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Analysis of Skew Bridge using Computational Method

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Abstract - *Bridge is very special type of structures which are characterized by their simplicity in geometry and loading condition. For this study, Dead Load, Impact Load, Vehicular Live Load and Lane Load along with load combination according to IRC & AASHTO are considered. Reinforced concrete T – Beam girder of various skew angle (0°, 15°, 30°, 45°, 60°) and different span (16 m, 18 m, 20 m & 24 m) with 2 lane carriage way is considered. The analysis is done using STAAD Pro Software and grillage method of analysis is used for designing. The skew angle is taken at interval of 15° starting from 0° up to maximum of 60°. The analysis result is present in teams of bending moment, torsion moment, shear force and deflection for T – Beam girder. After end of study conclusion will be made that comparison of skew bridge with normal bridge.*

Key Words: *IRC: 6, IRC: 112, AASHTO LRFD, STAAD Pro, T – Beam Girder.*

1. INTRODUCTION

Bridge is special type of structure which covers separation which carry heaviest responsibility of free flow of transport. Many methods are used for analysis of bridge such as grillage analysis, finite analysis of bridge and many more methods. This method of analysis using grillage analogy, is based on stiffness matrix approach, was made flexible to computer programming. In this analysis the deck is represented an equivalent grillage of beams. The finer grillage mesh provide more accurate results for design purpose which is founded by experiments. If the load is smaller than the grillage mesh, the moments and torque cannot be given by this method. The position of the longitudinal members should be always parallel to the free edges while the orientation of transverse members can be either parallel to the supports or perpendicular to the longitudinal beams. Here we used skew bridge with different angle but the force distribution is complicated compared to normal bridge.

1.1 Skew Bridge

Now days, Skew Bridge is designed due to space construction in congested urban areas and it gives large variety of solution in railway alignment. Analysis calculation does not provide sufficient accuracy for structural design. The change in direction of load path in skew bridge brings about the following special characteristics.

[1] Significant torsional moment in the deck slab.

[2] Decrease in longitudinal moment.

[3] Increase in transverse moment.

[4] Hogging bending moment near the obtuse corners.

[5] Concentration of reaction forces and negative moment at the obtuse corner.

[6] Smaller reaction and possibility of uplift reaction force at the acute corner.

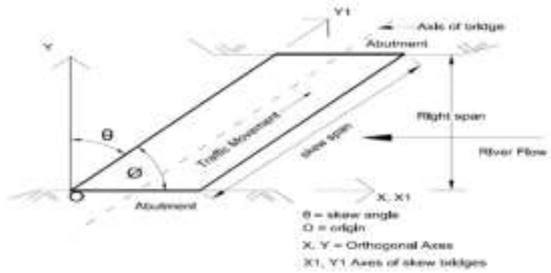

Figure 1 Geometry of Skew bridge

1.2 Guidelines of Grillage Layout

[1] Idealization of Deck into Equivalent Grillage
[2] Location and Direction of Grid Lines
[3] Number and Spacing of Grid Lines

2. LOAD ON BRIDGES

2.1 Dead Load

AS PER IRC: 6 (2014) – Clause 203

The dead load carried by a girder or member shall consist of the portion of the weight of the superstructure which is supported wholly or in part by the girder or member including its own weight. The following unit weights of materials shall be used to determining loads, unless the unit weights have been determined by actual weighing of representative samples of the materials in question, in which case the actual weights as thus determined shall be used.

AS PER AASHTO – Clause 3.5.1

Dead load shall include the weight of all components of the structure and utilities attached thereto, earth cover, wearing surface, future overlays, and planned widening.

2.2 Live Load

As per IRC: 6 (2014) clause 204

IRC Class AA Loading

This loading is to be adopted with in certain municipal limits in certain existing or contemplated industrial areas, in other specified areas, and along certain specified highways. Bridges designed for class AA loading should be checked for class A loading also, as under certain conditions, heavier stresses may occur under class A loading.

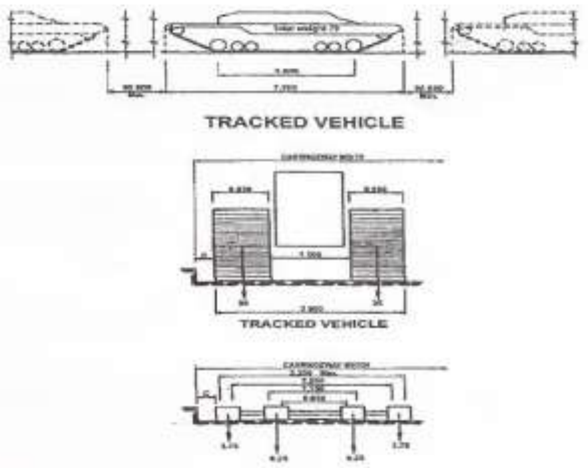

Figure 2 IRC Class AA Tracked and Wheeled Vehicle

Notes :

[1] The nose to tail spacing between two successive vehicle shall not less than 90m.

[2] For multilane, bridges and culverts, each Class AA loading shall be considered to occupy two lanes and no other vehicle shall be allowed in these two lanes. The passing or crossing vehicle can only be allowed on lanes other than these two lanes.

[3] The maximum loads for the wheeled vehicle shall be 20 tonne for single axle or 40 tonne for a bridge of two axles spaced not more than 1.2 m centers.

[4] Class AA loading is applicable only for bridges having carriageway width of 5.3 m and above. The minimum clearance between the road face of the kerb and the outer edge of the wheel or track, 'C', shall be 1.2 m.

[5] Axle loads are in tonne. Linear dimensions in meter.

IRC Class A Loading

This loading is to be normally adopted on all roads on which permanent bridges and culverts are constructed.

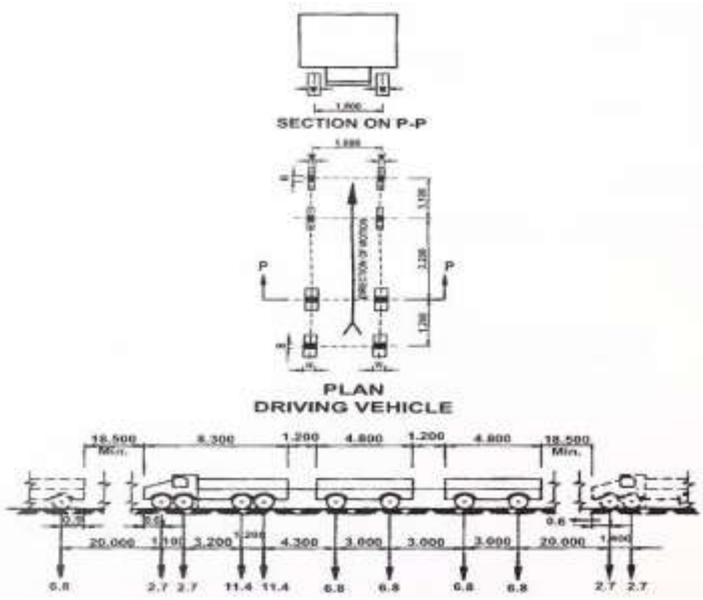

Figure 3 IRC Class A Tracked and Wheeled vehicle

Notes :

[1] The nose to tail distance between successive trains shall not be less than 18.5 m.

[2] For single lane bridges having carriage way width less than 5.3 m, one lane of class A shall be considered to occupy 2.3 m. Remaining width of carriageway shall be loaded with 500 kg/m^2.

[3] For multi-lane brides each class a loading shall be considered to occupy single lane for design purpose.

Similarly, Class B and Class 70 R loading Vehicle details are given in Indian Standard 6 (2014 code.

As Per AASHTO

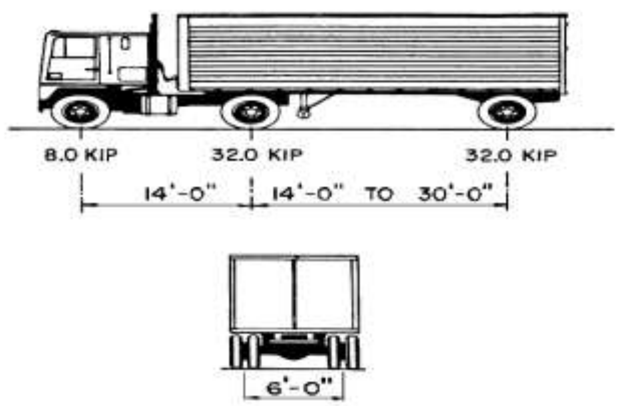

Figure 4 AASHTO Design truck

Design Truck

A dynamic allowance shall be considered. The spacing between the two 32.0 kip axles shall be varied between 14.0 ft and 30.0 ft to produce extreme force effect.

Design Tandem

The design tandem shall consist of a pair of 25.0 kip axles spaced 4.0 ft apart. The transverse spacing of wheels shall be taken as 6.0 ft. A dynamic load allowance shall be considered.

Design Lane Load

The design load shall consist of a load of 0.64 klf uniformly distributed in the longitudinal direction. Transversely, the design lane load shall be assumed to be uniformly distributed over a 10.0 ft width. The force effects from design lane load shall not be subject to a dynamic load allowance.

Tire Contact Area

The tire contact area of a wheel consisting of one or two tires shall be assumed to be single rectangle whose width is 20.0 in. and whose length is 10.0 in. This area load applies only to the design truck and tandem. For other design vehicles, the tire contact area should be determined as follows:

Tire Width = P / 8

Tire Length = 6.4 λ (1 + IM/100)

Where,

P = Design Wheel Load (kip)

IM = Dynamic Load allowance (%)

ɣ = Load Factor

Notes,

[1] This loading comprises of a heavy tractor truck with a semi trailer of total load of 320.3 kn or the corresponding lane loading.

[2] The lane load of uniformly distributed load of intensity 9.3 kn/m together with knife edge load of 80 kn for bending moment and 115.7 kn for shear force computations.

[3] In addition, impact effect is to be added for both the cases as recommended by the AASHTO recommendations.

[4] While designing bridges, both the truck and lane loading should be considered and the one which gives worst condition gives the worst effect is to be adopted.

[5] When truck loading is used, only one truck is considered for each traffic lane for the whole of its length. Also there is no reduction in load intensity for up to two lanes of traffic loaded.

3. DESIGN EXAPLE

1. Overall span of Bridge = 20.0 m
2. Effective Span = 19.20 m
3. Centre-to-Centre of Longitudinal Girder = 2.50 m
4. Center-to-Center of Transverse Girder = 5.0 m
5. Number of Longitudinal Girder = 3 Nos.
6. Depth of Girder = 1.75 m
7. Depth of Slab = 0.250 m
8. Thickness of Wearing Coat = 0.080 m
9. Width of Carriageway = 7.500 m
10. Width of Kerb = 0.375 m
11. Depth of Kerb = 0.550 m
12. Overall width of Super Structure = 8.25 m
13. Grade of Concrete = M35
14. Grade of Reinforced Steel = Fe415
15. Density of Reinforced Concrete As Per IRC = 25 KN/m^3
16. Density of Reinforced Concrete As Per AASHTO = $23KN/m^3$

LOAD CONSIDERATION

Table 1 Load Consideration in design

Sr. No.	Load Consideration	As Per IRC	As Per AASHTO
1	Dead Load	As Per IRC: 6 (2014) Clause 203	As Per AASHTO – LRFD Clause 3.5.1
2	Live Load	As Per IRC: 6 (2014) Clause 204 i. 2 Lanes of Class A Wheeled Loading ii. 1 Lanes of Class 70 R Wheeled Loading	As Per AASHTO – LRFD(2012) Clause 3.6.1.2 i. Design Truck HL 93 k + Design Lane Load - for all lane
3	Impact Load	As Per IRC: 6 (2014) Clause 208 i. For Class A Wheeled Loading Impact Factor, IM =(4.5 / 6 + L)= 15 % ii. Class 70R Wheeled loading, IM = 15%	As Per AASHTO – LRFD(2012) Clause 3.6.2, Impact Factor is 33%
4	Load Combination	As Per IRC: 6 (2014) i. Governing Load Combination = 1.35DC + 1.75 DW + 1.50 (LL+ IM)	As Per AASHTO – LRFD(2012) i. Governing Load Combination =1.25 DC + 1.50 DW + 1.75 (LL + IM)

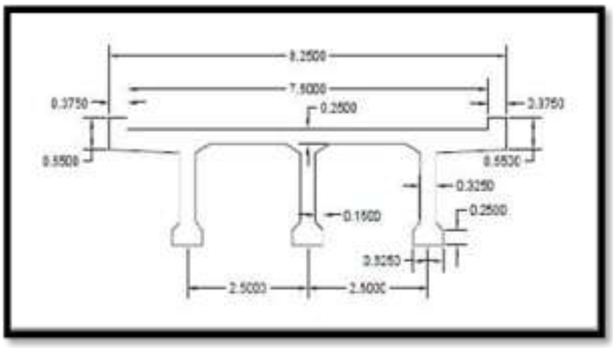

Figure 5 Cross section of T Beam Bridge

STAAD MODEL

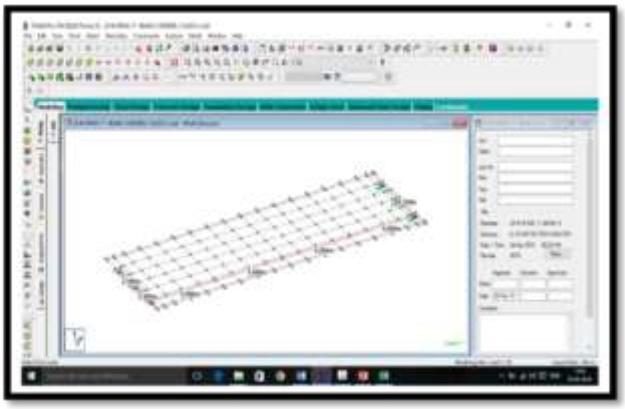

Figure 6 Screen Shot of 3D Model Generated in STAAD (0° Skew Bridge)

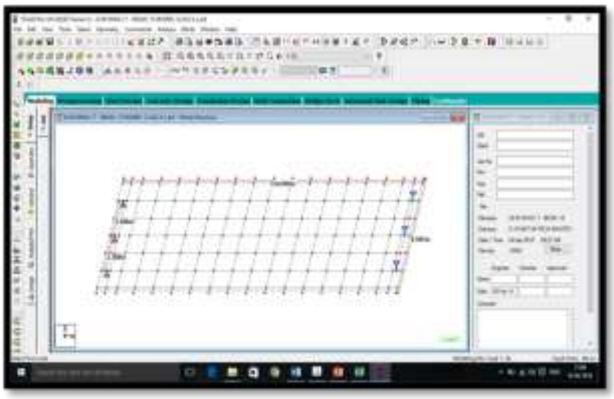

Figure 7 Screen Shot of 3D Model Generated in STAAD (15° Skew Bridge)

Similarly, Here We will create mesh for 30°, 45° and 60° in Staad Pro Software.

Analysis Summary

STAAD Pro is utilized for analysis purpose. The following are analysis summary including all load combination for both IRC & AASHTO code.

Table 2 SF, BM and TM Summary for 0 Degree Skew Bridge (Outer Girder-24 m Span) – As Per IRC & AASHTO Load and IRC & AASHTO Load Combination

24M Span - 0 Degree Skew - Outer Girder							
	Section	**Support**			**Mid Span**		
		SF (KN)	BM (KN.m)	TM (KN.m)	SF (KN)	BM (KN.m)	TM (KN.m)
1	DC	481.0	131.0	38.0	60.4	2727.0	9.2
2	DW	49.5	14.2	2.90	4.3	286.0	0.64
3	Class 70 R Wheeled	350.0	114.0	5.99	126.0	1675.0	25.7
4	Class A Wheeled	319.0	95.9	4.61	85.9	1479.0	19.9
	Max (3,4)	350.0	114.0	6.0	126.0	1675.0	25.7
5	HL 93 K	202.0	61.3	1.6	83.0	1215.0	5.2
6	Lane Load	68.4	19.3	0.015	6.1	388.0	0.435
	5 + 6	270.4	80.6	1.6	89.1	1603.0	5.6
	IRC COMBO						
7	1.35DC + 1.75DW + 1.50LL	481.0	131.0	38.0	278.1	6694.5	52.0
	AASHTO COMBO						
8	1.25DC + 1.50DW + 1.75LL	1148.7	326.1	54.7	237.9	6643.0	22.2

Table 3 SF, BM and TM Summary for 0 Degree Skew Bridge (Inner Girder-24 m Span) – As Per IRC & AASHTO Load and IRC & AASHTO Load Combination

24M Span - 0 Degree Skew - Inner Girder							
Sr NO.	**Section**	**Support**			**Mid Span**		
		SF (KN)	BM (KN.m)	TM (KN.m)	SF (KN)	BM (KN.m)	TM (KN.m)
1	DC	460.0	140.0	0.0	74.1	2800.0	0.0
2	DW	48.0	14.9	0.0	4.8	293.0	0.0
3	Class 70 R Wheeled	297.0	75.0	8.40	106.0	1575.0	36.4
4	Class A Wheeled	271.0	85.1	136.00	90.9	1436.0	54.9
	Max (3,4)	297.0	85.1	136.0	106.0	1575.0	54.9
5	HL 93 K	195.0	65.6	0.0	88.0	1262.0	0.0
6	Lane Load	64.4	19.7	0.000	5.5	399.0	0.000
	5 + 6	259.4	85.3	0.0	93.5	1661.0	0.0
	IRC COMBO						
7	1.35DC + 1.75DW + 1.50LL	1150.5	342.7	204.0	267.4	6655.3	82.4
	AASHTO COMBO						
8	1.25DC + 1.50DW + 1.75LL	1101.0	346.6	0.0	263.4	6846.3	0.0

Similarly, Here We will use different load combination as per IRC and AASHTO for different span length (24m, 20m, 18m, 16m) for different skew angle (0°, 15°, 30°, 45°, and 60°) of Outer and Inner Girder. We can also calculate SF, BM, and TM at different location of the bridge such as support, 1/8th span, 1/4th span, 3/8th span, 1/2th span.

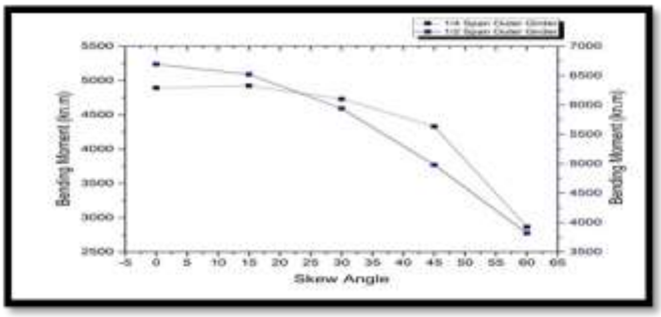

Figure 8 BM Comparison Graph for Outer Girder (24 m Span) As Per IRC Load Combination

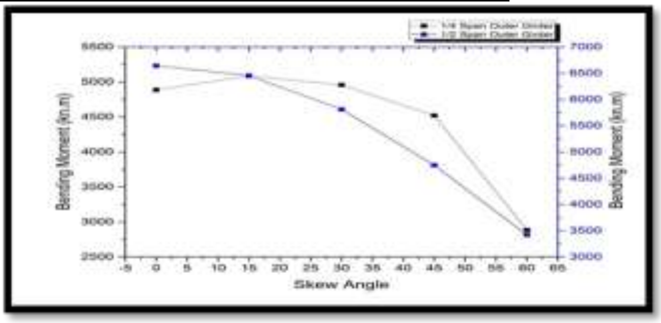

Figure 9 BM Comparison Graph for Outer Girder (24 m Span) As Per AASHTO Load Combination

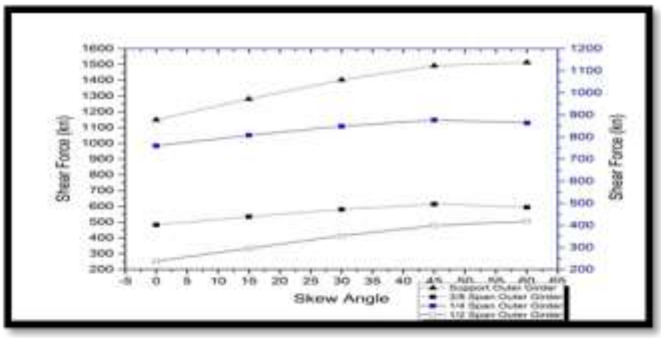

Figure 10 SF Comparison Graph for Outer Girder (24 m Span) As Per IRC Load Combination

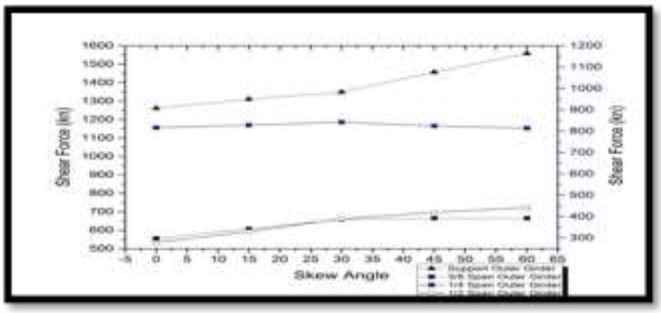

Figure 11 SF Comparison Graph for Outer Girder (24 m Span) As Per AASHTO Load Combination

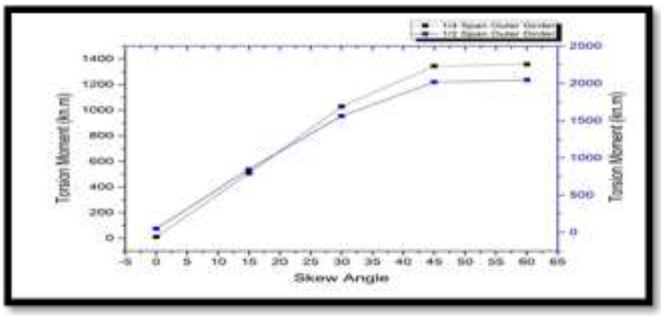

Figure 12 TM Comparison Graph for Outer Girder (24m Span) As Per IRC Load Combination

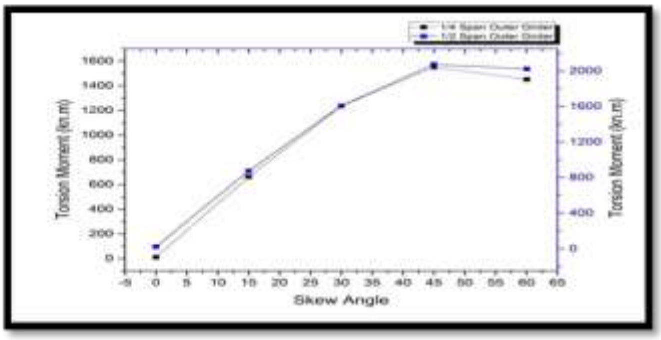

Figure 13 TM Comparison Graph for Outer Girder (24m Span) As Per IRC Load Combination

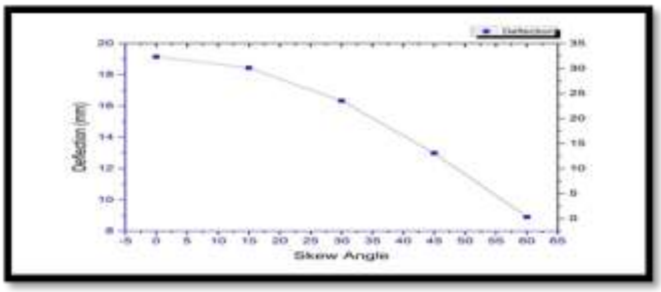

Figure 14 Deflection Comparison Graph AS Per Dead Load & IRC Live Load (24 m Span)

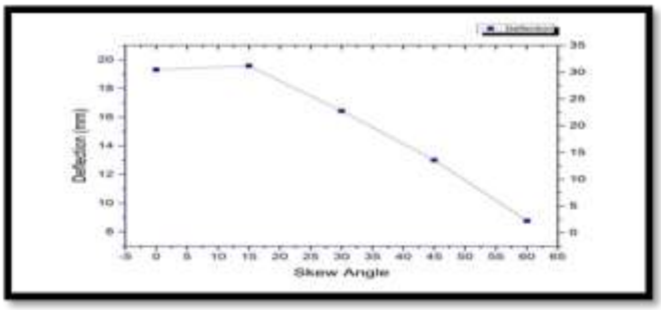

Figure 15 Deflection Comparison Graph AS Per Dead Load & IRC Live Load (24 m Span)

Remark

1. Bending Moment decreases with increasing Skew Angle, it decreased around 42.94 % & 42.44 %, compared to right bridge As per IRC Load Combination in case of Outer Girder and Inner Girder Respectively.
2. Bending Moment decreases with increasing Skew Angle, it decreased around 48.50 % & 45.26 %, compared to right bridge As per AASHTO Load Combination in case of Outer Girder and Inner Girder Respectively.
3. Shear Force increases with increasing Skew Angle, it increased around 19.09 % & 13.15 %, Compared to right bridge As per RC Load Combination in case of Outer Girder and Inner Girder Respectively.
4. Shear Force increases with increasing Skew Angle, it increased around 24.06 % Compared to right bridge As per AASHTO Load Combination in case of Outer Girder and result of Shear Force shows mix pattern in case of Inner Girder.
5. Torsion Moment increases with increasing Skew Angle, it increased around 97.45 % & 96.35 %, Compared to right bridge As per IRC Load Combination in case of Outer Girder and Inner Girder Respectively.
6. Torsion Moment increases with increasing Skew Angle, it increased around 98.9 % & 99.9 %, Compared to right bridge As per AASHTO Load Combination in case of Outer Girder and Inner Girder Respectively.
7. Deflection decreases with increasing Skew Angle, it decreased around 53.52 % & 54.58 % Compared to right bridge in case of IRC & AASHTO load combination Respectively.

4. CONCLUSION

Bending moments and deflection decreases with increasing Skew Angle (0°, 15°, 30°, 45°, 60°), it decreased compared to right bridge As per IRC and AASHTO Load Combination in case of Outer Girder and Inner Girder. Ironically, Shear Force and Torsion moment increases with increasing Skew Angle, it increased compared to right bridge IRC and AASHTO Load Combination in case of Outer Girder and Inner Girder.

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