

**BEHAVIOR OF SKEW INTEGRAL BRIDGES**Priyanka G Patil¹, Manjunath M²¹PG Student, Dept. Of Civil Engineering, KLE Dr.M.S.Sheshgiri college of Engg. & Tech. Belagavi, Karnataka, India²Associate Professor, Dept. Of Civil Engineering, KLE Dr.M.S.Sheshgiri college of Engg. & Tech Belagavi, Karnataka, India

Abstract - Integral abutment bridges establish a monolithic connection between bridge superstructure and substructure, they do not have bearings to accommodate horizontal movements induced in bridge superstructure. The motivation that made these bridges popular is it reduces maintenance cost produced due to leakages and deterioration of structure. The uncertainty of integral bridges are the continuity in structural members leading to the development of thermal stresses and since the horizontal movements are restrained the lateral pressure in soil behind the abutment increases. Apart from these issues, behavior of skew integral bridges is different than the straight joint-less bridge in case of load distribution pattern. To gain better understanding of behavior skew bridges a 3D finite element model is developed in STAAD Pro. Software, dead load is applied on bridge and vehicular load is introduced using STAAD Beava software. The study was carried out for performance of bridge deck and longitudinal girder in terms of bending moment, shear force, deflection and torsional moment for different skew angles. With introducing skew in bridge the bending moment, shear force and torsion in the deck due to dead load and live load increases from straight to 30° skew bridge and further it reduces. Whereas deflection along the deck reduces with increase in skew.

Key Words: Integral abutment bridges, skew angle, vehicular load, girders.

I. INTRODUCTION

Integral abutment bridges (IAB) are single or multiple span structures with a continuous concrete deck and approach slab, connected monolithic with abutment without any bearings [1]. Integral bridges are suited for medium spans and they are gaining popularity because of their simplicity in construction, they reduce the maintenance cost of bridge, the continuity in structural components makes the bridge resistance against leakage in terms reduces the corrosion and the monolithic connection between bridge super structure and substructure provides additional redundancy to the structure. Skew integral bridges are often adopted for river crossings, as flyovers in densely populated area or where there is a space limitation [2]. The behavior of skew integral bridge is different than the non-skew IAB in terms of the effects such as torsion, unequal load distribution, lateral translation and increase in length of abutment exposed to soil pressure. Due to this reason in NCHRP (National Cooperative Highway Research Program) report do not suggest the use of curved and skew integral bridge [3]. In USA in many of the state transport agencies has put restriction on the use of curved IAB's but skew integral bridges up to 10° is permitted. However from the many researches it is found that in skew bridges, the curvilinear alignment reduces internal stresses and it gives additional safety against unintended movements in the bridges by controlling bridge end movements [4].

1.1 Effect of skew

Often bridge designers avoid the skew type of bridge as it is tedious job to understand its behavior under vehicular load. And also in the Indian bridge design code IRC, there is not much explanation on the design of skew integral bridge but when it comes to the economic type of design and space limitations the design of skew bridge gain importance. In straight integral bridges, the deck slab spans in perpendicular direction to the supports and the load placed on the deck slab is transferred to the supports which are placed normal to slab. Load transfer from a skew slab bridge is complicated because there always remain an uncertainty in the direction in which the slab will span and the manner in which the load will be transferred to the supports. With increase in skew angle, the stresses in the bridge deck and reactions on the abutment vary significantly from those in straight slab.

1.2 Methodology

To gain better understanding of load transfer mechanism due to the stresses developed in skew bridges a three span 3D finite element model is developed in STAAD Pro. software, self weight for bridge is added, vehicular load (as per IRC:6-2014) Class 70R tracked and wheeled load is applied using STAAD Beava. (Bridge Engineering Automated Vehicle Application) software. Straight (0° skew), 30° and 60° skew bridges were modeled in the present study. Table -1 show the geometry and dimensions of the structural components adopted for finite element method of analysis.

Table 1. Geometry of integral bridge model

Structural component	Length (m)	Width (m)	Height/ Depth (m)	Thickness (m)
Deck slab	74	12	-	0.24
Longitudinal girder	74	1.4	0.375	-
Pier cap	12	0.525	1	-
Abutment	-	12	5	1.25

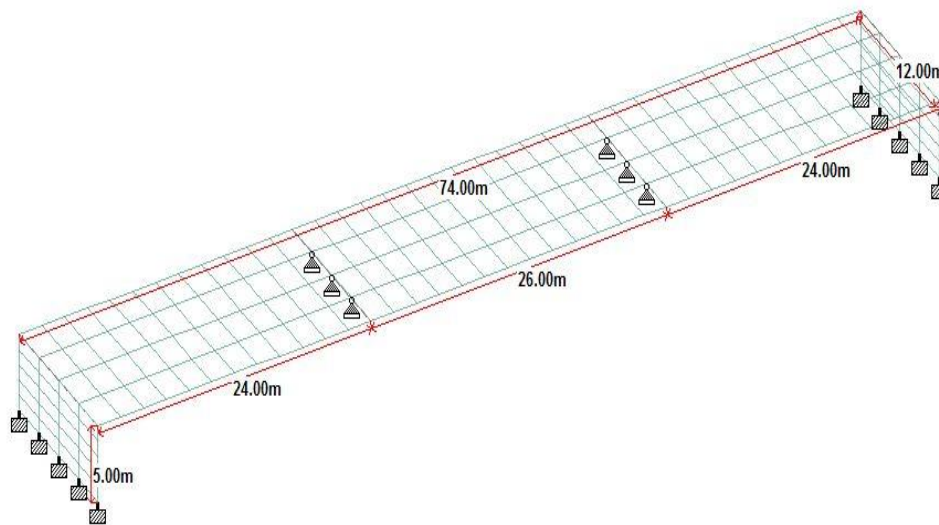


Figure1. Finite element model of IAB (Straight Bridge)

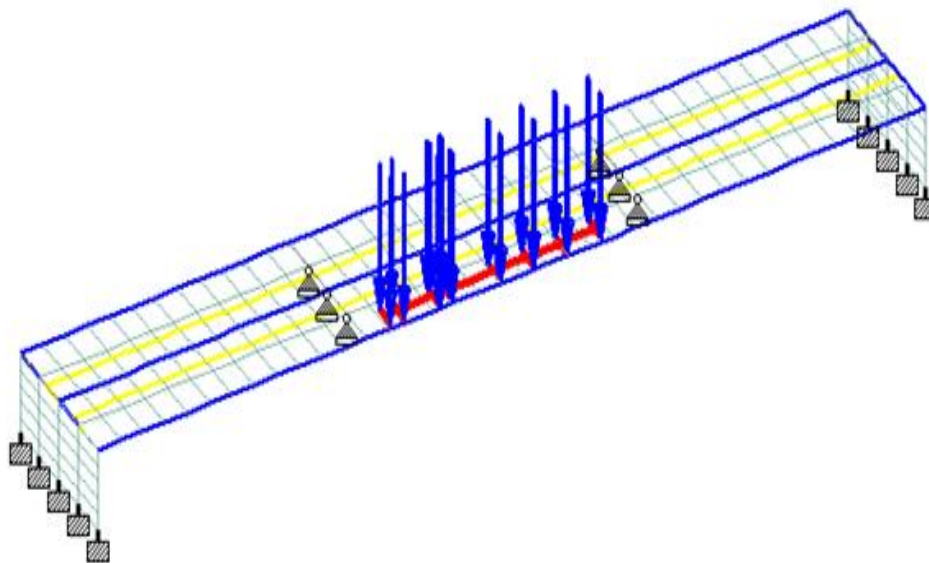


Figure 2. STAAD model showing IRC-class 70R wheeled vehicle loading

II. RESULTS AND DISCUSSION

The results from finite element analysis are discussed with the help of graphs. Here the effects of dead load and live load on the structural parameters such as deflection, bending moment, shear force and torsion on bridge components namely central girder is studied and skew bridges were compared with straight bridge.

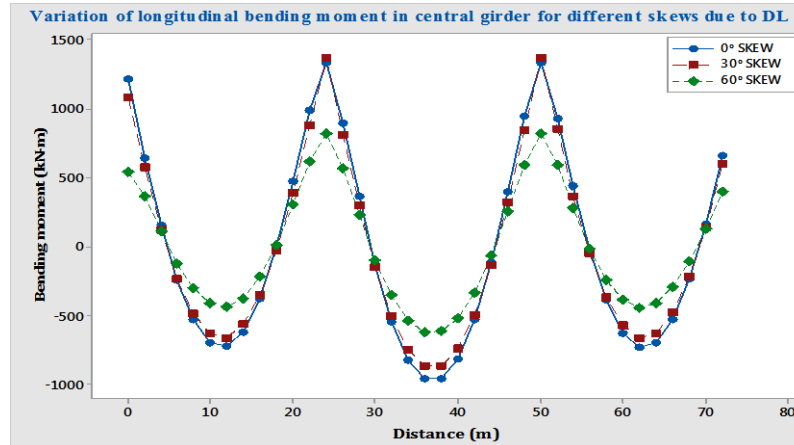


Figure 3.Bending moment in longitudinal girder for different skews due to dead load

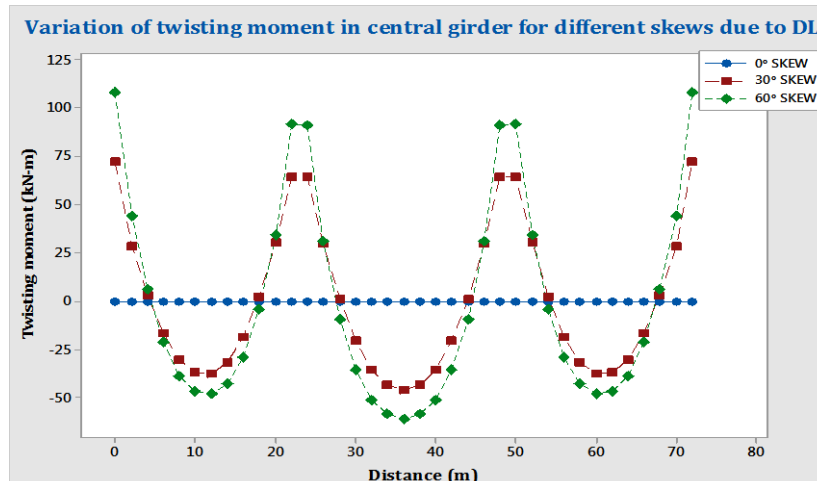


Figure 4.Twisting moment in longitudinal girder for different skews due to dead load

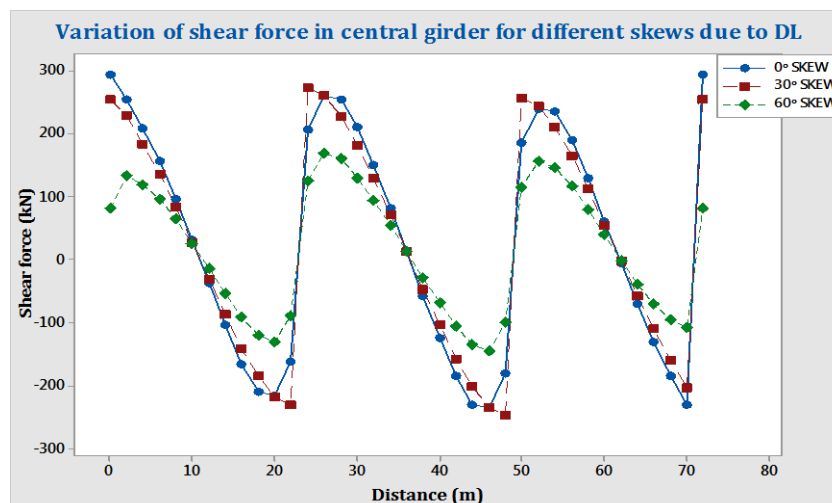


Figure 5.Shear force in longitudinal girder for different skews due to dead load

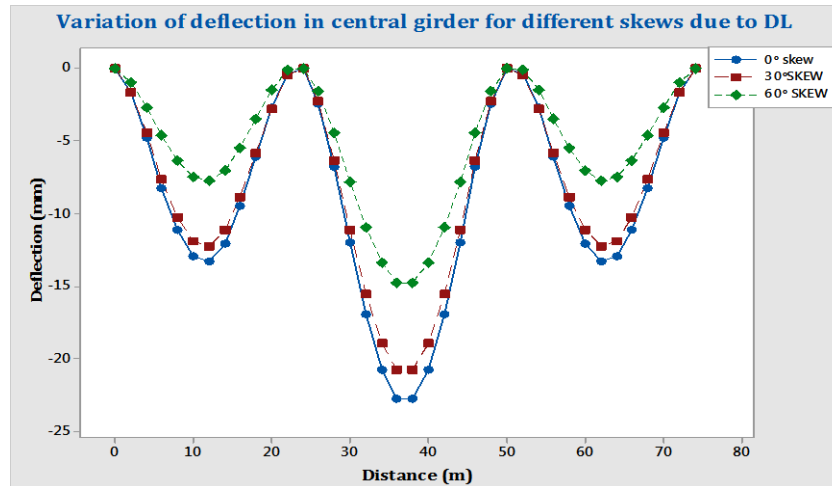


Figure 6. Deflection in longitudinal girder for different skews due to dead load

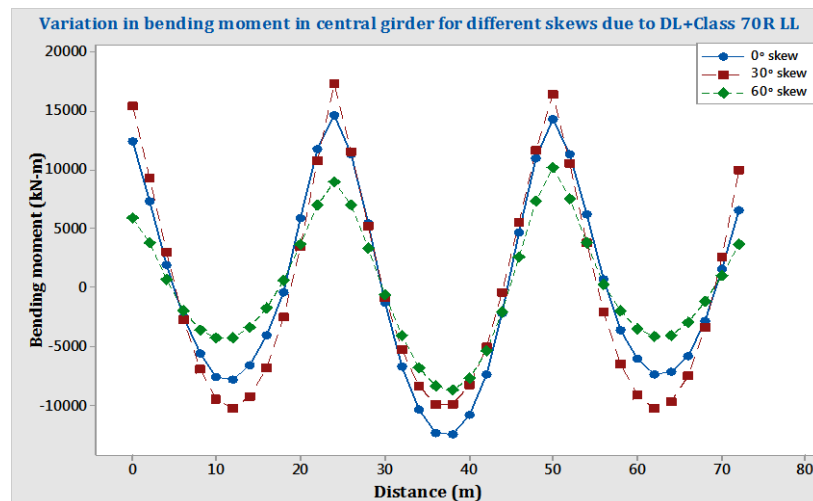


Figure 7. Bending moment in longitudinal girder for different skews due to DL+ Class 70R Live load

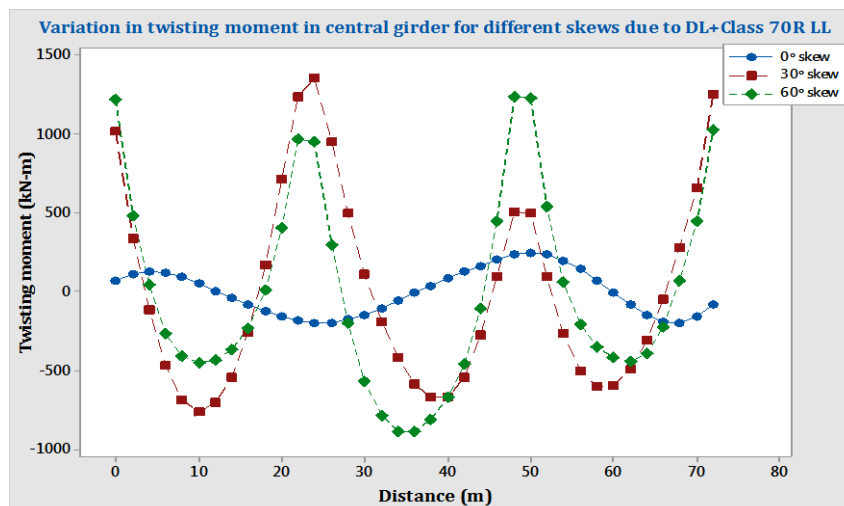


Figure 8. Twisting moment in longitudinal girder for different skews due to DL+ Class 70R Live load

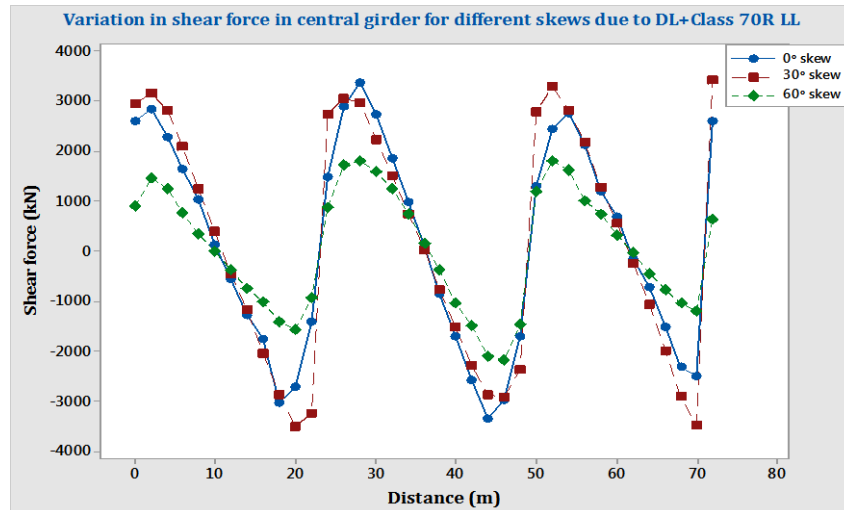


Figure 9. Shear force in longitudinal girder for different skews due to DL+ Class 70R Live load

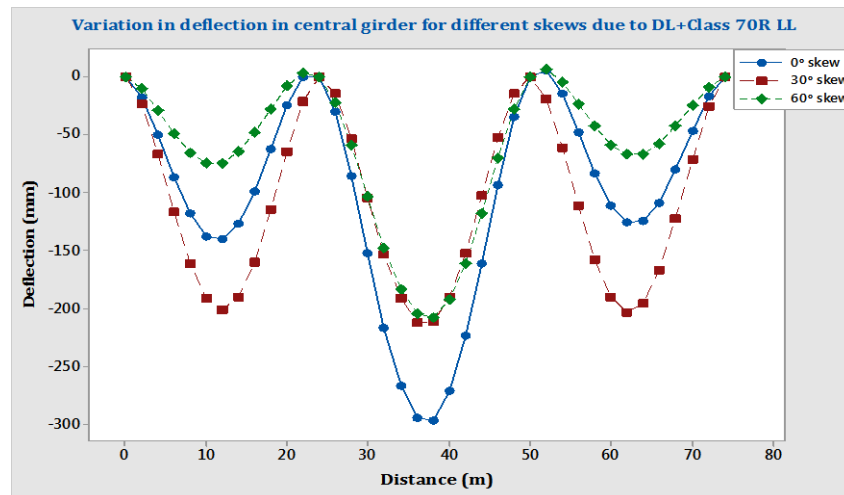


Figure 10. Deflection in longitudinal girder for different skews due to DL+ Class 70R Live load

- The variation in bending moment due to dead load and vehicular load increases up to 30° skew bridge and further it reduces for 60° skew integral bridge (Fig. 3 and Fig. 7).
- Twisting moment does not develop for straight integral bridge as the load distribution from deck to the support is uniform due to dead load. Twisting moment increases with increase in skew angle due to dead load, it is because the skewness in the deck makes the load distribution pattern complex (Fig. 4).
- Twisting moment due to live load increases by 81% for 30° skew bridge further it reduces by 9% for 60° skew bridge as compared to 30° skew bridge (Fig. 8).
- The variation in shear due to dead load is similar for straight and 30° skew bridge, shear force decreases for 60° skew bridge (Fig. 5).
- The variation in shear force due to vehicular load is similar up to 30° skew and decreases for further increase in skew as it contributes towards torsion (Fig. 9).
- The deflection of the central girder due to dead load shows a regular typical pattern for the different skew angles. The deflection in the central span is higher and at the end span it is less, because of the rigid connection (continuity) at the abutments (Fig. 6).
- As the skew angle increases the deflection in both exterior span and mid-span decreases due to dead load (Fig. 6).
- Displacement due to live load is diverse in nature and it has similar trends as observed in case of bending moment. That is variation differs from end span to mid span of IAB with variation in skew (Fig. 10).

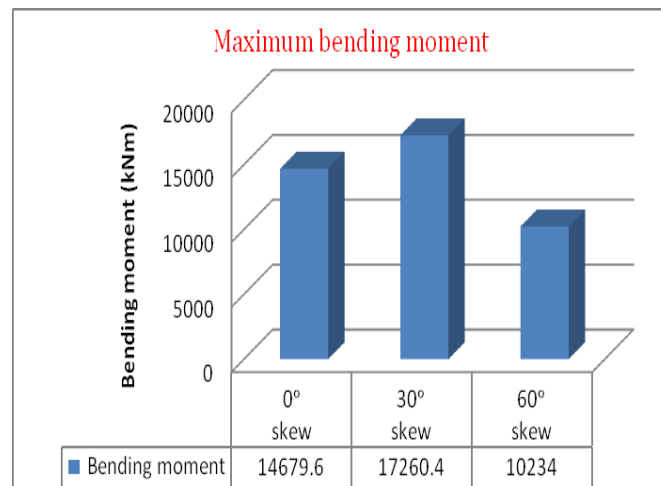


Figure 11. Maximum bending moment in central-span for different skews due to DL + LL

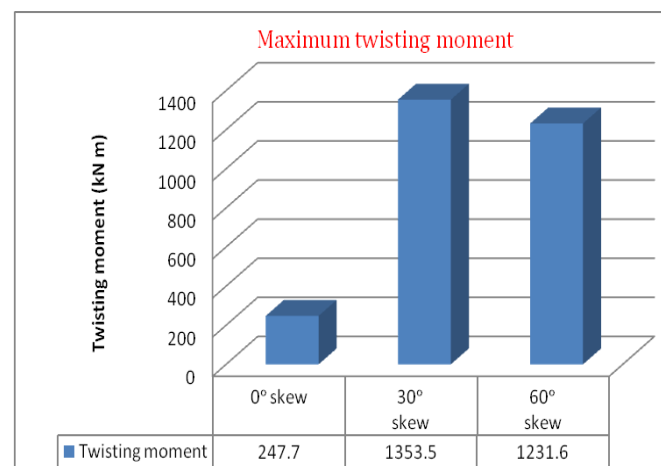


Figure 12. Maximum twisting moment at interior support sections for different skews due to DL + LL

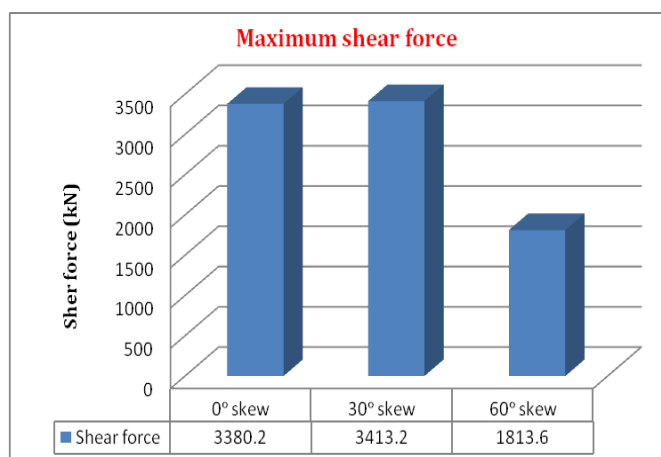


Figure 13. Maximum shear force at end support sections for different skews due to DL + LL

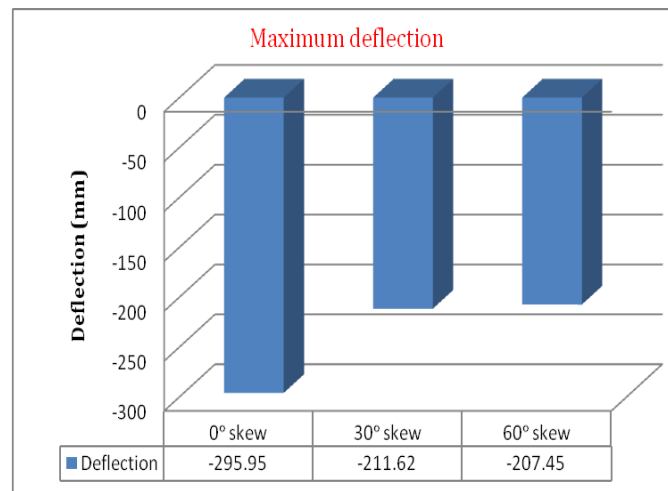


Figure 14.Maximum deflection at centre of mid-span section for different skews due to DL + LL

- The maximum bending moment occurred at mid-span, irrespective of skew and loading. Bending moment increased up to 15% for 30° skew, further it decreased for 60° skew bridge, the percentage decrease is -43% as compared to straight bridge. This is because for skew greater than 45°, the span (perpendicular distance between the supports) reduces resulting in reduction in longitudinal bending moment and it reflects in terms of torsional moment.
- The maximum twisting moment occurred at interior pinned support section, irrespective of skew and loading. Small amount of torsion has been developed for straight bridge due to position of vehicles on deck. Twisting moment increases up to 30° skew bridge by 81% and decreases for 60° skew bridge by 79% with respect to straight bridge.
- The maximum shear force occurred near support section, irrespective of skew and loading. There is slight increase in shear (1.1%) from straight IAB to 30° skew IAB. Shear force for 60° skew reduces by -86% with respect to straight bridge and -88% compared to 30° skew IAB.
- The maximum deflection occurred at the mid-span of central section irrespective of skew and loading. Deflection decreases as skew angle increased in the bridge deck. The percentage decrease is 28% and 30% for 30° and 60° skew bridge as compared to straight bridge.

III. CONCLUSIONS

Following conclusions are made by the above results:

- The variation in structural parameters for different skew is linear. That is with increase in skew the bending moment, shear force and torsion along the deck increases for 30° skew bridge and further it reduces for 60° skew integral bridge.
- The effect of bending moment is more significant for straight bridge and 30° bridge and it reduces for 60° skew IAB. It is due to variation in load distribution. And also the longitudinal bending moment in skewed bridges splits and reflects in terms of torsion along the deck.
- There is no effect (0%) of torsion on straight bridge due to self weight as the dead load has uniform load distribution pattern and twisting moment increases up to 91% and 124% due to DL and 81% and 79% for 30 and 60° skews respectively.
- There is slight increase in shear force up to 30° skew further it decreases for 60° skew due to dead load and live load.
- The variation of deflection is linear with variation in skew. That is deflection along the longitudinal girder decreases with increase in skew. It decreases from 11% to 41% from straight bridge to 30° and 60° skew bridge respectively when dead load is considered. The variation in deflection when live load is considered is 28% to 31% from 0° to 30° and 60° skew bridges respectively. The deflection shows similar variation as bending moment.

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