A4-1. Seismic Analysis - 1

# Response of Three Span Skew Bridges Subjected to Longitudinal and Transversal Earthquake loading

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**Essam AYOUB**
Assistant Professor
Structural dept., Cairo Univ.
Dar al-handasah
Cairo, Egypt
*Essam.Ayoub@dargroup.com*

**Charles MALEK**
Director
Dar al-handasah
Cairo, Egypt
*Charles.Malek@dargroup.com*

**Gamal HELMY**
Head of Bridge Dept.
Dar al-handasah
Cairo, Egypt
*Gamal.Helmy@dargroup.com*

## Summary

Skew bridges are extensively required in highway and railway engineering projects. 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 displacements when subjected to in-plane loading such as earthquake forces. In the present paper, the effect of bridge skewness on three span bridges resting on pot bearings and subjected to longitudinal and transversal seismic loading is studied. The response spectrum analysis as presented by AASHTO LRFD is considered. . Moderate seismic condition with 0.20 g seismic acceleration is applied. The effect of the abutment pot bearing articulations is also included in this study. Finite element models are adopted for the seismic analysis of the skew bridges. A modal analysis is conducted for bridges with different skewness in order to estimate the periods and the mass participation coefficients resulting from each dominant mode shape. The study focused on the output results related to the bridge pot bearing reactions at abutments, the longitudinal and the transversal base shear forces as well as torsion applied on central piers in addition to the bridge displacements.

**Keywords:** skew bridge; pot bearings; 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, reinforced 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 investigated the retainer gap distance effect on the transverse vibration. Nonlinear time history dynamic analysis was conducted on the simple span slab-girder bridges with side retainers. He concluded that ignoring the gap in the analysis can cause non-conservative results. Whelan et al. [3] studied experimentally and analytically the dynamic response of three-span multi girder skew bridge supported on elastomeric bearings within traffic-induced vibration and seismic loading. They concluded that the linear dynamic analysis provides conservative estimate of multimodal displacement for such bridge type. The damages of the skew multi girder bridge namely 'Pico-Lyons Bridge' in California [4] and caused by 1994 Northridge earthquake were investigated using non-linear finite element analyses. The study showed that for bridges with skew angle of about 40°an increase of 50 to 60% in stresses arise in the end girders. Ayoub et al. [5] conducted analytical study on the skewness effect of two span slab type bridges subjected to longitudinal and transversal earthquake conditions and they concluded that significant interactions in forces and displacements exist between longitudinal and transverse bridge directions. No torsion on piers is reported in their study. In the present paper the behavior of skew bridges under seismic loading is analytically investigated. Three span continuous skew bridges (22.5, 30 and 22.5 m) consisting of pre-stressed slab type deck of 10 m width and 0.25/1.25 m thick are considered. The bridges are supported on pot bearings resting on two rectangular wall type central piers of 9 m height and 1x9 m cross section and on two abutments as shown in figure 1. The bearings are considered fixed at the

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