# Analysis of Skew Bridge with Varying Skew Angles

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**Abstract**—Many highway bridges are skewed and their behavior and corresponding design analysis need to be furthered to fully accomplish design objectives. The research deals with the finite element modeling of simply supported skew slab with varying skew angles using ETABS 2013 software. The behavior of the simply supported skew slab under point load applied at the center depends on the ratio of short diagonal to its span. In the theoretical study, the skew angle and the concrete grade had a significant influence on the overall behavior of the slab. The simply supported skew slab is analyzed with a concentrated load at the center and knife edge load. The analysis is done on the varying span length and the skew angles. Moment, shear force and Torsional variations are analyzed. The research deals with the design of skew bridge with suitable skew angle. The bending moments in the concentrated load condition and the knife edge load condition are decrease up to 65% and 75% respectively as the skew angle increases to $60^0$. The increment of torsional moments is of 60% in both the conditions.

**Index Terms**—Concentrated Load, Knife edge load, Skew angles, Skew Bridge, Static behavior, Torsional Moment.

## 1 Introduction

Skewed bridges are commonly used to cross roadways, waterways, or railways that are not perpendicular to the bridge at the intersection [4]. Skewed bridges are characterized by their skew angle, defined as the angle between a line normal to the centerline of the bridge and the centerline of the support [1] which is shown in Fig. 1.

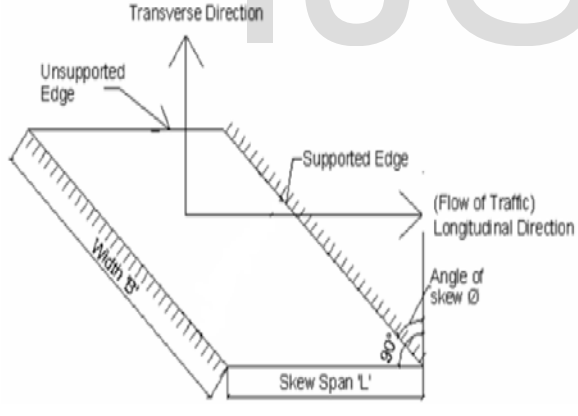


Fig. 1 Plan of a skew deck slab

In skew slabs, the load path tends to take a short cut through the strip of area connecting the obtuse-angled corners and the slab primarily bends along the line joining the obtuse angled corners [2], [3], [5]. The width of this primary bending strip is a function of skew angle and aspect ratio (skew span: width of deck).The areas on either side of the strip do not transfer the load directly to the supports, but only to the strip as cantilever. The load is transferred from the strip to the support over a defined length along support line and then eventually gets redistributed over the whole length. The load transfer mechanism is shown in Fig. 2.

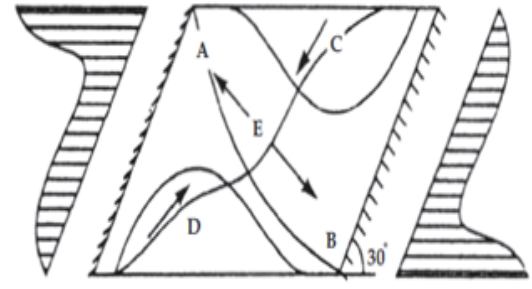


Fig. 2 Load transfer mechanism of skew deck slab

The effects of skew on the response of completed structures have been well documented, with effects being shown to be more significant for skew angles greater than 30° [6]. Conversely, torsional rotations, shears and moments have been shown to be larger for skewed bridges. Skew deck slab is perpendicular to the supports and as such the load placed on the deck slab is transferred to the supports which are placed normal to slab. With increase in skew angle, the stresses in the bridge deck and reactions on the

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abutment vary significantly from those in straight slab.

Deepak and Sabeena (2015) studied the effect of skew angle on uplift and deflection of R.C. C. Skew slab and revealed that when skew angle increases the uplift at both the acute corners also increases. And also suggests that the load carrying capacity increases with increase in skew angle. Mallikarjun et al. (2015) studied the effect of a skew angle on single-span reinforced concrete bridges and PSC bridges are analyzed using the finite-element method to study the influence of aspect ratio, skew angle and type of load and reflected in significant decrease in longitudinal bending moment and transverse moment and longitudinal stresses. Abozaid et al. (2014) presented a comparison between certain results of previous experimental studies and the nonlinear finite element analysis of a reinforced concrete skew slab and reveals the skew angle and concrete grade had a significant influence on the overall behaviour of the slab. Sindhu et al. (2013) studied the effect of a skew angle on single-span reinforced concrete bridges which reflected in significant decrease in deflection, longitudinal bending moment and torsional moment.

## 2 Scope Of Work

Skew bridges are common at highways; the analysis and design of skew bridges are much more complicated than those for a right bridge. There are no detailed guidelines addressing the performance of skewed highway bridges. Therefore, there is a need for more research to study the effect of skew angle on the performance of highway bridges.

## 3 Objective Of The Work

The objective of this work is to investigate the effect of skew angle on varying carriageway width and span length. The parameters considered are:

a) Variation of skew angles as $0^0$, $20^0$, $40^0$ and $60^0$.

b) Variation of carriageway width as 4.5 m, 7.5 m and 10.5 m.

c) Variation of span length as 10 m, 15 m and 20 m.

## 4 Parametric Study

A simply supported skew slab of varying span length and skew angles are considered. The various span lengths are 10 m, 15 m and 20 m. he carriageway widths are 4.5 m, 7.5 m and 10.5 m and skew angles are $0^0$, $20^0$, $40^0$ and $60^0$. Edge beam is of depth and width 200 mm. the bridge deck is analyzed for two conditions i.e., concentrated load at the centre and knife edge load parallel to the abutment. A total of 36 models are analyzed for different conditions.

## 5 Modelling Of Bridge

The analysis is carried out in ETABS 2013 software. The concrete skew slabs are of membrane type of 200 mm thickness. The edge beams provided are of concrete section. Table 1 shows the properties of concrete.

Table 1. Properties of concrete

| *Elastic modulus* | *2500 N/mm²* |
|---|---|
| Poisson's ratio | 0.2 |
| Density of concrete | 25 kN/m2 |

The effect of carriageway width on the behavior of skew bridge is analyzed. Fig. 3, 4 and 5 shows One Lane Bridge, Two Lane Bridge and Three Lane Bridge respectively.

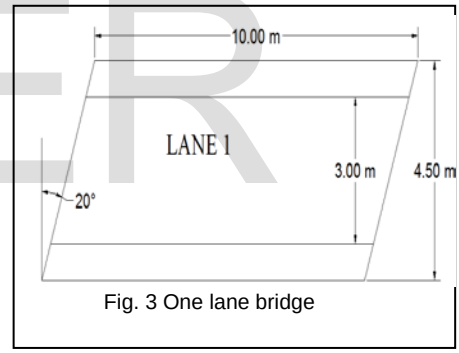


Fig. 3 One lane bridge

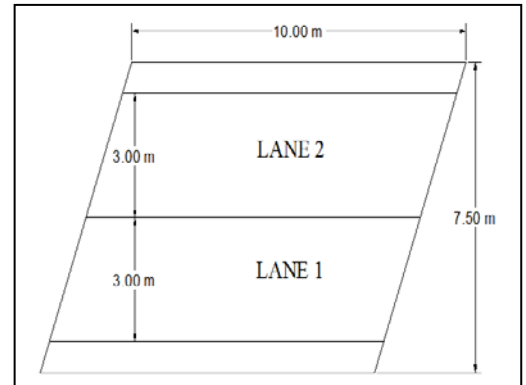


Fig. 4 Two lane bridge

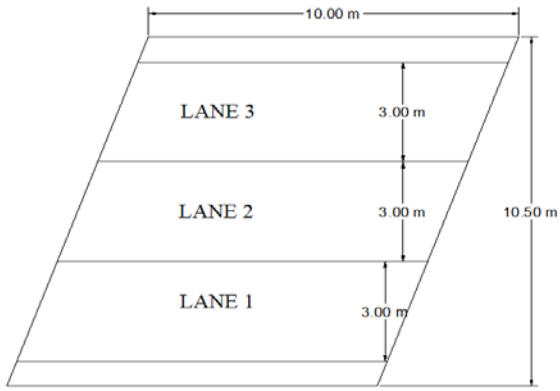


Fig. 5 Three lane bridge

## 6 Results And Discussions

The results are obtained based on the bending moments, shear forces and torsional moments. The critical structural responses are represented in various graphs.

### 6.1 Bending Moment

Bending moment for skewed slabs in Knife Edge Load condition and Concentrated Load condition compared to that of straight deck slab decreases with the increase in skew angle for all carriageway widths and it is shown in Fig. 6 and 7 respectively. The load is transferred through the strip area at the ends i.e., at the obtuse corners.

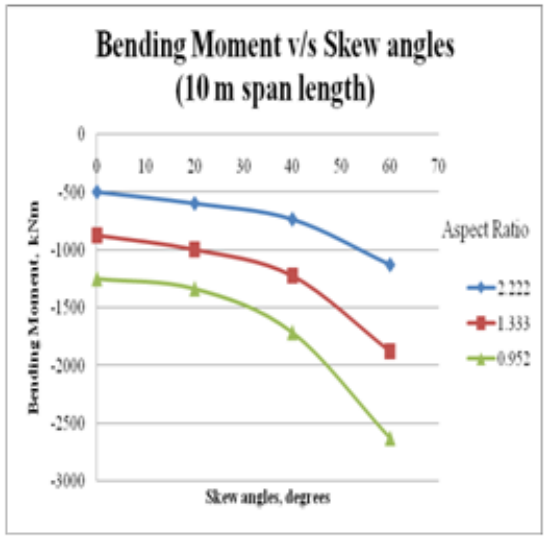


Fig. 6 Graphical representation of bending moment for knife edge load condition

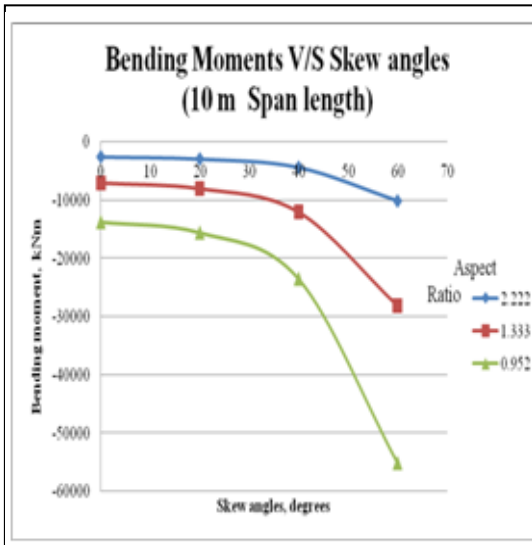


Fig. 7 Graphical representation of bending moment for concentrated load at the center

### 6.2 Torsional Moment

The maximum torsion in beam bridge decks for skewed bridges compared to that of straight bridges increases with increase of skew angle up to $40^0$ for considered span lengths 10 m, 15 m and 20 m. Beyond $40^0$, a decrement occurs as skew increases. The torsional values are considered based on the aspect ratio (span: width). Around 60 % increment in the torsional moments. Fig. 8 shows the torsional variation of 10 m span lengths.

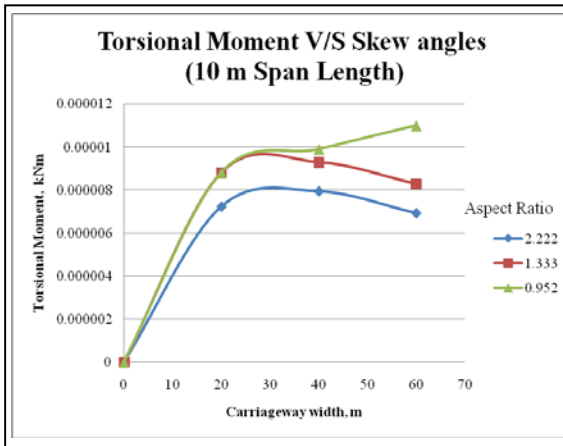


Fig. 8 Graphical representation of torsional moment v/s skew angles of 10 m span length

In the case of concentrated load at the center, when skew angle increases from $20^0$ to $60^0$, the increments of torsional moment for aspect ratios 2.222, 1.333 and 0.952 are 70.66%, 70.71% and 71.18% respectively. Around 70% increment in

torsional moment as skew angle reaches to $60^0$. Fig. 9, 10 and 11 shows the graphical representation of the torsional variation in concentrated load condition.

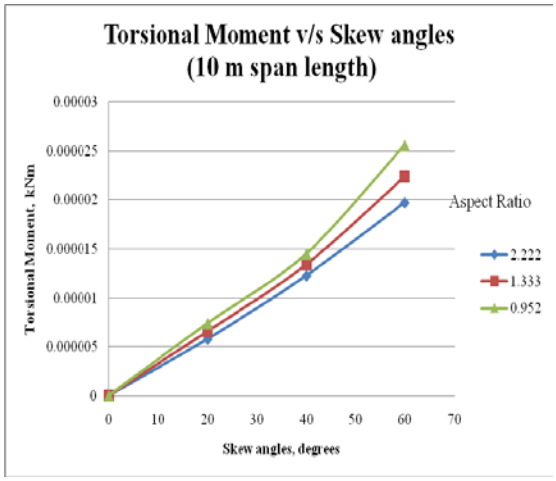


Fig. 9 Effect of skew angles on torsional moments in the concentrated load condition (10 m span length)

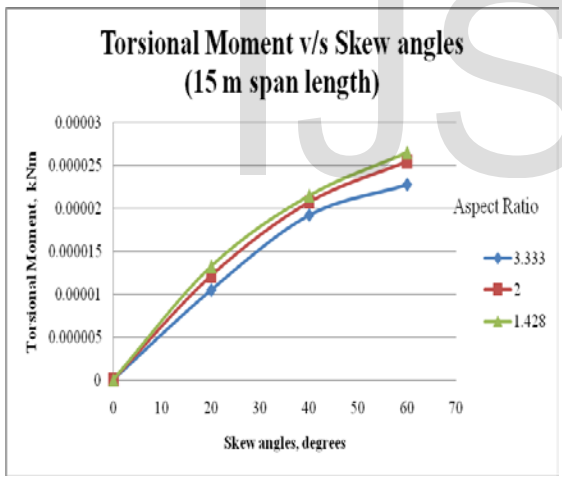


Fig. 10 Effect of skew angles on torsional moments in the concentrated load condition (15 m span length)

## 7 Conclusions

According to the analytical investigation on skew bridge with varying span lengths and skew angles and also with varying carriageway widths, the following conclusions are arrived.

1) The shear force in the knife edge loading condition is increasing gradually and the increment is nearly 30%.
2) The bending moments in the concentrated load condition and knife edge load condition are decrease up to 65% and 75% respectively as the skew angle increases to $60^0$.
3) The increment of torsional moments are of 60% in both the conditions i.e., in concentrated loading condition and knife edge loading condition.
4) From the present study, it is evident that most effective skew angle is $20^0$ skew angle, the increment of torsional moment is larger and so that the failure of bridge will be greater compared to the other skew angles.

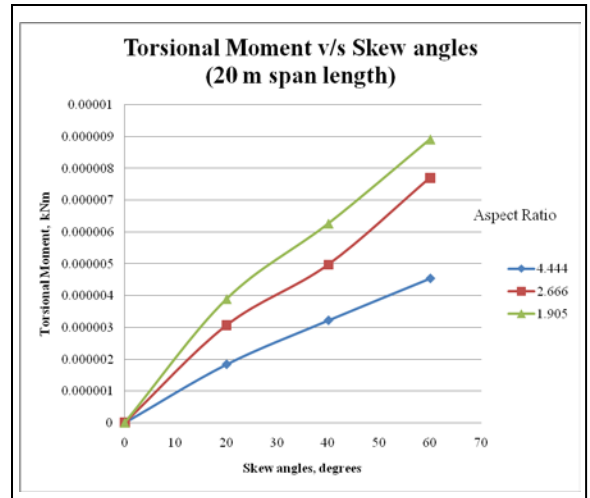


Fig. 11 Effect of skew angles on torsional moments in the concentrated load condition (20 m span length)

## 8 References

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