A Comparative Study on T-beam Girder and Box Girder Bridges for Different Skew Angles

Ankush H. Patel and Spurti Mamadapur

Abstract--- *To cater the need of rapid urbanisation construction of bridges becomes the need of the time. It is often found that there is a need to change the layout of the bridge or to skew it by certain angle due to the presence of natural or man-made obstacles like river crosses, important structures, etc. Due to this it is often necessary to construct bridges with a certain skew angle. Skew angle can be defined as the angle subtended by the center line of the support and the global vertical direction. The response of the bridge structure depends on many factors like the cross-sectional parameters, span of the bridge, skew angle, type of live load, etc. In the current dissertation a study is carried out to understand the behavior of a two lane skew T-beam bridge and a skew box girder bridge for a fixed span of 20m and skew angles of 10°, 20°, 30°, 40°, 50° and 60°. The live load considered on the bridge are IRC Class AA Tracked and IRC Class A Train. Modeling and analysis of all the bridge models was performed in SAP2000 (Version 14) software after validating it with the values obtained by manual calculations. The analysis results for bending moment on girders/web, shear force on girder/web and bending moment on deck slab are obtained and compared with the results obtained for a normal bridge along with the comparison for different live loads.*

Keywords--- *Skew Angle, SAP2000, T-Beam, Box Girder, Dead Load, IRC Class AA Tracked and IRC Class A Train.*

I. INTRODUCTION

A. Bridge

A Bridge can be defined as an elevated structure above the ground level for easy and comfortable flow of traffic. Bridges are usually provided to cross over any obstacles like flowing water, railway lines, important buildings, etc. Bridges are sometimes also provided for better connectivity in the city areas helping in providing emergency routes, medical aids. Depending on the type of load it carries brides are classified into Roadway bridges, Railway bridges, Pedestrian walks, etc. Roadway bridges are most widely used and studied as roadway is the most commonly used way of transportation.

B. T-Beam Bridge

A T-Beam bridge can be said to be a load bearing structure which resembles the shape of letter "T" in cross-section. T-beam sections are usually of reinforced cement concrete (RCC) structures or composite structure with steel longitudinal girders. However RCC longitudinal structure casted monolithically with RCC slabs are most widely used and advantageous. Transverse cross girders are also provided in the bridge section to resist transverse stresses in the bridge. The number of longitudinal and cross girders is usually decided based on the span and width of the bridge.

C. Box Girder Bridge

Box girder bridges are the bridges which resemble the shape of a box in the cross-sectional view. It usually has two vertical webs connected by two horizontal flanges at the top as well as at the bottom of the web. However in many designs intermediate webs are also sometimes provided to have a multi-cell type of box girder bridge. Box girders bridges are widely used today due to its various advantages over slab and beam type of bridges. Box girder bridges have found its wide spread importance in long span bridges. Box girder bridges are usually in the pre stressed concrete form for long span bridges. However, RCC box girder bridges are also being used for medium spans. Box girder bridges are preferred over slab and beam type of bridges as it provides better structural efficiency and stability, economy and pleasing appearance for long span bridges.

D. Skew bridge

A skew bridge is one whose longitudinal axis that is the direction of flow of traffic is not perpendicular to the axis of the support or abutment. The angle that the transverse axis of the bridge or the support makes with the vertical is known as a skew angle. The behavior of a skew bridge differs from that of a normal straight bridge due to the presence of the skew angle. In case of straight bridges the load distribution path is straight in two directions (General X and Y co-ordinate axis directions) whereas for a skewed bridge the load distribution takes the shortest possible paths between the two nearest supports [13]. Figure 1 shows the load distribution for normal and skewed bridges.

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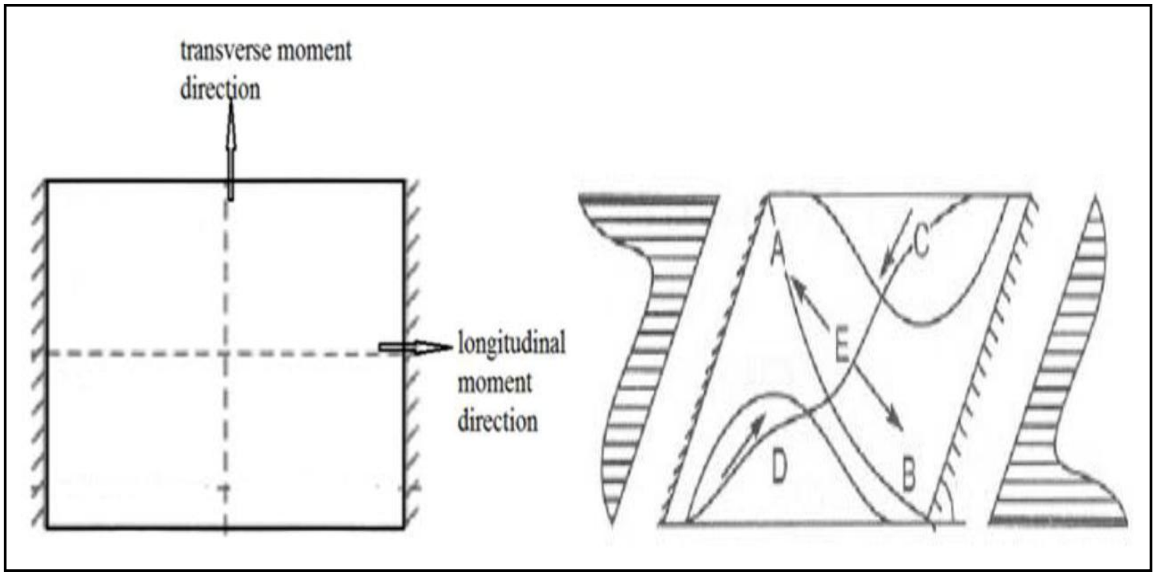


Figure 1: Load Distribution in a Bridge

E. Objective

The present study is carried out to study the behavior of T-beam girder and box girder under different live loads conditions for different skew angles. The results so obtained are compared with that of normal bridge.

II. MODELING

A. Finite Element Analysis

Finite Element Method (F.E.M.) involves solving a complex problem by discretizing it into a number of elements known as finite elements. Finite elements are held together by nodes. The finite elements connected by nodes are assumed to possess two dimensional or three dimensional degrees of freedom according to the requirement of the designer. At first, when F.E.M. was introduced it was initially used just to solve two dimensional problems but ever since then the method has grown widely now to solve complex problems of structural analysis with an ease. F.E.M. today is being used to solve complex problems of civil, aeronautical and mechanical engineering. F.E.M. provides a complete tool for designing a problem, refine it and optimize the solutions obtained as per the requirement. Due to this advantage the importance and use of F.E.M. for the purpose of analyzing bridge model problems has increased considerably.

Problem Definition

Span	20 m
Carriage-way width	7.5 m
Overall Depth	2000 mm
Kerbs	1 m x 0.5 m
Width of T-beam and cross beam	300 mm
Depth of top slab	200 mm
Thickness of wearing coat	80 mm
C/C distance of T-beam	2.5 m
C/C distance of cross beam	4 m
Grade of concrete	M25
Grade of steel	Fe415
Live Load - IRC Class AA Tracked and A Train	
Variation in skew angle	0^o to 60^o
Type of box girder	Single Cell
Width of web	300 mm
Depth of top slab	200 mm
Thickness of the bottom slab	200 mm
C/C distance between the webs	5.0 m

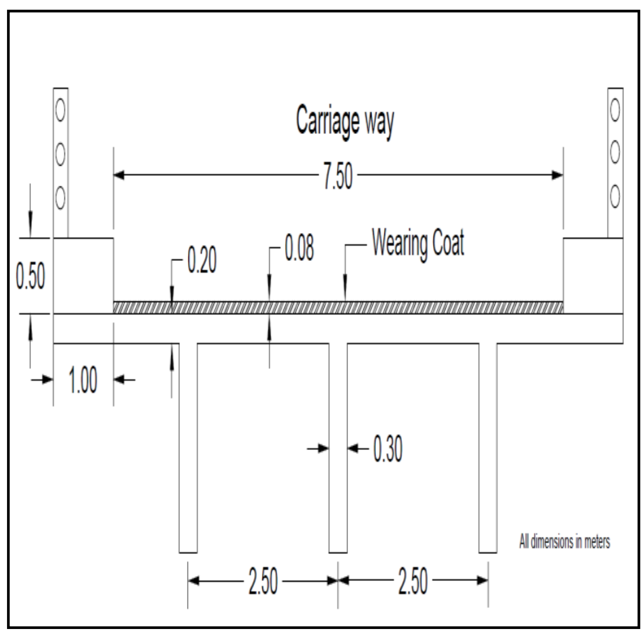


Figure 2: Cross Section of T-Beam Bridge

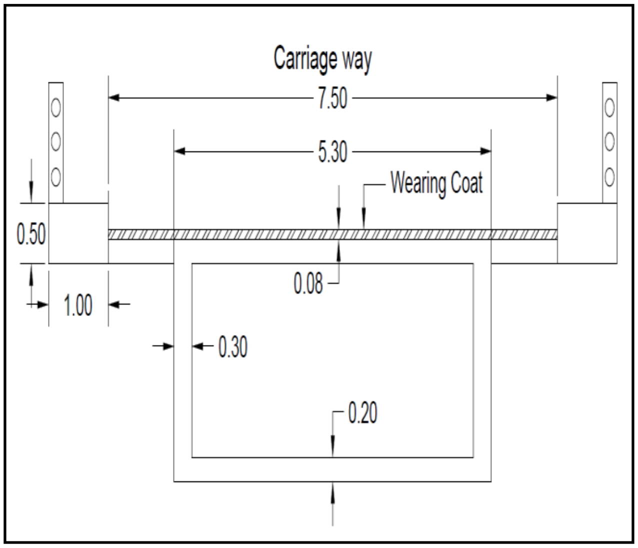


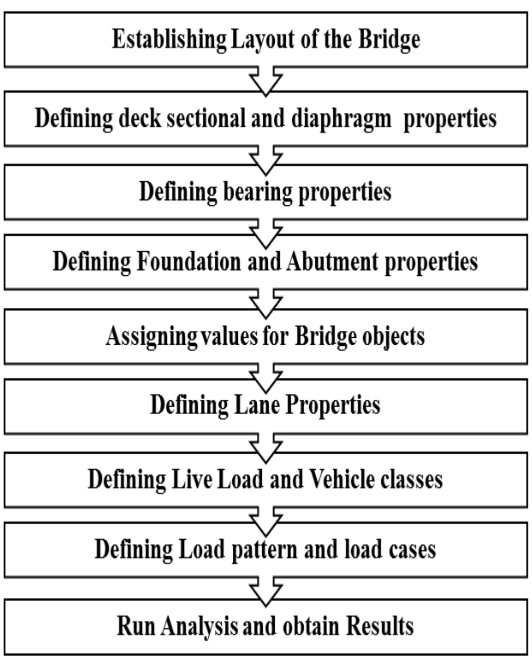
Figure 3: Cross Section of Box Girder Bridge

B. List of Models

In all 28 models are being modeled 14 each for T-beam girder and box girder bridge as follows

No.	Skew angle (°)	Type of Live load	No.	Skew angle (°)	Type of Live load
1.	0	AA Tracked	8.	0	A Train
2.	10	AA Tracked	9.	10	A Train
3.	20	AA Tracked	10.	20	A Train
4.	30	AA Tracked	11.	30	A Train
5.	40	AA Tracked	12.	40	A Train
6.	50	AA Tracked	13.	50	A Train
7.	60	AA Tracked	14.	60	A Train

C. Steps to Model in SAP2000



III. Results and Discussion

The variations observed in all the models for bending moment, vertical shear force, torsion for the longitudinal girders and stresses in the deck slab are tabulated and discussed in the following sections. The results are tabulated for Dead Load + Live Load combination.

For T- beam

Bending Moment

1. AA Tracked

The maximum value of bending moment for the outer girder decreases along with the increase in the skew angle from 0º to 60º. It is also observed that the point of maximum bending point shifts towards the first half of the span for 50º and 60º skew angles.

The maximum bending moment at the inner girder decreases with the increase in the skew angle up to a skew angle of 30º and it increases from 40º skew angle.

2. A Train

Bending moment for the outer girder decreases along with the increase in the skew angle. The percentage decrement for 60º skew of the bridge is 12%. It is observed that the point of maximum bending moment shift towards the first half for 60º skew angle.

The maximum bending moment for the inner girder increases along with the increase in the skew angle. The percentage increase at 60º skew angle is 6.57%. The behavior of the point of maximum bending moment follows the similar pattern and shifts towards the first half of the span.

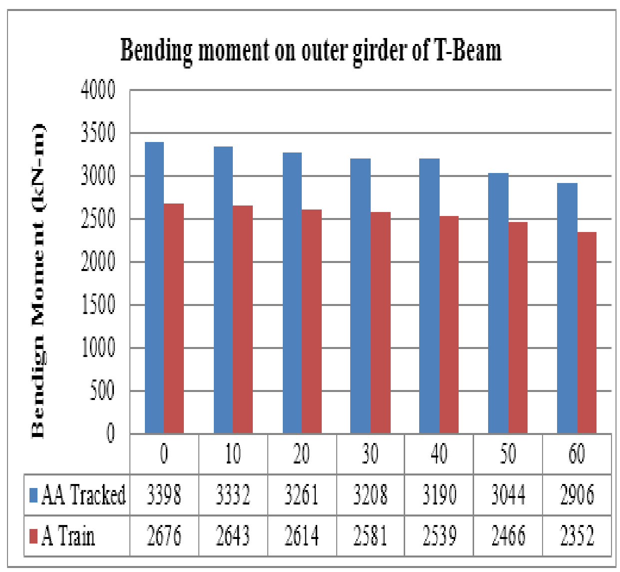
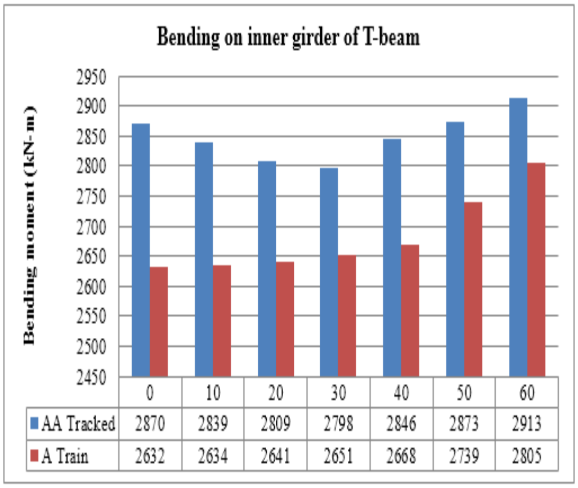


Figure 4: Bending Moment on Outer Girder for Different Skew Angles



	0	10	20	30	40	50	60
AA Tracked	2870	2839	2809	2798	2846	2873	2913
A Train	2632	2634	2641	2651	2668	2739	2805

Figure 5: Bending Moment on Inner Girder for Different Skew Angles

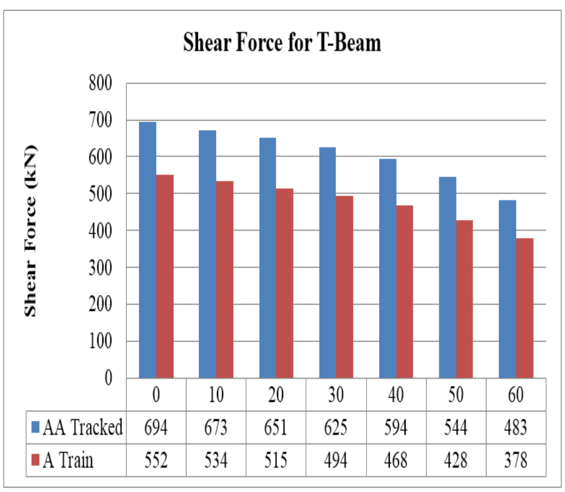
Shear Force

1. AA Tracked

The maximum shear force on the girder decreases as skew angle increases from 0º to 60º. The percentage decrease for 60º skew is 30.39%.

2. A Train

Shear force is maximum for a straight bridge and it decreases till the skew angle of 60º. The percentage decrement in the shear force value is 31.54%.



	0	10	20	30	40	50	60
AA Tracked	694	673	651	625	594	544	483
A Train	552	534	515	494	468	428	378

Figure 6: Shear Force of T-Beam for Different Skew Angles

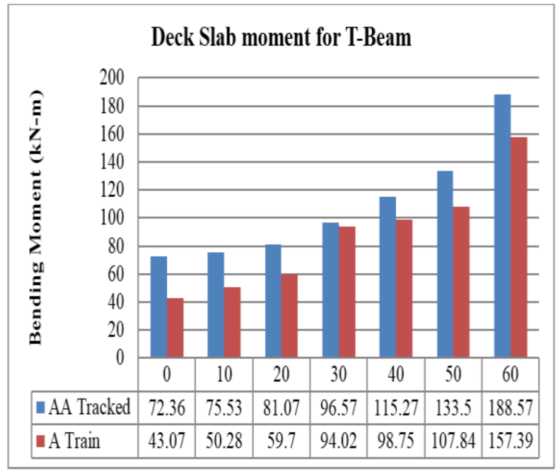
Deck Slab Moment

1. AA Tracked

The bending moment developed in the deck slab of the T-Beam increases along with the increase in the skew angle. The bending moment is maximum for 60º with an increase of 61.67%.

2. A Train

Bending moment generated in the deck slab is minimum for a straight bridge. It increases by 68.07% to be maximum at 60º skew angle.



	0	10	20	30	40	50	60
AA Tracked	72.36	75.53	81.07	96.57	115.27	133.5	188.57
A Train	43.07	50.28	59.7	94.02	98.75	107.84	157.39

Figure 7: Deck Slab Moment of T-Beam for Different Skew Angles

For Box Girder

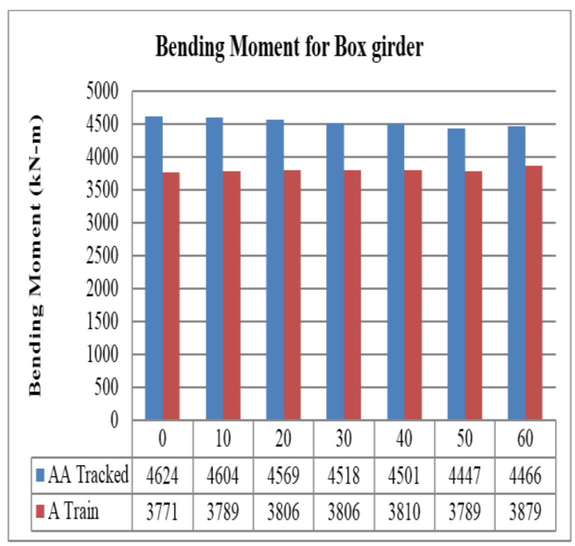
Bending Moment

1. AA Tracked

The bending moment generated in the web of the box girder decreases as the skew angle increases from 0º to 60º. It is observed that the point of maximum bending moment shifts towards the first half of the span for the skew angles of 40º and above.

2. A Train

Bending moment increases along with the increase in the skew angle. However the percentage increase is small. The maximum bending moment found at 60º skew angle is 2.87% more than that for a straight bridge.



	0	10	20	30	40	50	60
AA Tracked	4624	4604	4569	4518	4501	4447	4466
A Train	3771	3789	3806	3806	3810	3789	3879

Figure 8: Bending Moment of Box Girder for Different Skew Angles

Shear Force

1. AA Tracked

The shear force developed in the web decreases as the skew angle increases from 0º to 60º. The percentage decrease in the shear force for 60º skew is 24.87%.

2. A Train

The shear force generated in the web of the girder is observed to decrease as the skew angle increases. The percentage decrement for 60º skew angle is 28%.

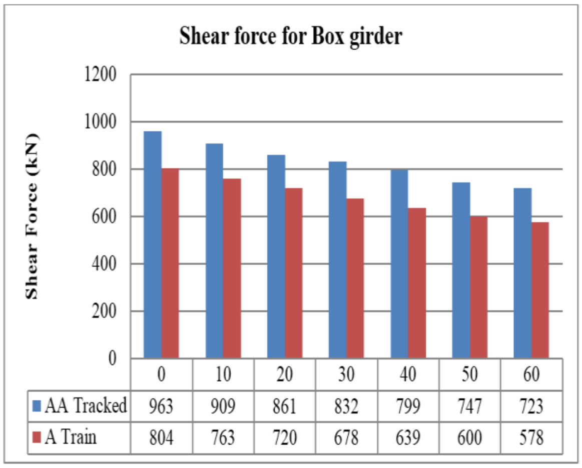


Figure 9: Shear Force of Box Girder for Different Skew Angles

Deck Slab Moment

1. AA Tracked

The bending moment developed in the slab of the girder decreases initially till 20º with a percentage decrement at 20º skew angle of 25.05%. The bending moment generated in the slab increases rapidly for skew angles greater than 30º.

2. A Train

The bending moment generated in the deck slab of the bridge follows the same pattern as that of AA Tracked live load. It decreases by 4.70% at 20º skew angle after which it increases by 61.61% for 60º skew angle.

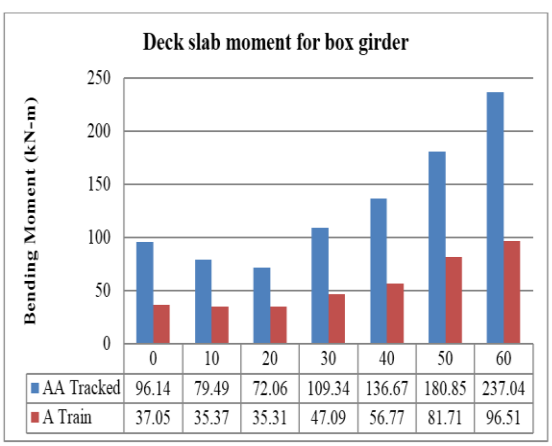


Figure 10: Deck Slab Moment of Box Girder for Different Skew Angles

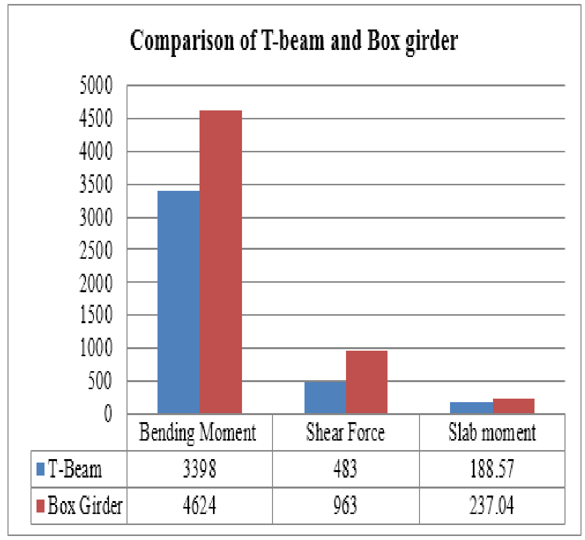


Figure 11: Comparison of T-Beam and Box Girder Bridge

IV. Conclusion

In the present study comparison of various parameters like live load, skew angles and different cross-sections is carried out, the conclusions drawn from the work carried out are listed below.

1. The longitudinal bending moment on the obtuse angled girder of the T-beam decreases as the skew angle increases whereas for the inner girder it decreases till a skew angle of 30º and it further increases till the skew angle of 60º. Similarly for the obtuse angled web of the box girder the bending moment decreases and it increases for the acute angled web. This is because the centerline of the bridge or the traffic flow is not parallel to the plane of maximum stress.
2. The shear force for both T-beam and box girder bridges decreases as the skew angle increases.
3. The deck slab moments generated also increases along with the increase in the skew angle due to wrapping of deck.
4. It is observed that the stresses generated by IRC Class AA Tracked vehicle are more compared to IRC Class A Train vehicle. Indicating that the bridges designed using IRC Class AA Tracked can be adopted for multipurpose use.
5. Comparing the results of longitudinal bending moment, shear force and torsional moment suggest that T-beam section is better than box girder section for medium span bridges.
6. SAP2000 software is useful in developing bridge models and providing comparable results.

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