Effect of Skewness on Bridges Subjected to Seismic Loading

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Summary

Skew bridges are basically required in highway and railway engineering. Unlike straight bridges, the behavior of skew bridges under seismic loading is not quite simple due to the interaction which exists between longitudinal and transversal bridge directions when subjected to in-plane loading such as earthquake forces. The aim of the present paper is to study the behavior of skew bridges when subjected to longitudinal and transversal earthquake loading. The response spectrum analysis as presented by AASHTO LRFD is considered in the present study. Straight, moderate and sharp skew bridges are included. The effect of pier stiffness is also discussed. The present study is based on two span skew bridges resting on pot bearings. Two types of finite element models are adopted for the seismic analysis of the skew bridges. In both models shell elements are used to represent the bridge superstructure; while, frame and shell elements are considered for the pier representation of model 1 and model 2 above, respectively.

Keywords: skew bridge; seismic; finite element; AASHTO LRFD; response spectrum, modal analysis

1. Introduction

Many papers dealing with the seismic analysis of skew bridges have appeared in the literature. However, in most of them the effect of skewness is not comprehensively presented. Wakefield et al. [1] considered the seismic behavior of an actual skewed concrete bridge namely, 'The foothill Boulevard Undercrossing' in San Fernando, California which suffered a severe damage during the 1971 earthquake. They concluded that the rigid-body modes dominated the earthquake response of the short stiff skew bridges if the deck is not properly fixed to the abutments. Maleki [2] conducted a parametric study on a nonlinear spring mass model representing straight and skewed simple span slab-girder bridges resting on elastomeric bearings with side retainers. He concluded that ignoring the gap in the analysis can cause non-conservative results. In the present paper the behavior of skew bridges under seismic loading is analytically investigated. Two 30 m span continuous skew bridges consisting of slab type deck as shown in figure 1 below are considered in the present work. Parametric studies including bridge skew angles and pier heights are presented. The study is based on the elastic seismic response coefficient C_{sm} computed according to AASHTOO-LRFD [3]. Two 3-D finite element models are developed using SAP2000 software [4] to achieve the above study. The deck in the above models consists of shell elements; while, the pier is represented by frame elements in one model and shell elements in the second one. Modal analysis results in addition to seismic response results, due to longitudinal and transversal earthquake loadings corresponding to 0.15g seismic acceleration coefficient, are presented for the above straight and skew bridge types.

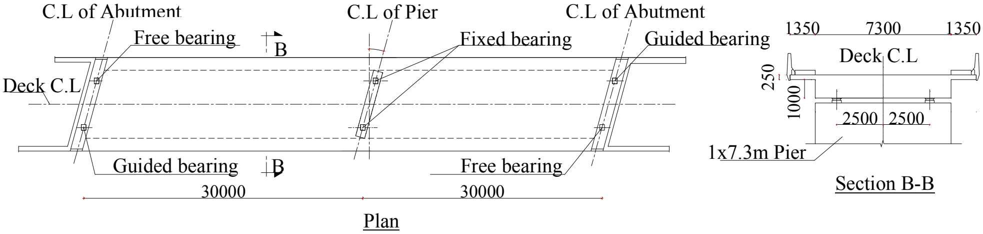

Fig.1: Plan and cross section of two 30m span skew bridge used in the present study

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2. Longitudinal and transversal earthquake results

Results corresponding to 0.15g seismic acceleration coefficient for different skew bridge angles with 9 m pier height are presented in the current section for longitudinal and transversal earthquake conditions. The results focused on the pier base shear in the weak V33 and the strong V22 pier axis directions, the transverse abutment bearing reaction Ra and the maximum longitudinal bridge deck displacement Δx. A sample of the load results extracted from SAP2000 output for 30° skew bridge is displayed below in figure 2.

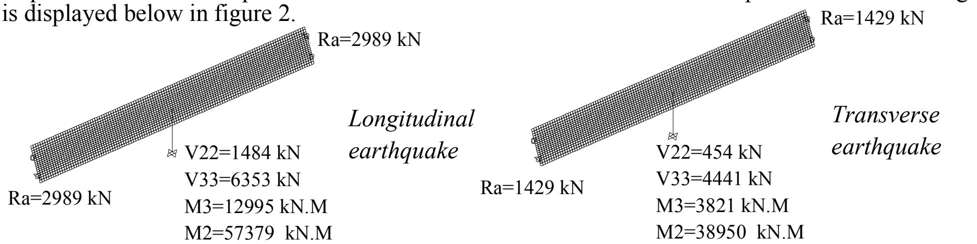

Fig.2: Longitudinal and transverse earthquake SAP2000 load results for bridge with 30^o skew angle

3. Results discussion and conclusion

Based on the above study, the following remarks can be made for the two span skew bridges investigated in the present work:

- Under seismic loading, unlike straight bridges, the behavior of skew bridges is distorted due to the skew orientation of the central pier. This is clear from the modal analysis conducted in the current work.
- Due to longitudinal earthquake, significant transverse reactions at abutment bearings, even for slight skew bridge angle, are induced due to the longitudinal and transversal displacement interaction in skew bridge for such earthquake condition. These reactions increase with the increase of the Ixy and the Iy of the central pier. Same remark is applied for the central pier base shear. On the other hand, under longitudinal earthquake condition, the bridge longitudinal displacement decreases with the bridge skew angle.
- The results obtained from the two finite element models adopted in the present study are reasonably in good agreement with a maximum difference of about 5%.
- The lower the lateral pier stiffness is, the higher the lateral abutment bearing reactions are for both longitudinal and transversal earthquake conditions.

4. References

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