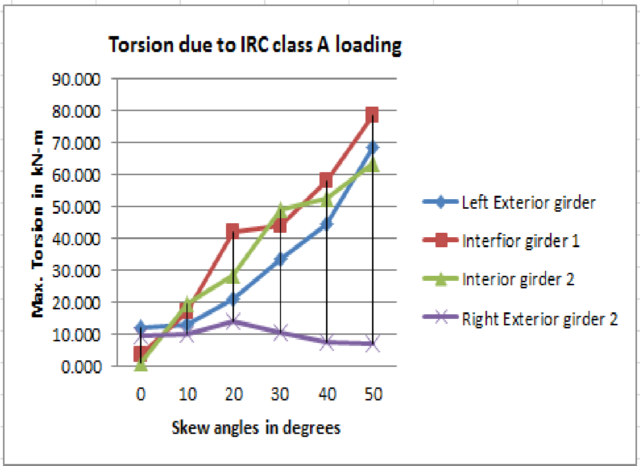


Figure 10: skew angle vs live load torsion

Due to IRC class A loading the torsion is maximum in 50^0 skew bridge, it seen that as the increase in skew angle there is increase in torsion also in Left exterior girder, Interior girder 1 and 2. Whereas in right exterior girder the t maximum torsion is at 20^0 skew, thereafter it goes on decreasing.

Individual girders for IRC class 70R

Bending moment

Table 9: Bending moment due to IRC class 70R loading

Skew angles in Degrees	Left Exterior girder	Interior girder 1	Interior girder 2	Right Exterior girder 2
0	1817.605	1244.081	1662.519	2535.175
10	1718.395	1178.035	1711.321	2602.005
20	1543.290	1078.428	1730.190	2645.975
30	1298.381	975.628	1739.560	2615.373
40	999.706	861.615	1676.304	2635.962
50	852.391	798.463	1658.221	2561.414

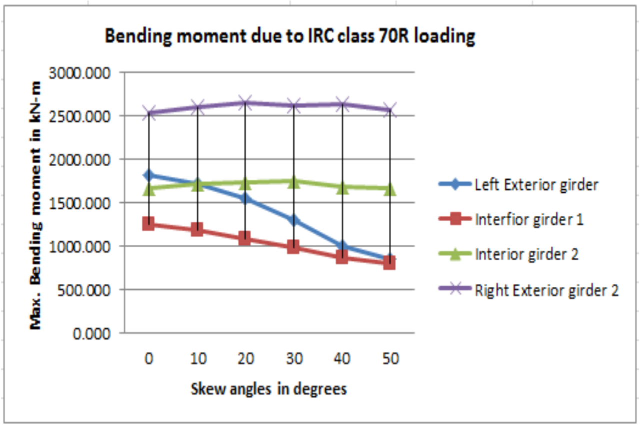


Figure 12: skew angle vs live load torsion

It observed that the bending moment is maximum in left exterior girder and interior girder 1, as the skew angle increases the bending moment decreases. In case of interior girder 1, the bending moment is maximum which occurred in 30^0 skew and case of right exterior girder is at 40^0 skew.

Shear force

Table 10: Shear force due to IRC class 70R loading

Skew angles in Degrees	Left Exterior girder	Interior girder 1	Interior girder 2	Right Exterior girder 2
0	126.679	74.271	61.200	98.233
10	110.871	71.546	67.168	108.724
20	95.053	69.058	75.914	97.639
30	78.407	65.073	70.113	111.528
40	61.145	65.937	74.306	111.178
50	42.490	52.228	95.511	122.690

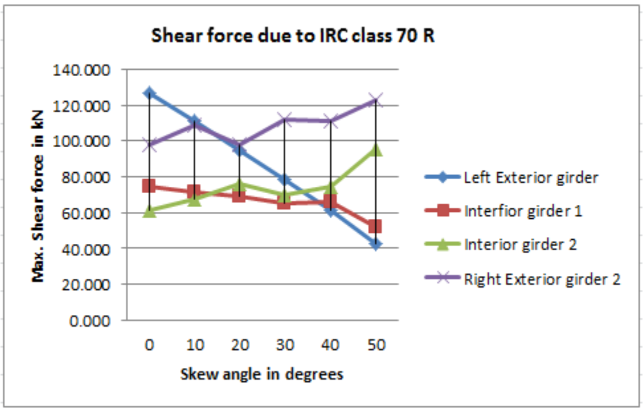


Figure 12: skew angle vs live load shear force

The maximum shear force is at 0^0 skew bridge for left exterior girder and minimum shear force is observed in interior girder 2 at support. Whereas at mid span the maximum shear force is occurred in right exterior girder and minimum shear force observed in left exterior girder.

Torsion

Table11: Torsion due to IRC class 70R loading

Skew angles in Degrees	Left Exterior girder	Interior girder 1	Interior girder 2	Right Exterior girder 2
0	34.211	67.014	111.575	60.936
10	31.742	67.064	106.021	60.857
20	27.699	66.026	114.212	63.324
30	34.865	66.627	110.592	50.945
40	31.759	84.885	137.800	41.207
50	60.710	84.082	147.514	44.523

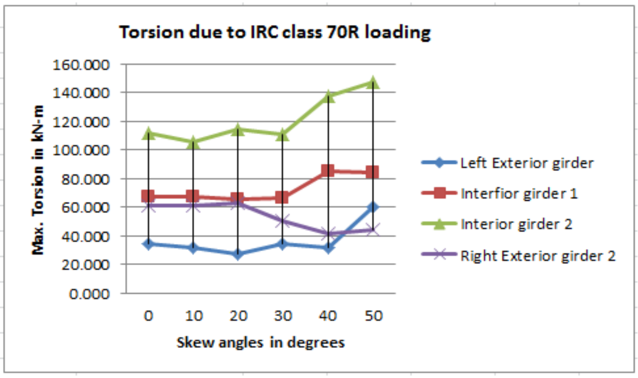


Figure 12: skew angle vs live load torsion

The torsion maximum at 50^0 skew bridge for interior girder 1, 2 and left exterior girder. It is observed that the torsion is will increase for large skew angles. The interior girder 2 is carrying more torsion in bridge for IRC class 70R loading.

6. CONCLUSIONS

Based on the analysis results of different skewed bridges, the following conclusions can be made;

1) The bending moment for dead load case, with increase in skew angle there is uniform decrease in the bending moment, about 14% of bending moment is decreases.

2) For the case of IRC class A loading and class 70R loading, the bending moment decreasing with the increase in skew angle. About 17% for class A loading and about 25% for class 70R loading bending moment decreases.

3) In case of dead load the shear force is increased in small amount about 0.2% with increase in skew angle.

4) For live load case also the shear force is varying with respect to skew angle. About 25% shear force increased for class A loading and about 22% shear force is decreasing for class 70R loading.

5) Torsion is about 68% increased due to increase in skew for class A loading and about 33% decreases for class 70R loading.

7. SCOPE FOR FURTHER STUDY

1) This study is conducted by considering single span simply supported Steel I-girder Bridge, further the study can be made on multiple spans using I- girder or U- girder with cast-in-situ deck slab.

2) In this study effect of seismic and wind are not considered, therefore inclusion of seismic and wind effect (Dynamic effect) can be taken up as the research or study topic.

REFERENCES

[1] Ansuman kar, Vikash Khatri, P.R. Maiti, P. K. Singh (2012) " Study on Effect of skew angle in skew bridges", International Journal of Engineering Research and Development, Vol 2, pp. 13-18

[2] Gholamreza Nouri, Zahed Ahmadi (2012), "Infuence of Skeew Angle on Continuous Composite Girder Bridge", ASCE library visheshwaraya Technological University, Belgaum, pp. 617-623

[3] Himanshu Jaggerwal, Yogesh Bajpai (2014), " Effect of Skewness On Three span Reinforced Concrete T Girder Bridges", International Journal of Computational Engineering Research, vol 4, pp. 2250-3005

[4] M. Ameerutheen, Aravindan (2014). "Study of Stresses on Composite Girder Bridge Over Square and Skew Span", International Journal of Civil Engineering and Technology, Vol 5, pp 88-96

[5] Nikhil V. Deshmukh. U. P. Waghe (2015), " Analysis and Design of Skew Bridges", International Journal of Science and Research, vol 4, pp. 399-402

[6] Patrick Theoret, Bruno Massicotte, David Concistori (2012), " Analysis and Design of Straight and Skewed Slab Bridges", Journal of Bridge Engineering, pp 289-301

[7] Sindhu B. V, Ashwin K. N, Dattatreya J. K., S. V. Dinesh (2013), " Effect of Skew Angle on Static Behaviour of Reinforced Concrete Slab Bridge Decks.

[8] Sujih P. S, Jiji Anna varughese, Tennu Syriac (2015), " Comparative Study on the Behaviour of T- Beam Skew Bridge", Internation journal of Innovative Research in Science, Vol 4, pp. 8287-8295

[9] Vikhas Khatri, P. R. Maiti, P. K. Singh, Ansuman Kar (2012), "Analysis of Skew Bridges using Computational Methods", International Journal of Computational Engineering Research, Vol 2, pp.628-636

BIBLIOGRAPHY

[1] Mahmoud Sayed-Ahmedc, Khaled Sennah (2013). "Finite Element and Model Analysis of 3D Jointless Skewed RC Box Girder Bridge', Concrete Research Letters, vol 4, pp. 557-568

[2] Ankit Gupta, Diwakar prakash Verma, Jagdish Singh Dasouni, Girija Shanker,() "Suitability of POT/PTFE Bearing in Bridges", International Journal of Current Research and Academic Review, vol 2, pp 47-53

[3] Gokhan Pekan, Ahmed Abdel-Mohti (2008) "Seismic Response of Skewed RC Box-Girder Bridges", The 14th World Conference on Earthquake Engineering.

[4] P. Pattatheere, P. Renault (2008), "Seismic Vulnerability Assessment of Skew Bridges", The 14th World Conference on Earthquake Engineering.

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