Static and Vibration Analysis of Bridge Deck Slabs

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Abstract

Bridge deck slabs are the most important structures commonly supported at the two edges. Such supports are generally orthogonal to the traffic course. However, once in a while they may not be orthogonal to the traffic route necessitated by many reasons. Such bridge decks are defined as skew bridge decks. Very little research work is reported on static and vibration behavior of skew slab bridges. Subsequently, in this study an attempt has been made to evaluate the static and vibration behavior of skew slab bridge decks and the usage of finite element analysis. Static analyses are done for distinctive skew angles and for defferent aspect ratios, loading situations together with dead load, Indian Road Congress (IRC) class A loading and also for the cases of deck slab with out and with edge stiffening beams. Similarly, parametric studies on bridge deck having 30° skew angle and aspect ratio of 0.4 are done to assess the impact on area stiffening, bearing flexibility at the static behavior. Vibration analysis of simply supported skew slab bridges of various skew angles and aspect ratios are also performed.

Keywords: *Skew bridge decks, Skew angles, Edge stiffening, Bearing flexibility.*

1. INTRODUCTION

The structures are generally analyzed by static and dynamic methods. Selection of an appropriate method depends upon the several factors such factors includes importance of analysis, importance of structure, type of the structures and its surrounding soil conditions. Structures are designed in such way that it should carry self-weight, live loads, super imposed loads and wind loads. These loads are considered as maximum load taken by the structure and they are static in nature [1-5]. In some of studies it includes static and dynamic loads also [6]. The analysis of dynamic loading are evaluated by equivalent static method, or by an impact factor, or by a modification of the factor of safety etc. The finite element evaluation performs an essential function for any complex analysis.

It is very beneficial in which difficulty of Geometrical conditions, material properties, boundary situations and loading are involved.

2. METHODOLOGY

2.1 Details of Finite Elements used

The finite element approach has turn out to be a powerful computational tool, which allows complex analyses of the structures to be completed in a recurring fashion. There are various finite element software applications along with STAAD pro, SAP 2000, ATENA, ABAQUS, ANSYS, E-TABS, etc. STAAD pro (Structural analysis and design) is used for the present observation. Bridge deck slabs are modeled using Plate/Shell detail. Area stiffening beams are modeled using beam element and support elastomeric bearings is modeled using solid elements.

2.2 Material Properties and Load Modeling

Properties for Deck slab is taken as $E= 25 \times 10^6$ kN/m^2; $\mu= 0.2$; $\rho= 25$ kN/m^3
The dead load contains of self-weight of the whole structure. This is accounted through geometrical properties of sections and unit weight of materials used. The primary live load on Highway Bridge is of the cars moving on it. Indian Roads Congress (IRC) recommends different kinds of widespread hypothetical vehicular loading systems in IRC 6:2000, for which a bridge is to be designed. The vehicular live load consists of a set wheel loads which can be distributed over small areas of contacts of wheels and form patch loads and dealt with as concentrated loads acting at centers of contact areas. This will acquire the maximum response resultants for the layout, different positions of every type of loading system as per IRC 6:2000 is tried at the bridge deck. The load is moved longitudinally and transversely in small steps to occupy a large number of various positions on the deck. The largest force reaction is obtained at each node. As per IRC 6:2000 Table-2, lane of class A or one lane of class 70R should be considered to get most response under hypothetical vehicular loading systems.

2.3 Support Conditions

For simply supported case, the nodes must be constrained in the vertical direction (Y direction). A single line of nodes on the plate along the supported width are constrained in vertical direction (Y course). For the evaluation to run, small spring stiffening of 1 kN/m is provided all along the supported width of plate in Z direction. The simple support is shown in the Figure-1.

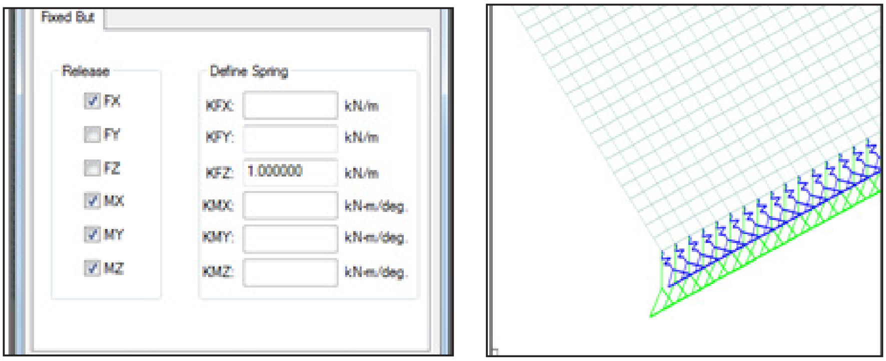


Figure- 1 Details of simply supported condition

3. STATIC ANALYSIS

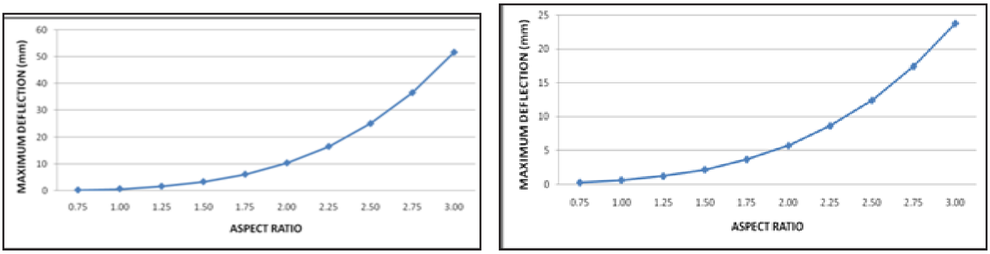
Typical simply supported two- lane bridge study cases are considered in this study. Ten aspect ratios 0.75, 1.0, 1.25, 1.50, 1.75, 2.00, 2.25, 2.50, 2.75 and 3.00 are considered as parameters of deck slab of 0.75m thickness. The aspect ratios considered for analysis are shown in Table-1.

Table-1 Different aspect ratios for deck slab

Span in m	Right widthin m	Aspect ratio (L/B)
5.25	7	0.75
7.00	7	1.00
8.75	7	1.25
10.50	7	1.50
12.25	7	1.75
14.00	7	2.00
15.75	7	2.25
17.50	7	2.50
19.25m	7	2.75
21.00m	7	3.00

It is observed that the deflection increase with the increase in span to width ratio (Aspect ratio). Variation of deflection under dead load and IRC Class A load is shown in the Figure-2 (a) and (b) respectively.

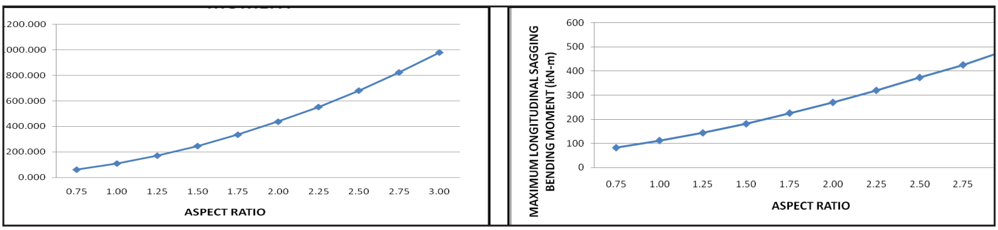
3.1 Variation of Deflection



(a) **(b)**

Figure-2 Variation of deflection

3.2 Variation of Longitudinal Sagging Bending Moment

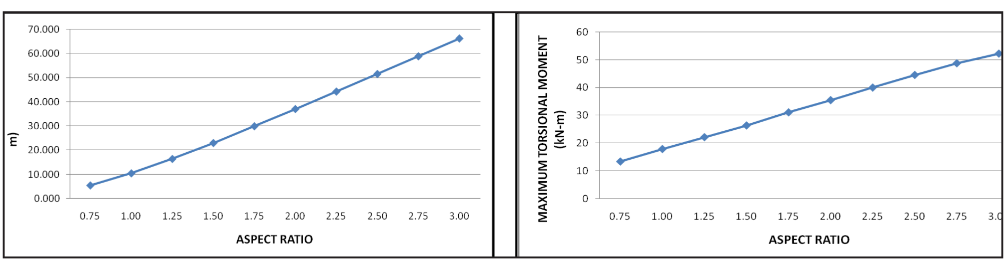


(a) **(b)**

Figure-3 Variation of longitudinal sagging bending moment

It is observed that longitudinal sagging bending moment increases with increase in aspect ratio. And the effect under dead load and IRC Class A load is shown in the Figure-3(a) and 3(b) respectively

3.3 Variation of Torsional Moment



(a) **(b)**

Figure-4 Variation of torsional moment

The variation of torsional moment with respect to Aspect ratio for dead load and IRC Class A load is shown in the Figure-4.

4. VIBRATIONAL ANALYSIS

Natural frequencies are obtained by carrying out vibration analysis of different cases mentioned in previous sections. Figure-5 and 6 shows variation in natural frequencies of bridge deck with respect to the varying aspect ratios

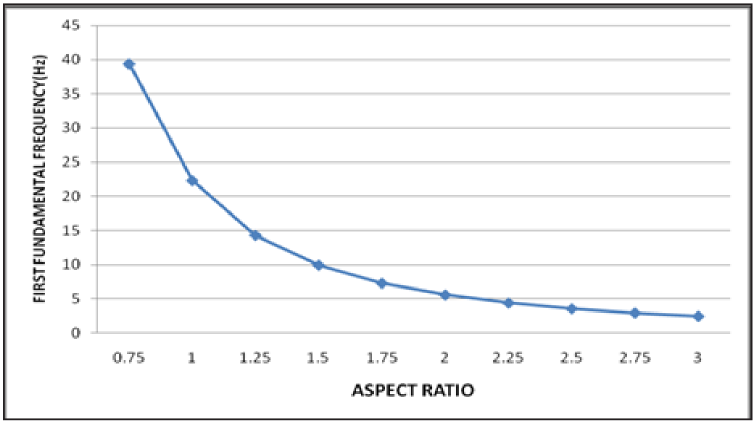
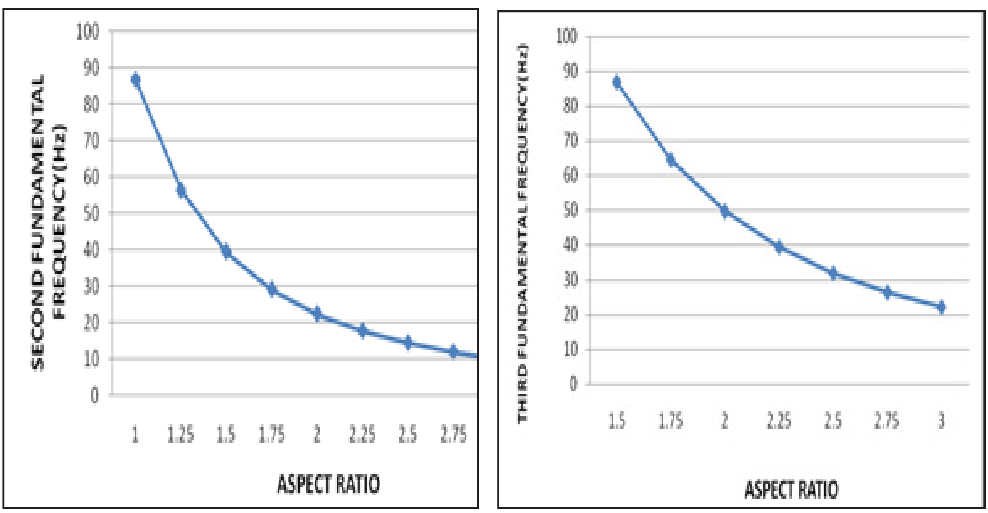


Figure-5 Variation of first fundamental frequency of bridge deck slab with aspect ratio

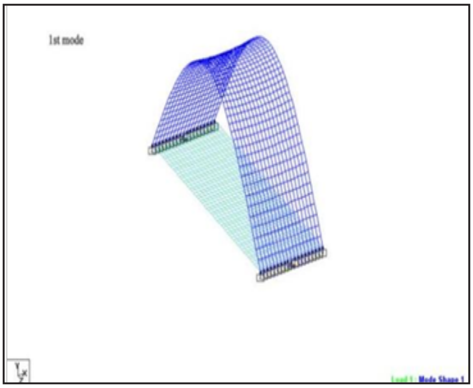


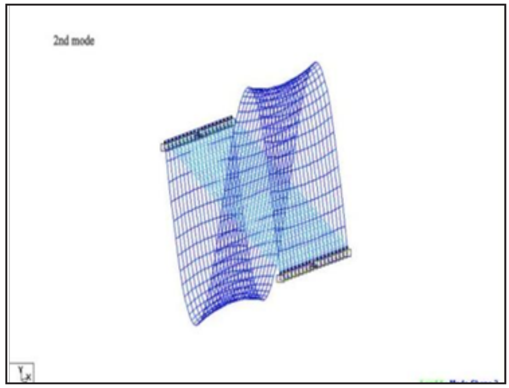
(a) **(b)**

Figure-6 Variation of second and third fundamental frequency bridge deck slab with aspect ratio

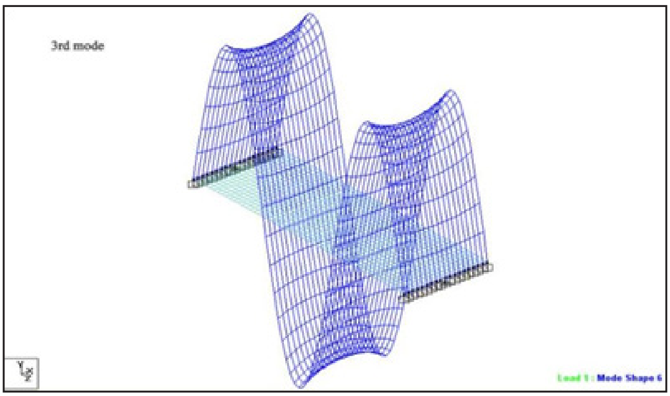
4.1 Mode Shapes

First three Mode shapes for the aspect ratio 1.0 are shown in Figure-7(a),7(b) and 7(c) respectively.





(a) (b)



(c)

Figure-7 First three mode shapes for 1.0 aspect ratio of bridge deck slab.

5. CONCLUSIONS

Based on the Static evaluation and vibrational evaluation of Bridge deck slab, the following conclusions are drawn.

- The maximum deflection for the deck slabs increases with increase in aspect ratios for all loading situations.
- The maximum longitudinal sagging bending moment for the deck slabs increase with increase in aspect ratios for all loading conditions.
- The maximum torsional moments increase with increase in aspect ratios for all loading situations.
- As aspect ratio will increase first fundamental frequency decreases.
- As aspect ratio increases second fundamental frequency decreases.
- As aspect ratio will increase third essential frequency decreases.

Legend

μ	=	Poisson's Ratio
ρ	=	Density
B	=	Right Width in m
E	=	Modulus of Elasticity
L	=	Span Length in m

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