Estimation of Seismic Demands in Bridges Crossing Fault Rupture Zones

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ABSTRACT
This paper presents an analytical procedure for estimating seismic demands of a bridge crossing a strike-slip fault that is capable of producing motions with permanent offset. In this procedure for linear elastic systems, seismic demands are computed by adding the results from: (1) quasi-static analysis for all support displacements applied simultaneously, and (2) dynamic analysis for reference ground acceleration using the "effective" influence vector. A unique feature of this procedure is that even though the bridge is subjected to multi-support excitation, its dynamic response can be estimated by procedures similar to standard procedures for systems subjected to uniform ground motion.

Analysis of a linear elastic, three-span symmetric bridge subjected to transverse support motions resulting from a fault rupture between its two bents shows that only the torsional modes are excited even though the bridge is subjected to transverse motions; in contrast, only transverse modes are excited for symmetric bridge subjected to uniform transverse support motions. Furthermore, it is found that deck displacement at abutment 1 is dominated by the quasi-static part, whereas column drift is dominated by the dynamic part. Therefore, no generalization should be made about ignoring either quasi-static or dynamic parts in estimating seismic demands.

Finally, responses of bridge with nonlinear shear keys obtained from nonlinear response history analysis are compared with bridges without shear keys and bridges with elastic shear keys. A simple tri-linear model for shear-key behavior is used to "mimic" the experimental results. It is shown that response of bridges with nonlinear shear keys may be significantly different compared to the bridge either without shear keys or with elastic shear keys. However, the cases without shear keys and with elastic shear keys may be used to obtain bounding values on the response of bridges with nonlinear shear keys. Since different shear key condition may provide upper bound for different seismic demands, both cases – without shear keys and with elastic shear keys – must be considered to establish upper bounds on all seismic demands. The current Caltrans practice of ignoring shear keys may not always provide conservative estimates of all seismic demands.