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Study on Behaviour of Skew PSC Box Girder Bridge

Mr. Praveen Naik[1], Dr. R. Shreedhar[2]
[1]PG Student, [2]Professor, Dept. of Civil Engineering Gogte Institute of Technology , Belagavi., Visvesvaraya Technological University Belagavi

Abstract: Skew bridges are built where geometry cannot accommodate straight bridge. The most common and basic type of bridge, that is widely used for roadways is Girder Bridge. The two most common types of girders that are used in practice are beam and Box Girders. Though box girder design is more complicated, it has wide acceptance due to their structural efficiency, aesthetic appearance, better stability and serviceability. Over years simple RCC box girders used for short spans resulted in long span prestressed concrete bridges. The use of pre-stressing enables concrete bridge beams to span long distances. Box girders are constructed in single cell, double cell or multicell. Generally bridge with a skew angle less than 20° is designed as normal bridge. If it is more than 20° there is change in the behavior of the skew bridge. Thus Geometry and behavior of skew bridge are affected by the presence of skew angle. The Structural response of skewed bridge to stresses in slab and reactions on abutments can be significantly altered by the skew angle of the substructure. The objective of present study is to compare normal and skew bridge of box girder type, with parameter such as bending moments, shear forces & torsional moments for two span deck slab by considering IRC CLASS AA TRACKED loading. A simply supported two span, two lane PSC slab bridge deck is considered in the present study. The different bridge spans considered are 50m, 60m and 70 m and skew angle is varied from 0° to 60° at 15° interval. The analysis has been carried out using SAP 2000 software.

Keyword: Skew angle, Skew Bridge, FEM analysis, Bending moment, Shear force & Torsional moment.

I. INTRODUCTION

Cellular box girder bridges decks with multiple cells are being increasingly adopted for urban fly overs & long span bridges in preference to the traditional tee beam & slab bridges decks due to their inherent advantages. The development of cantilever construction techniques by Finisterwalder using pre cast or cast in situ elements has paved the way for use of multi-celled modular units for bridge decks. Segmental bridges deck construction by free cantilever method for long spans compensates for the high cost of tall piers & deep foundations. According to Raina, cantilever construction is ideally suited for box girders decks & method of construction is elegantly convenient & cost effective in comparison with other traditional methods.

The cellular segments 2.5 to 3 m long can either be cast in situ on travelling gantries or can be precast in a yard & erected by launching truss or floating cranes. In the case of bridges with fewer spans, it is more economical to adopt in situ construction. In the case of long span bridges, progress of work is speeded up by using precast element.

A. Skew Bridge

A bridge is said to be skew bridge when stream crosses the road at an angle other than 90˚. Construction of skew bridges effects in saving of time and traffic requirements. The stresses in skew slab are considerably influenced by the skew angle. Loads applied on the deck slab are transferred to the supports by the strips which are perpendicular to the faces of abutments and piers. Hence the planes of maximum stresses are not corresponding to the centre line of roadway & the slab inclines to be warped, resulting in larger reactions at obtuse angled end of slab.

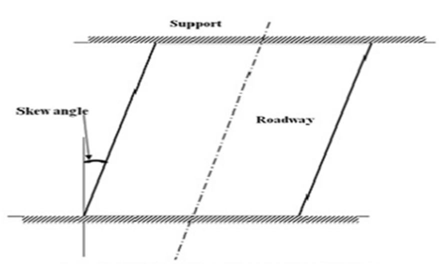

Fig. 1 Typical skew bridge

B. Need For Study

Nowadays large programming and computing skills are available, but the analysis of box girder skew bridge requires advancement. Hence this provides more scope for more research in the field of skew bridges. The lack in the knowledge to know the effects of the disproportionate distribution of the dead loads and live loads on super structure with skew angle demands further study. So in the present work, the distribution of bending moment, shear force and torsion in the girders have been studied.

II. LITERATURE REVIEW

Pranithi Reddy, Karuna S, In this paper study has been conducted on normal & skew PSC box girder. The effect of skew angle on bending moment & shear force under same loading "IRC CLASS 70R" was studied. Analysis was conducted using SAP 2000 software.It was concluded that for two or three spans under dead load the bending moment reduce as rise in skew angle & under live load bending moment rises as there is rise in skew angle. Similarly shear force under dead load reduces as rise in skew angle & under live load shear force rises as skew angle rises [1]. Omkar Velhal, J.P.Patankar, in this paper the behavioral characteristics of skew T-beam bridges are studied & equated those with straight bridges by FEM. The effect of skew angle is witnessed on maximum bending moment, maximum shear force & maximum torsional moment, maximum deflection due to dead load & live load at acute locations. Live load "IRC Class AA Tracked Vehicle" is applied as per IRC: 6 2000 guidelines. This study indicates that the influence of skew angle on torsional moment of longitudinal girder is substantially high, hence it is significant to consider torsional moment while designing skew bridges [2]. Sujith P S, Dr. Jiji Anna Varughese, Tennu Syriac This paper consists of study on the behavior of T-beam skew bridges with respect to support reactions, shear force, bending moment under standard "IRC Class AA" loading & the study also relates analytical modeling of T-beam bridges by Grillage analogy method & FEM. It is found that FEM gives more efficient design compared to Grillage analysis. With escalation in skew angle, the stresses in slab vary considerably from those in right angle slab & reaction is increased with increase in skew angle [3]. Mallikarjun.I.G, Ashwin K.N, Dattatreya J.K, Dr. S.V Dinesh This paper shows the effect of skew angle on single span reinforced concrete bridges & PSC bridges using FEM. Study is carried out on RC slab bridge decks & PSC bridge decks by varying aspect ratio, skew angle & type of load. The FEM results for skewed bridges are compared with those of right angled bridges under "IRC Class A" loading. The FEA results of dead load & live load longitudinal bending moments reduce with rise in skew angle & maximum torsional moment rises with surge in skew angle & the maximum longitudinal stresses reduce with skew angle upto 30^0 & thereafter escalates [4]. Deepak C, Sabeena MV, In this study finite element modelling of simply supported skew slab with variable skew angles using ANSYS software. The performance of simply supported skew slab under point load applied at the centre rests on the ratio of short diagonal to its span. Skew slabs with ratio of short diagonal to span less than unity indicate lifting of acute corners while slabs with ratio of short diagonal to span greater than unity do not. For study, skew angles varying from 0^0 to 30^0 were taken. After the nonlinear FEA of all skew slabs it is observed that when skew angle surges the uplift at both the acute corners also upsurges. The results also indicate that load carrying capacity enhances with rise in skew angle [5]. Nikhil V. Deshmukh, Dr. U P.Waghe This paper comprises of analysis & design of skew bridges by FEM under "IRC CLASS A" loading. Study was conducted for shear force, bending moment & torsional force as parameter & it was concluded that for a skew angle upto 15^0 there is a rise in shear force & thereon it gets reduced when there is rise in skew angle. Bending moment & torsional moment are higher when there is rise in skew angle [6].

III. OBJECTIVE AND METHODOLOGY

A. Objective

The objectives of the present study have been mentioned below:

1) Analysis of box girder for different span & different skew angles.
2) Comparison of maximum bending moment, shear force & torsional force for different skew angles. & for different spans.

B. Methodology

Different methods are available for analysis of box girder. FEM is one method available when structure under study exposed to high degree of intricacy. This method idealizes actual range as the equivalent structure made up of elemental points known as finite elements linked together at number of joints.

In the present study a PSC Box girder is taken for analysis. PSC Box girder of different spans i.e 50m, 60m, & 70m & different skew angles i.e., 0^0,15^0,30^0,45^0, & 60^0 are modelled & analysed using SAP 2000 software. The parameters such as bending moment, shear force & torsional moment are compared for different span & different skew angles. The models are executed referring to posttensioned properties.

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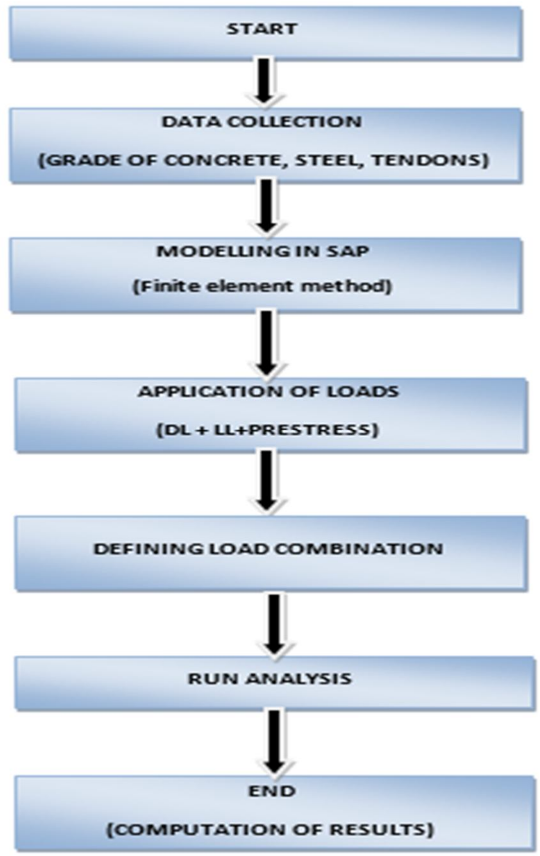


Fig 2: Flow chart procedure for modelling & analysis.

C. Model Description

DATA

Span = 50 m, 60m & 70m

Cross section - Multi celled box girder

Cell dimensions - 2 m X 2 m width & depth respectively

Road width - 7.5 m

Wearing coat -80 mm

Thickness of web - 300 mm to house 27K-15 Freyssinet type anchorages (27 strands of 15.2 mm diameter in 110 mm diameter cables)

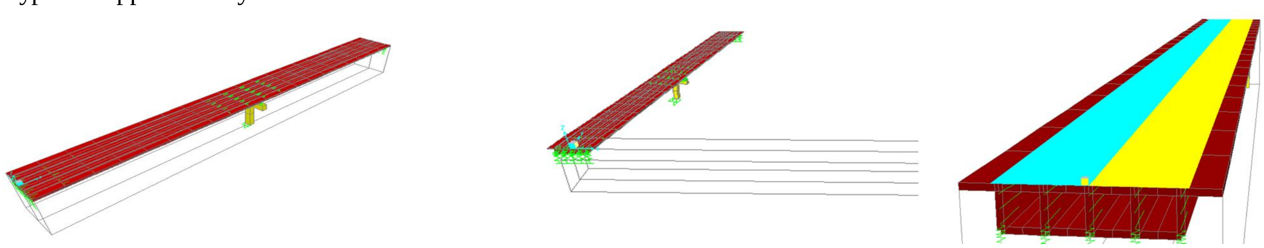
Thickness of top and bottom slabs - 300 mm

Concrete grade - M40

Loss ratio - 0.8

Type of tendons - High tensile strands of 15.2 mm diameter

Type of supplementary reinforcements - Fe-415 HYSD bars



(a) (b) (c)

Fig 3 (a) FEM model of 50m span. (b) FEM model of 50m span with 15^0 skew. (c) Sectional view of FEM model 50m span.

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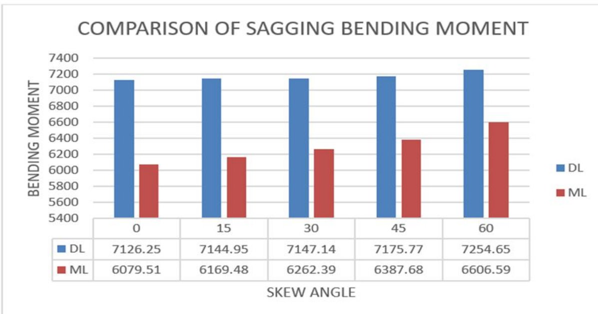
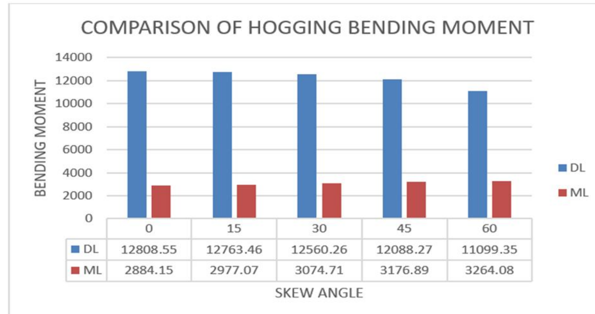
IV. RESULTS

PSC Box girder of different spans i.e 50m, 60m, & 70m & different skew angles i.e., 0^0,15^0,30^0,45^0, & 60^0 are modelled & analysed for "IRC CLASS AA TRACKED" vehicle using SAP 2000 software. The parameters such as bending moment (Sagging & Hogging), Shear force & Torsional moment are compared for different span & different skew angles for Dead Load (DL) and Moving Load (ML).

A. Comparison of Results 50m Span



(a)



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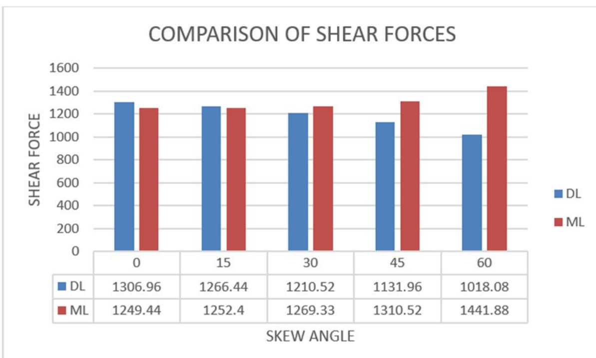

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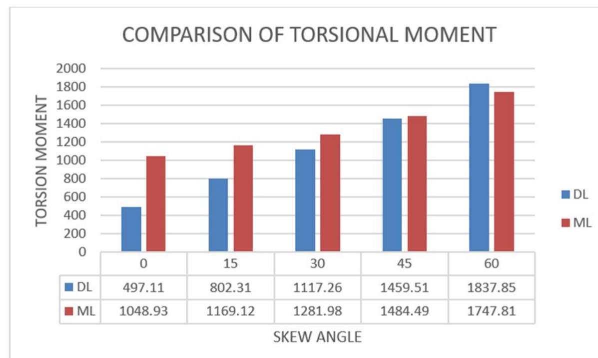
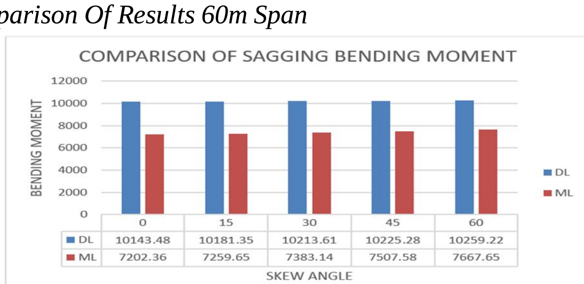


(d)

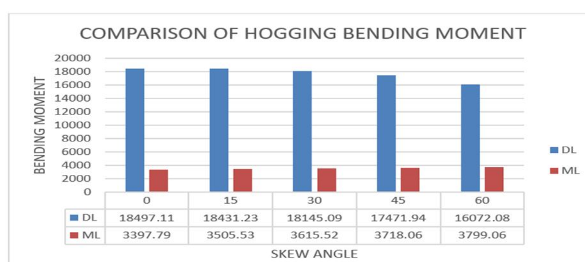
Fig. 4 (a): Bending Moment (Sagging) (b) Bending Moment (Hogging) (c) Shear Force (d) Torsional Moment Comparison 50m Span.

The above graphs fig. 4 (a), (b) compare both sagging & hogging moments for 50m span & different skew angles. For sagging moment under dead & moving loads the bending moment increases with increase in skew angle & for hogging moment under dead load the bending moment reduces with increase in skew angle but it rises under moving load with increase in skew angle.
The above graph fig. 4 (c) compares the shear force for 50m span & different skew angles. It is observed that under dead load the shear force reduces with rise in skew angle & under moving load the shear force increases with rise in skew angle.
The above graph fig. 4 (d) compares the torsional moments for 50m span & different skew angles. It is observed that under dead load & under moving load torsional moment increases with rise in skew angle.

B. Comparison Of Results 60m Span



(a)



(b)

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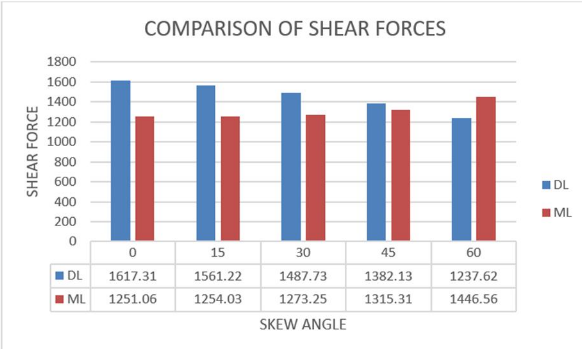

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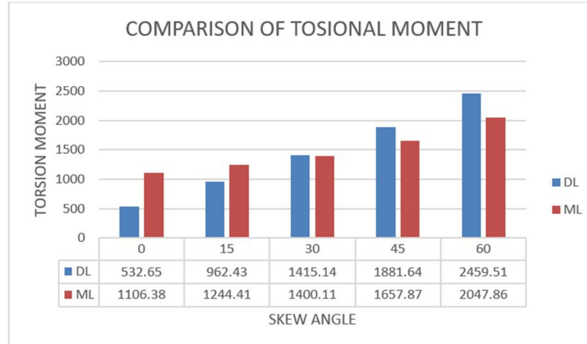
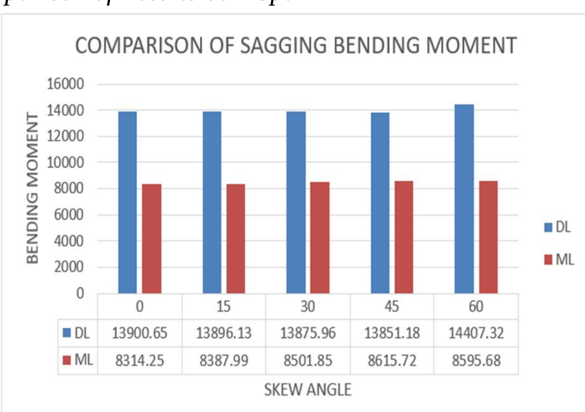


(d)

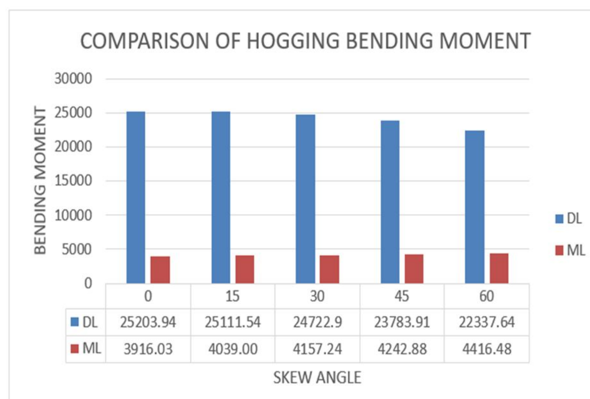
Fig. 5 (a): Bending Moment (Sagging) (b) Bending Moment (Hogging) (c) Shear Force (d) Torsional Moment Comparison 60m Span.

The above graphs fig. 5 (a), (b) compare both sagging & hogging moments for 50m span & different skew angles. For sagging moment under dead & moving loads the bending moment increases with increase in skew angle & for hogging moment under dead load the bending moment reduces with increase in skew angle but it rises under moving load with increase in skew angle.
The above graph fig. 5 (c) Compares the shear force for 50m span & different skew angles. It is observed that under dead load the shear force reduces with rise in skew angle & under moving load the shear force increases with rise in skew angle.
The above graph fig. 5(d) Compares the torsional moments for 50m span & different skew angles. It is observed that under dead load & under moving load torsional moment increases with rise in skew angle.

C. Comparison of Results 60m Span



(a)



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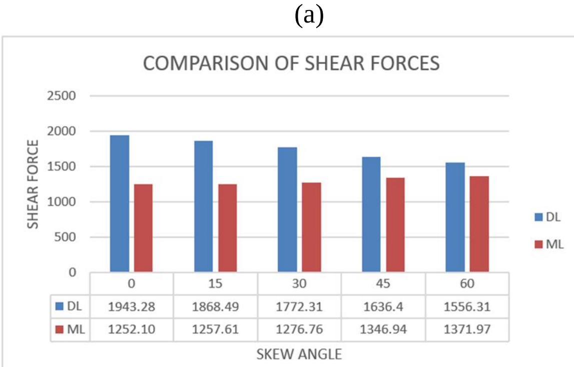
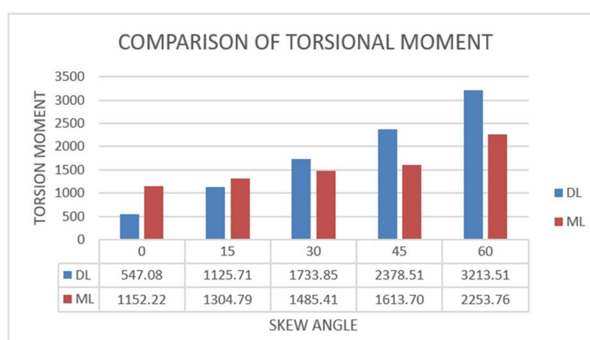


(c)



(d)

Fig. 6 (a): Bending Moment (Sagging) (b) Bending Moment (Hogging) (c) Shear Force (d) Torsional Moment Comparison 70m Span.

The above graphs fig. 6 (a), (b) compare both sagging & hogging moments for 50m span & different skew angles. For sagging moment under dead & moving loads the bending moment increases with increase in skew angle & for hogging moment under dead load the bending moment reduces with increase in skew angle but it rises under moving load with increase in skew angle.

The above graph fig. 6 (c) compares the shear force for 50m span & different skew angles. It is observed that under dead load the shear force reduces with rise in skew angle & under moving load the shear force increases with rise in skew angle.

The above graph fig. 6 (d) compares the torsional moments for 50m span & different skew angles. It is observed that under dead load & under moving load torsional moment increases with rise in skew angle.

V. CONCLUSIONS

Following are the conclusions made from the above study

A. For sagging moment under dead & moving loads the bending moment increases with increase in skew angle.

B. For hogging moment under dead load the bending moment reduces with increase in skew angle but it rises under moving load with increase in skew angle.

C. Under dead load the shear force reduces with rise in skew angle & under moving load the shear force increases with rise in skew angle.

D. Under dead load & under moving load torsional moment increases with rise in skew angle.

VI. FUTURE SCOPE

A. The present study has been carried out for analysis purpose the same results can be used for designing PSC box girder.

B. Further study can be carried out for smaller skew angles such as 5^0,10^0,20^0 & 25^0

C. The present study can be extended for different IRC CLASS loadings for different span & skew angles

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