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Investigate the Mode Shapes, Time Periods and Natural Frequency of the Skew- Curved Bridges under Free Vibrations using Finite Element Models

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ABSTRACT

Time period ratios for first longitudinal mode are found to increases as the degree of skewness and curvature increases, whereas mode participation factor decreases with increase in curvature and increases with increase in skewness for the same mode. Mode participation factor of first transverse (in-plane) vibration mode increases with increase in both skew and curvature angle. Results of response spectrum analysis indicates that all the three principal moments experience higher moment demand under transverse components of seismic excitations. For skew-curved bridges moment demand gets increases with increase in curvature in most of the cases. However, increase in skew angle causes decrease in moment demand in most cases.

KEYWORDS: *longitudinal, curvature, transverse, vibration, spectrum*

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INTRODUCTION

When a structure undergoes seismic excitations, during that interval a large amount of horizontal force is applied on the structure in short period. Bridge's behaviour under the effect of applied seismic force, decides its seismic performance. Under seismic and service loads, behaviour of skew and/or curved bridges become more complex due to the influence of its unconventional geometry. As compared to straight bridges, skew bridges exhibit higher potential to unseat [1]. When skew bridges are subjected to seismic force, unseating of the deck occurs due to the translation motion and rotation of the deck [1-4]. Seismic demands in case of curved bridges are higher as compared to the seismic demands in case of straight bridges [5]. The bridges become more vulnerable as the horizontal deck curvature increases. In case of curved bridges, seismic response in the longitudinal and transverse directions get couple [6]. Moreover, when such skew alignment of abutments is introduced in curved bridge geometries, their susceptibility for damage under earthquake forces becomes manifolds [7]. Owing to action of the seismic waves, the vibrations occur in the bridge system generates internal deformations and stresses which governs the seismic response of the bridge

LITERATURE REVIEW

Meng et. al (2001) concluded that dynamic response of skew bridge is significantly influenced by rotational to translational frequency ratio (R/T). As R/T ratio of the bridge increases, the maximum normalised displacement of the bridge gets decreased irrespective of the damping considered [24]. Translational modes under free vibrations were found to be naturally coupled for symmetric skew bridges having one span [25]. An approximate seismic analysis was presented by Kalantari and Amjadian in which reaction forces of the elastomeric bearings wereconsidered at abutments to prove that translational modes deviate from bridge principal axes incase of symmetric skew bridges [26-28]. In their later study, they incorporated the effect of seismic pounding on skew bridge torsional response [29]. Dimitrakopoulos also investigated effects of deck-abutment pounding for skew bridges and observed that tendency of skew bridges to express transverse displacement and rotation of the deck after pounding is dependenton skewness, friction and in-plan geometry [30,31].

Foothill Boulevard Undercrossing suffered serious damages under the great 1971 San Fernando earthquake and many researchers had tried to find out the reasons behind the failure of this bridge [1,11] by analytical approach. Figure 5 shows the structural details of the bridge.

METHODOLOGY

3-D finite element models have been generated to perform analysis of skew-curved bridges under free and forced vibrations. Finite element models for several skew-curved bridgeconfigurations taken for this study have been modelled with the help of finite element program

Finite Element Method

Finite element method is a numerical approach for analysis of the structures. It is a computational approach which is used to obtain approximate results for problems of engineering. Problems are described by partial differential equation or can be formulated as functional minimization.

At present, finite element analysis is used at large extents in structural analysis. This method is developed after the intervention of the digital computers and is used in providing the solution for physical problems (such as an actual structure subjected to a force) of engineering analysis. The finite element analysis involves the various steps for the solution of the idealized mathematical model as shown in the figure 3.2. Physical problem is idealized as a mathematical model on the basis of the certain assumptions, from which the differential equation can be generated that governs the mathematical model. Mathematical model is solved using the finiteelement analysis. As this is a numerical approach, therefore it is necessary to check the obtainedsolution for accuracy. If the solution is not found satisfactory as per the accuracy criteria, the finite element analysis is repeated with refined parameters until the solution with sufficient accuracy is obtained.

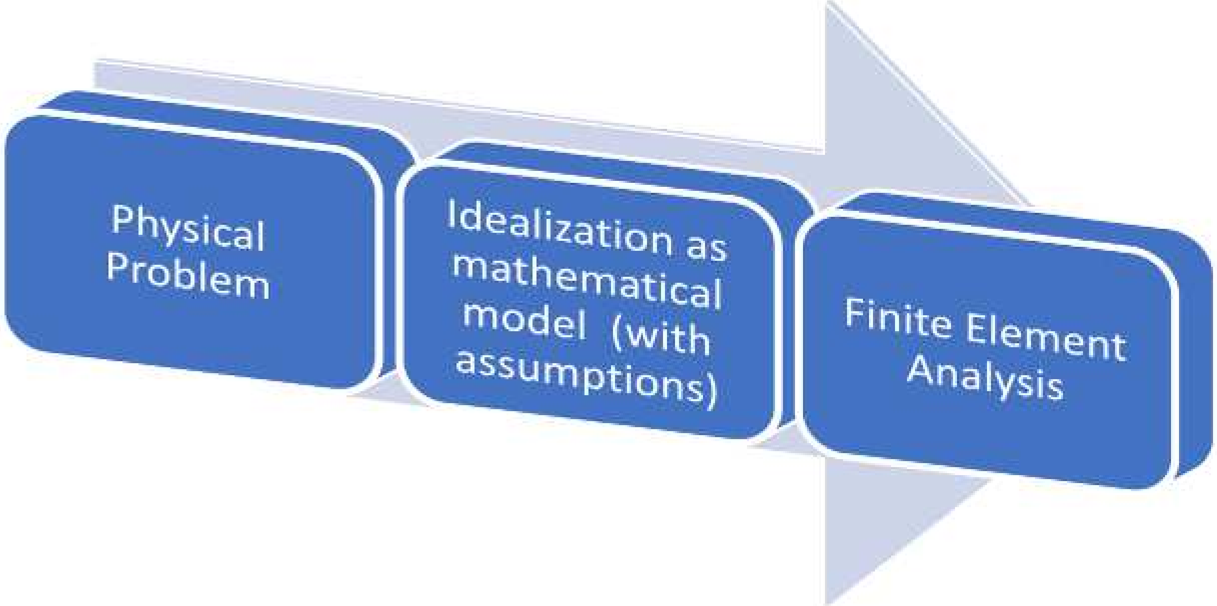

Figure 1 Phenomenon of solving the physical problem using finite element method

β=0° and θ=45°

β=0° and θ=60°

Figure 2. 3-D Bridge models for the configuration of β=0° with varying skew angles (θ)

Conclusions

1. Usually, the mode participation factor of third out of plane vibration mode have very least changes with increase in curvature angle for any particular skew angle.
2. Mass participation ratio of first longitudinal vibrational mode usually increases as the skewness increases, whereas decreases as the deck-curvature increases.
3. Out-of-plane bending moment at mid span increases with increase curvature up to the curvature angle of 60° under longitudinal component of seismic excitations which reduces for curvature angle of 90°.
4. Out-of-plane bending moment of skew-curved bridges under transverse and vertical components of seismic excitations decreases with increase in skew angle for a certain angle of curvature. However, for combination of higher curvature with higher skewness, a different variation trend is noticed.
5. For a constant curvature angle, when skew angle is increased then in-plane bending moment under longitudinal component of seismic excitations decreases, whereas it increases under transverse component of seismic excitations.
6. When skew-curved bridges are subjected to vertical component of seismic excitations, thenthe in-plane bending moment does not varies linearly for various skew-curved bridge configuration and hence, forms a complex variation trend.

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