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Effects Of Skewness On Three Span Reinforced Concrete T Girder Bridges

[1,]Himanshu Jaggerwal , [2,]Yogesh Bajpai
[#1]Student- M.Tech (Structural Engineering), Civil Engineering Department, GGITS Jabalpur M.P, India
[#2]Associate Professor- Civil Engineering Department, GGITS Jabalpur M.P, India

ABSTRACT:

A very limited study has been carried out in the field of skew bridges and even that does not hold much relevance in Indian perspective due to difference in design live load standards and type of bridges being built there. Therefore it does not provide any help to designers regarding the quick estimation of design bending moments and shear forces which are of prime interest. In this paper an attempt has been made to study the effect of skewness directly on the design parameters i.e. B.M, Shear Force and Maximum Reaction in simply supported RC T-Beam 3 lane bridges. For this purpose a parametric study of Simply Supported 3-Lane T-Beam Bridge has been performed in STAAD PRO. The parameters varied were span and skew angle. The effect of same was observed on maximum live load bending moment, maximum live load shear force and maximum live load reaction at critical locations. Live Load "Class 70R Tracked "and "Class 70R Wheeled" were applied as per IRC 6 guidelines. The spans used were 10 m, 15 m, 20 m and 25 m. The skew angles were taken at an interval of 150 starting from 0^0 up to a maximum of 60^0. Bridges with skew angle more than 45^0 are rare.From the study it was observed that as the skew angle increases from 0^0 to 60^0 there is a consistent reduction in Moment Distribution Factor (MDF) of the inner longitudinal girder of bridge. Similar trend of reduction in MDF were observed for other spans. This suggests that skew bridges designed, ignoring the skew effect is conservative with respect to the bending moment. The effect of skew angle was also studied on the shear coefficients. The shear coefficients as increases almost linearly with skew angle and span. Hence it can be concluded that proper estimation should be made in the live load shear when designing skew bridges.

KEYWORDS: *Skew angle, distribution factor, T Beam Bridge, grillage analogy, bending moment,*

I. INTRODUCTION

Most of the bridges in elder days were straight and skew bridges were preventing as far as feasible. Lack of information about the structural behaviour and construction difficulty were obvious reasons contributing to the designer's choice to help in a straight line bridges rather than skew bridges. But in the recent circumstances there is a rising trend of providing skew bridges rather than curved or straight bridges with long approach road at oblique intersections. There is immense pressure of increasing population due to which the cost of land acquisition for approach roads has hiked many folds. It is difficult for them to negotiate on curve roads even at low speeds. The introduction of curves also increases the distance travelled by the vehicle which in turn affects the economy. In hilly regions also due to topographic conditions, it is very difficult to provide curved approaches and many times skew bridge remains the only option. The railway and roadway intersection are also often oblique and requires approach road if skew bridge is to be avoided. Also old and overcrowded city due to be short of space, bridges have to be skew in nature if the intersection is not orthogonal. Hence there is need to study the behavior of skew bridges so as to facilitate quick estimation of design BM, shear force and support reactions and thus obviating the need of a rigorous analysis. The results have been presented in the form of ready to use design charts. In the present thesis behaviour of RC T Beam Bridge having skew angle from 0-60^0 has been investigated. Further on the basis of a parametric study an attempt has been made to develop suitable design charts for quick estimation of design forces in skew bridges.

II. METHODOLOGY

With the advancement in modeling and computing facilities world over, it has now become possible to perform a near exact analysis of any kind of bridge. The commercially available software packages like ANSYS, ABAQUS, SAP etc has made it possible to use the methods of Finite Element Analysis, etc with much ease. In spite of the fact that these methods are highly efficient and accurate, these methods are often criticized also for the reason that the efficiency is achieved at the cost of exorbitant computations and time requirement. Hence, care must be taken in selection of the appropriate method of analysis, appropriate to the type of bridge depending upon the required accuracy in the parameters under investigation.Grillage Analogy on the other hand presents a sufficiently accurate method to analyze slab-beam bridges for estimation of design bending moment, torsion, shear force etc. It is a comparatively simpler method to analyze the bridge decks and gives an excellent visualization of distribution of forces among different longitudinal and transverse girders in a bridge. It can easily handle complicated geometric features of a bridge such as skew, edge stiffening, and deep haunches over support, continuous and isolated supports etc with ease. It is a versatile method and can also take into account the contribution of kerb beams, footpaths and the effect of differential sinking of girder ends over yielding supports. The method has proved to be reliable and versatile for a wide variety of bridge decks. It do possess some limitations such as inability to take into account the effects like shear lag, warping and distortional effects for which more sophisticated methods like FEM have to be used.

Basically grillage analogy method uses stiffness approach for analyzing the bridge decks. The whole bridge deck is divided into no of longitudinal and transverse beams. The intersection of longitudinal and transverse beams is called as node. Each node has six degrees of freedom, namely 3 rotations and three translations. But if we assume the slab to be highly stiff in its own plane, which is actually the case in most of the bridges, the degrees of freedom are reduced to three i.e. 1- vertical translation and 2-rotations about the axes in plane of the bridge deck. The properties of cross-section such as beam moment of Inertia about their principal axes, Torsional constant, Effective Area etc are calculated and the grid is solved for the unknown degrees of freedom using the matrix stiffness method. After the nodal displacements are known, the forces in the grid members are calculated using the force displacement relationship. The overall equations of equilibrium are given below.

$\{p\}= [k] \{u\} + \{ q \}$ At member level
$\{P\} = [K]\{ U\}$, At structural level
Where,
P represents the unknown nodal forces (BM, Torsion, and SF), K is the assembled stiffness matrix of the structure and U represents the vector of nodal displacements or degrees of Freedom at structural level. Similarly p, k, u are the representatives at member level, which are in respect to local coordinate system. Represents equivalent member end forces due to member loads.

Conceptually, grillage analogy method attempts to discretized the continuous or dispersed stiffness of bridge and concentrates it into discrete longitudinal and transverse members. The degree of structural similarity between the original bridge and grillage so formed depends on the fineness of the grid formed. But practically it is observed that after a certain degree of fineness in the grillage mesh, law of diminishing returns is followed and further reducing the size of grillage doesn't significantly add to the accuracy. The choice of the designer is the best judge to decide grid fineness.
The solution of grillage mesh involves a large no. of equations, which is beyond the scope of the manual solution. Hence it becomes mandatory to take aid of computer programs in the grillage analogy method. Commercially available software package like Staad Pro, are very helpful in analyzing bridges with grillage analogy method considering all the 6-DOFs i.e. 3 translations and 3 rotations per node. The use of same has been made in this study.

2.1 Gridlines, their locations, direction and properties: Gridlines are the beams representing the discretized stiffness and other structural properties of the slab portions which it replaces. Strictly speaking, gridlines represents the lines of strength. So they must be provided at all the locations where there is concentration of stiffness. Therefore gridlines must be provided at the centre of each longitudinal and transverse girder, running along them. Where isolated bearings are provided, gridlines should also be provided along the lines joining the bearings. Generally gridlines must coincide with the centre of gravity of the section but some shift may be permitted for the ease of calculation. A few guidelines for the Grillage Idealizations for slab T beam bridges are as follows.

(a) Generally longitudinal gridlines are parallel to the free edge of Deck. (For straight bridges without skewness)
(b) For skew Bridges with skew angle less than 15^o the transverse girders are provided parallel to the support lines so the gridlines should also be parallel to the support lines. But for skew angles exceeding 15 degrees, where transverse diaphragms perpendicular to the longitudinal girders are provided as they are found to be more efficient in transverse load distribution amongst longitudinal Girders. Hence gridlines should be along the transverse diaphragms i.e perpendicular to the longitudinal beams.
(c) End transverse gridlines must be provided along the center lines of bearings on each side of span.
(d) For determining the sizes of gridlines aid form relevant IRC code can be taken.

III. PARAMETRIC STUDY OF RC T BEAM BRIDGE

A 3 lane RC T-Beam Bridge has been chosen for the study. Spans have been varied from 12m to 21 m with an increment of 3m. The no. of longitudinal girders has been kept as three. Cross Girders are hindrance in the speed of construction as they pose practical problems in construction. So their spacing is generally kept not less than 4 m and for this reason the spacing of cross girders is kept between 4.5 m to 6 m. For skew bridges of 0^0 and 10^0, the cross girders (& transverse gridlines) are parallel to the abutment, while for 20^0, 30^0, and 40^0, the cross girder (& transverse gridlines) are provided orthogonal to longitudinal girders for the reason explained in above section. The cross-section shown in Fig 1 has been chosen. The sizes of longitudinal and cross beams is given in Table 1

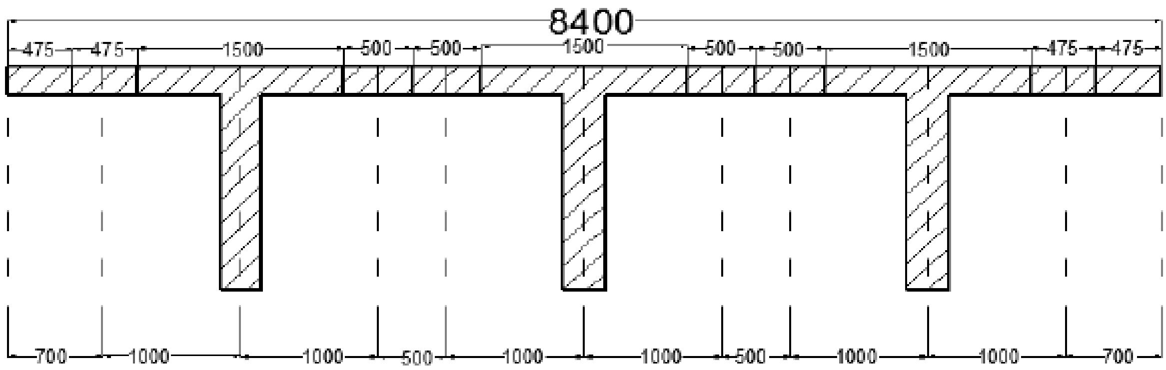


Figure 1 Division of bridge cross-section into equivalent grillage

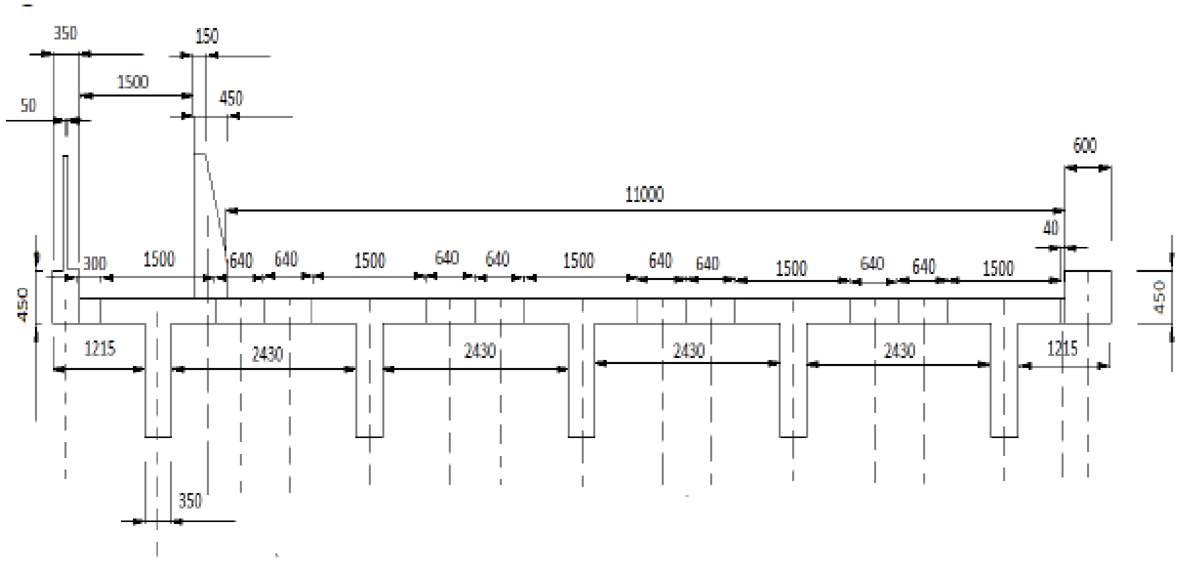
3.1 Grillage Idealization Of Bridge:

In grillage analogy method, the continuous bridge deck is discretized into a no of longitudinal and transverse beams. Since the distribution of bending stress in the flange of the T-Beam bridge is not uniform as suggested by the simple bending theory, so the effective width concept is used to define the flange of the T-section. For this purpose assistance from IRC 21: 2000 clause 305.15 was sought in the selection of sizes of T-Beam. It suggests

be = bw + lo / 5…………. IRC 21: 2000 clause 305.15

Where, be = effective flange width of T-Beam; bw = width of T-Beam and lo = distance between the points of contra flexure.

Exact modelling of bridge is difficult so some approximations were made in grillage idealizations and the slab was assumed to be of uniform thickness taking partially into account the effect of kerbs. Figure 2 shows the grillage idealization of the bridge in longitudinal direction. Same method was used for discretizing the bridge in transverse direction also.



GRILLAGE IDEALIZATION OF CROSS SECTION OF THREE LANE ONE WAY BRIDGE

Figure 2: Grillage Idealization of the cross section of bridge. All dim in mm

IV. LIVE LOAD (LL) APPLICATION ON THE BIRDGE

The Bridge deck was analyzed for "Class A", "Class 70R Tracked" and "Class 70R Wheeled" vehicles. As per IRC 6: 2000 Table 2, a two lane bridge should be loaded with either one lane of " Class 70R " or two lanes of " Class A". For the transverse placement of the vehicle, guidelines of IRC 6: 2000 clause 207 were followed which suggests that the minimum spacing of vehicle form the face of the kerb is 1.2 m for "Class 70R" and 0.15 m for "Class A" loading. .Many other trials of the transverse placement of vehicles were also made to obtain the maximum LL moments and maximum LL shear force and maximum LL reactions in the bridges. Following observations were made during these trials.

(a)For "Class 70R W heeled" and " 70R Tracked" the maximum bending moment in the bridge is always obtained in the outer girder when the vehicle is placed at minimum spacing from the kerb.
(b)For maximum bending moment in the middle girder the vehicle is placed both eccentrically and centrally as it does not always occur for same transverse placement loads.
(c) For all Class of loading, the maximum LL shear occurs in the outer girder, near the obtuse corner.
(d) For "Class 70R Wheeled" and "70R Tracked" the maximum LL support reaction occurs in the middle girder when the vehicle is placed centrally.

The loads were placed accordingly to obtain maximum bending moment, maximum shear and reaction in the bridge.

4.1 Idealization of Vehicle : The details of vehicles have been given in IRC 6: 2000. The Class 70 R Tracked vehicle has been simulated as train of 20 equal point loads as shown below in figure 3. The load values shown in the longitudinal details are the axle loads and since there are two wheels on each axle, so the values are halved when seen in the transverse view.

(1) 70R Wheeled Vehicle

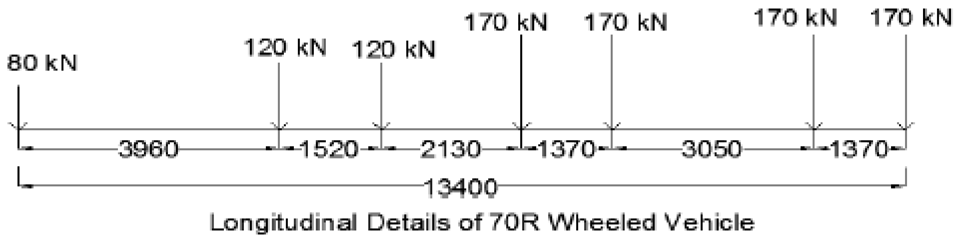
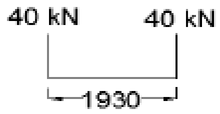


Figure 3: Class 70R Wheeled Vehicle



Rear Axle

(2) 70R Tracked Vehicle

The tracked vehicle was idealized as shown below. The uniformly distributed load, 4570 mm has been converted into equivalent train of 20 equal point loads for ease in application.

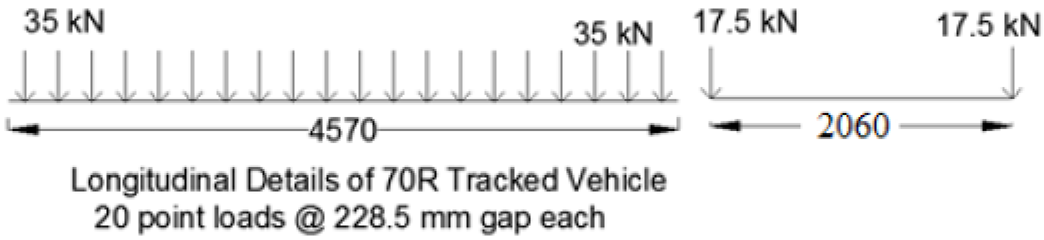


Figure 4: Class 70R Tracked Vehicle

4.2 Impact Factor : Provision for impact or dynamic action shall be made by an increment of the live load by an impact allowance expressed as a fraction or a percentage of the applied live load.

(1) For Class 70R Loading: for 70R Wheeled and 70R Tracked impact factor determined according to IRC: 6-2000 Clause 211.3 The impact factor for 70R Wheeled, 70R Tracked and Class A and for all span are given below in Table 4.1.

Table 1: Impact factor

Span (m)	**10 m**	**15 m**	**20 m**	**25 m**
70 R Wheeled	0.28	0.21	0.17	0.14
70 R Tracked	0.10	0.10	0.10	0.10

V. RESULTS AND DISCUSSION

Bridges of span 10 m, 15 m, 20m, and 25m were analyzed for skew angles 0^0, 15^0, 30^0, 45^0 and 60^0. The results are shown below. All the moment values are for live load only and the word “moment” is synonymously used for “maximum moment” at many places of this chapter. Also the abbreviation G1, G2, G3, G4, & G5 are shown in Results and Discussions Figure 23

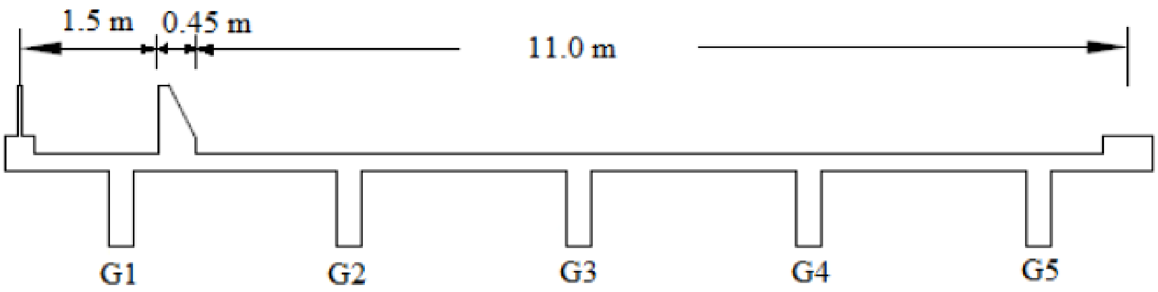


Figure 5: Cross section of three lane T-Girder bridge

G1 is the outer longitudinal girder on the left side of the middle girder.
G2 is the inner longitudinal girder on the left side of the middle girder.
G3 is the middle longitudinal girder.
G4 is also the inner longitudinal girder but on right side of the middle girders.
G5 is also the outer longitudinal girder but on right side of the middle girder.

5.1 Effect of Arrangement of Loading

5.1.2 Class 70R Wheeled with Class A Vehicle : The Class 70R Wheeled vehicle was placed centrally on G3 & G4 and Class A vehicle was placed at a minimum spacing of 1.2m (minimum spacing specified in IRC: 6 - 2000 for Class A vehicle) from 70R Wheeled Vehicle and moved over the span (Figure of placement of IRC loading over bridge is given in Annexure B). The maximum moments obtained in the girders G1, G2, G3, G4 and G5 were recorded. The maximum moment occurred simultaneously in all girders for 0^0 skew angle but for other skew angles it occurred with some lag due to skew effects. The lag increased with skew angle. A total of 1000 KN load was applied in this loading on 13.4m distance.

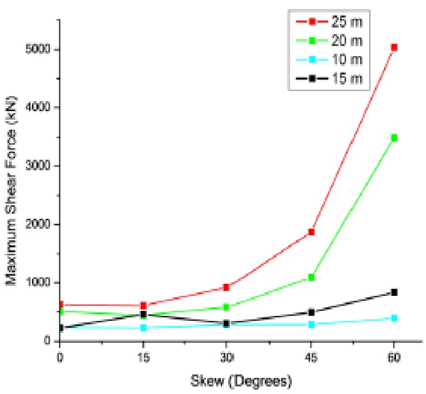


Figure 6: Maximum Shear Force Class70RW+A

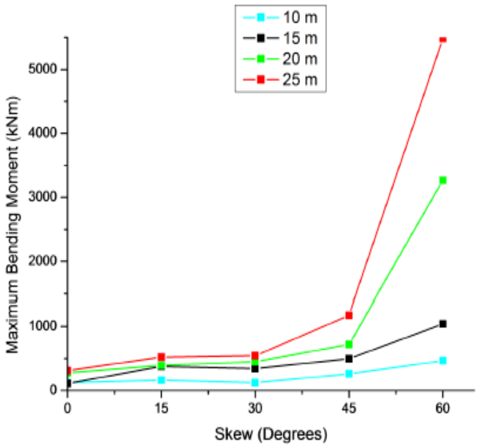


Figure 7: Maximum BM Class70RW+A

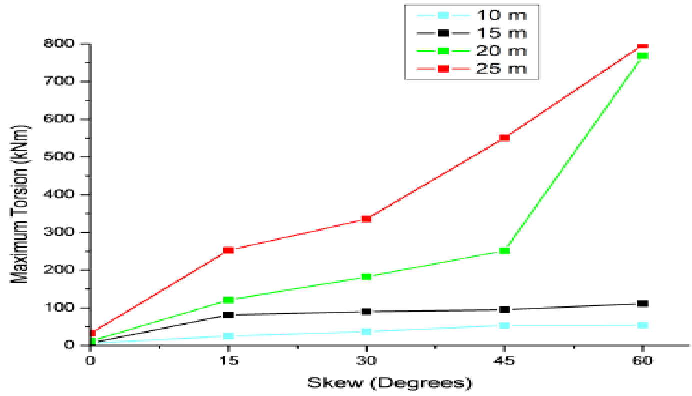
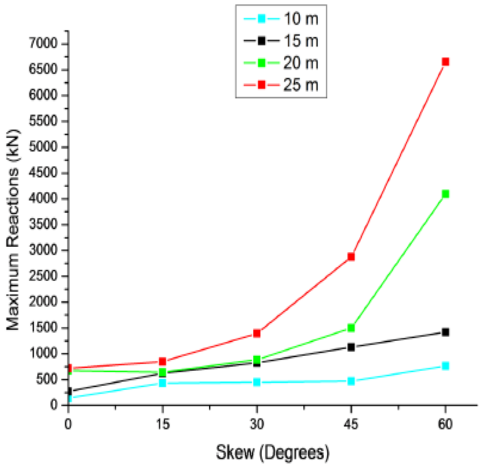


Figure 8: Maximum Torsion Class70RW+A



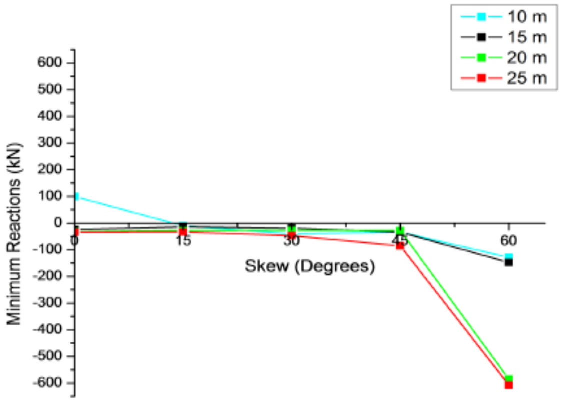


Figure 9: Maximum Positive Reaction Class70RW+A   Figure 10: Maximum Negative Reaction Class70RW+A

5.1.3 Class 70R Tracked with Class A Vehicle : The Class 70R Tracked vehicle was placed centrally on G3 & G4 and Class A vehicle was placed at a minimum spacing of 1.2m (minimum spacing specified in IRC: 6 - 2000 for Class A vehicle) from 70R Wheeled Vehicle and moved over the span (Figure of placement of IRC loading over bridge is given in Annexure B). The maximum moments obtained in the girders G1, G2, G3, G4 and G5 were recorded. The maximum moment occurred simultaneously in all girders for 00 skew angle but for other skew angles it occurred with some lag due to skew effects. The lag increased with skew angle. A total of 700 KN load was applied in this loading on 4.57m distance

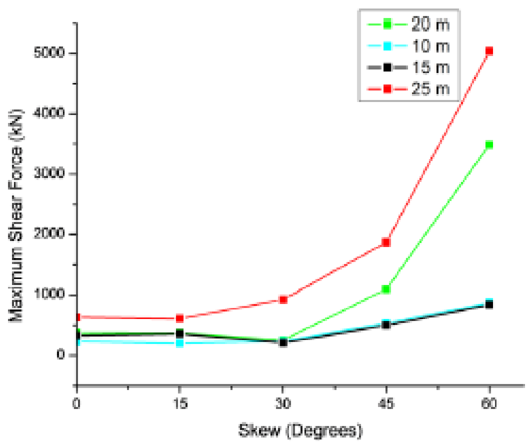


Figure 11: Maximum SF Class70RT+A

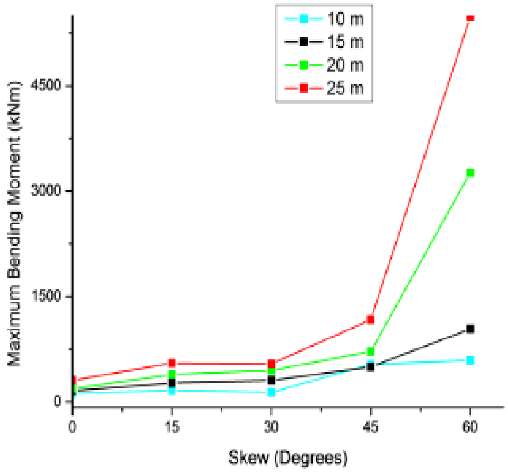


Figure 12: Maximum BM Class70RT+A

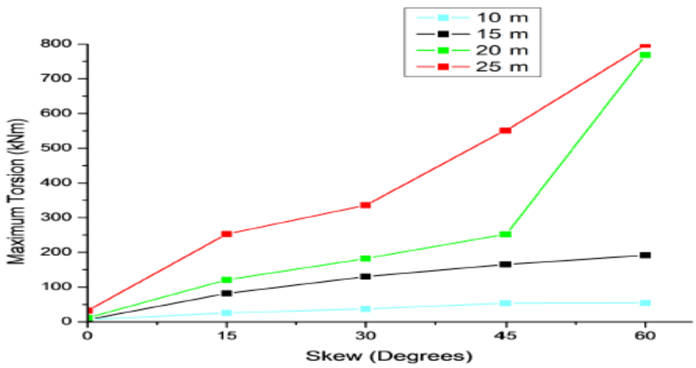
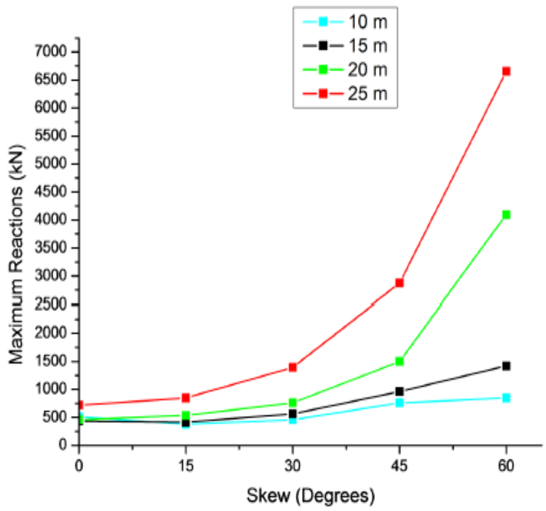


Figure 13: Maximum Torsion Class70RT+A



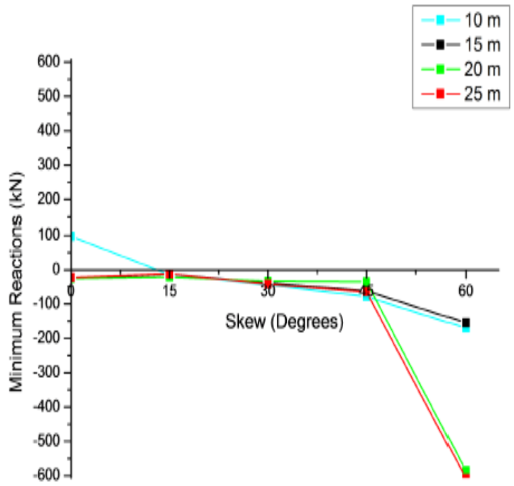


Figure 14: Maximum Positive Reaction Class70RT+A Figure 15: Maximum Negative Reaction Class70RT+A

VI. CONCLUSION

The analysis of bridges and comparisons of the results of different span and skew angles have led to the following conclusions.

[1] For skew bridges the arrangement of cross girders perpendicular to the longitudinal girders is more effective in transverse load distribution as compared to the arrangement in which the cross girders are parallel to the abutments.

[2] Grillage analogy method, based on stiffness matrix approach, is a reliably accurate method for a wide range of bridge decks. The method is versatile, easy for a designer to visualize and prepare the study for a grillage.

[3] The increase in BM up to 40 degree skew angle is less. At higher skew angle sharp increase is observed. Results show that end girder placed in centre of skew span has maximum BM.

[4] Torsion, with increase of skew angle increases appreciably in all directions.

[5] Maximum positive and negative reactions are noted in skew bridges ,very close to each other

[6] Results of SF shows mixed pattern i.e. value of maximum SF do not follow a regular pattern. However the difference of SF, as the span increases, decrease.

[7]

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