I-B 306

POUNDING OF SUPERSTRUCTURE SEGMENTS OF ELEVATED BRIDGE DURING EARTHQUAKES

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1. INTRODUCTION

During severe earthquakes, such as Great Hanshin Earthquake of 1995, pounding of adjacent superstructure segments of multiple supported elevated bridges was observed. The phenomenon is mainly caused by seismic wave propagation effect. When wave travels, supports of long structures receive different input loads and thus parts of superstructure are subjected to different excitations. The collision of bridge segments can also occur due to the difference in stiffness of adjacent piers. Pounding can cause difficult and expensive to repair damage to deck ends and in some cases a collapse of bridge.

In this paper the analysis of pounding of adjacent superstructure segments of bridge is studied. It was observed that size of gap between deck ends can be optimized to reduce the pounding effect. Further improvement is intended to be achieved by installing between adjacent segments an energy absorber.

2. MODELING AND PRELIMINARY ANALYSIS

The structure used in the analysis is an isolated (high damping rubber) highway elevated bridge with dimensions and cross section properties specified in "Manual for Menshin Design of Highway Bridges" 1). For the analysis, five superstructure segments with neglected parts of the bridge simulated as spring elements were taken into consideration (Fig. 1). It was checked that for such layout the influence of the boundary conditions is minimized and correct response of the middle segment can be obtained.

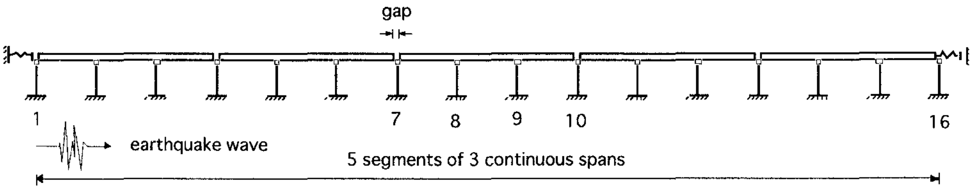

Fig.1 Full model of bridge

A simplified model of 5 degree-of-freedom system, presented in Fig. 2 was first analyzed. Superstructure segments were discretized as point masses, *m*, mounted on bearings represented as spring--dashpot elements, *K, C*. The influence of piers was neglected. Pounding was modeled using elastic impact elements with stiffness, *k* 2). These elements become active when the distance between adjacent masses is smaller than initial gap, *d*. The sinusoidal loading with the frequency and peak value equal to the adequate values of NS component of Kobe Earthquake was applied. The seismic wave traveling effect was taken into consideration. The input load acting on every degree of freedom was shifted by the time delay parameter depending on the mean wave velocity and distance between masses. The values of maximum bending moments for the middle mass as a function of gap are presented in Fig. 3.

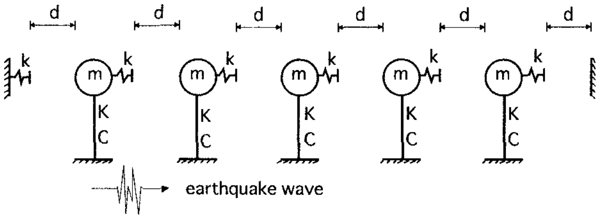

Fig.2 Simplified model of bridge

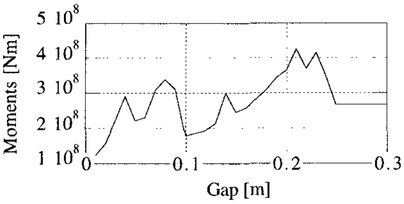

Fig.3 Maximum moments with change of gap for constant earthquake velocity

3. FULL MODEL ANALYSIS

FEM analysis of full model presented in Fig. 1 was performed to compare the results. Seismic wave was modeled to travel in the conditional random field assuming high correlation between points. The spatial correlation function of a negative exponential form was used[3]:

$$K(\mathbf{r}_{ij}) = \sigma^2 \exp\left(-\frac{|\mathbf{r}_{ij}|}{b}\right) \qquad (1)$$

where $\mathbf{r}_{ij}$ is a separation vector between points i, j, σ is a standard deviation of field and b is a correlation coefficient, $b>0$. It's value depends on earthquake dominant frequency, mean velocity of the wave and local geological and topographical conditions. For stochastic simulations regression model based on rejection method was applied[4]. Examples of generated ground motions for Kobe Earthquake for several piers are presented in Fig. 4. Results of FEM analysis using simulated records for piers of middle superstructure segment as a function of gap are shown in Fig.5.

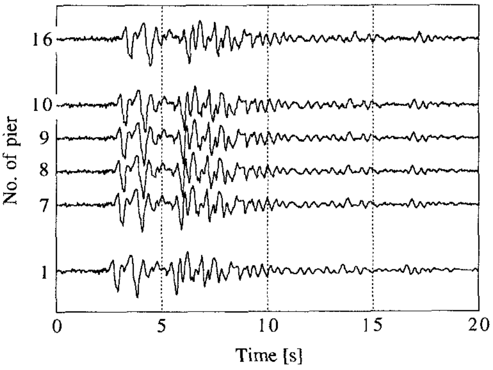

Fig.4 Simulated ground motions for Kobe Earthquake

To minimize pounding and reduce the response of bridge, an energy absorber, placed between decks, was designed. During severe earthquake it is being destroyed by compression, absorbing the energy and giving the optimal space between superstructure segments. Moment histories for base of pier 9 for 0.05m gap with and without energy absorber are presented in Fig. 6.

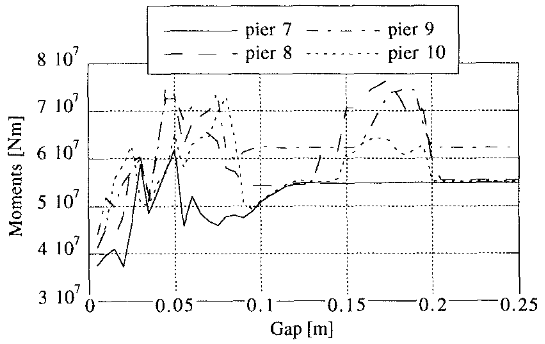

Fig.5 Maximum moments of middle section piers for Kobe Earthquake with change of gap

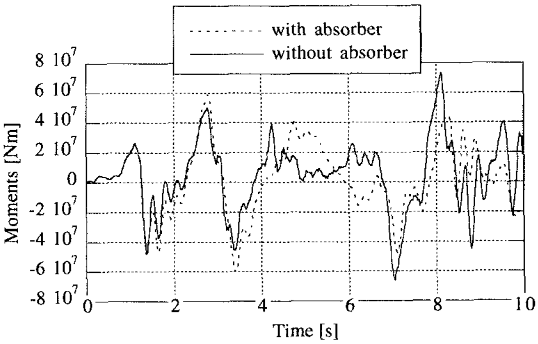

Fig.6 Moment histories for pier 9 with and without energy absorber

4. CONCLUSIONS

Results of simple 5 degree-of-freedom model seem to be in good agreement with results of FEM full model analysis. It can be noticed from Fig. 3 and Fig. 5 that there are three intervals of gap where values of bending moments are the smallest. It seems that the most reasonable gap interval to be used in real structure is the middle one. As can be seen from Fig. 6 experiments with energy absorber which is being compressed during earthquake show the reduction of bending moments up to about 20%.

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