AN ANALYSIS ON SEISMIC RESPONSE OF ELEVATED BRIDGES WITH BIAXIAL MODELS

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Introduction

After the Great Kobe earthquake in 1995, there is a trend to utilize aseismic rubber bearings in elevated bridges. As elevated bridges are usually spatial coupled structures, an analysis, which can reveal bi-axial effects of components of the bridges, becomes necessary. Referring works of spatial analysis of elevated bridges[1], this study uses a bi-axial model for rubber bearings and fiber model for piers. Using a program written in C++, the study conducted an analysis of a typical bridge for several cases.

Biaxial Models

A biaxial model for rubber bearing[2], which is capable at two horizontal directions, is used in the analysis. Using differential equations as follow (where, F_i, U_i, S_i – force, displacement and back force at i direction) this model employs ten parameters (Y, U_0 – yield load and displacement, α, β, γ, n, p, q, η) to describe load-displacement relations.

$$F_i = F_{i1} + F_{i2}, \quad \frac{\dot{F}_{i1}}{Y} = \frac{\dot{U}_i}{U_0} - \frac{\sqrt{\dot{U}_x^{\,2} + \dot{U}_y^{\,2}}}{U_0}\left|\frac{\sqrt{(F_{x1}-S_x)^2 + (F_{y1}-S_y)^2}}{Y}\right|^{n-1}\frac{F_{i1}-S_i}{Y}, \quad F_{i2} = \eta \dot{U}_i^{dashpot} = kU_i^{spring}, \quad U_i^{dashpot} + U_i^{spring} = U_i$$

$$\frac{S_i}{Y} = \left(\frac{U_i}{U_0} - \frac{F_i}{Y}\right)\left(\alpha_0 - \beta\left|\frac{U_{\max}}{U_0}\right|^q\right), \quad Y = Y_0\left\{1 + \gamma\left(\frac{\sqrt{U_x^{\,2} + U_y^{\,2}}}{U_0}\right)^p\right\}, \quad U_{\max} = \sqrt{U_x^{\,2} + U_y^{\,2}}\Big|_{\max\_past}, \quad i = x, y$$

The fiber model, known as a discretized-section model for nonlinear 3-dimensional analysis[3], is used to model piers in the analysis. A bilinear hysteresis model is employed for fibers of steel.

Analysis and Results

A typical three-span steel bridge has been selected for analysis. As shown in Fig.1 & Fig. 2, fiber model is adopted at the first segment of each pier from foundation. Number of fibers is 200 for each pier. Two rubber bearings are applied for each pier. A case of this bridge without applying rubber bearings (using fix supports) has also been analyzed for comparing to the case with rubber bearings. Takatori earthquake waves are used for ground excitations, which are 657 (EW), 279 (UD) and 606 (NS) gal at X (longitude), Y (vertical) and Z (transverse) directions respectively.

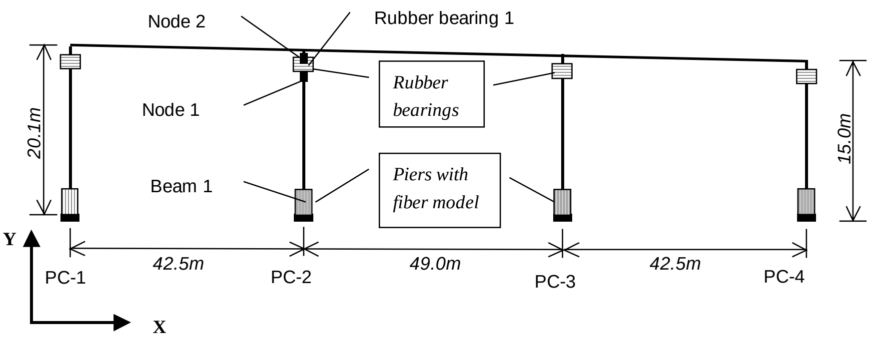

Fig. 1 The Elevated Bridge – Longitudinal View

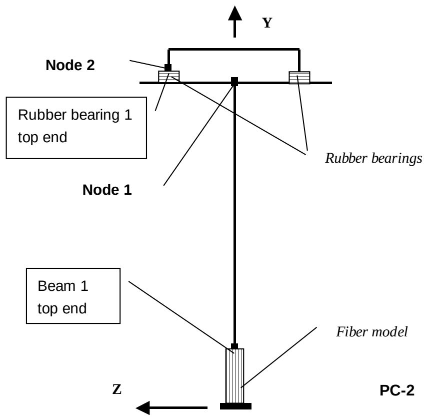

Fig. 2 Section View of PC-2

Keyword: 3D nonlinear analysis, biaxial model, rubber bearing, fiber model
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Conditions of time history analysis: time interval=0.005 (s), duration=10 (s), output data at each 0.01 (s). Results are shown as follow from Fig. 3 to Fig. 7. Note that with the case using rubber bearing, piers (with fiber model) stay almost in elastic, this way, the ships of curves in Fig. 4 and Fig. 5 are nearly the same.

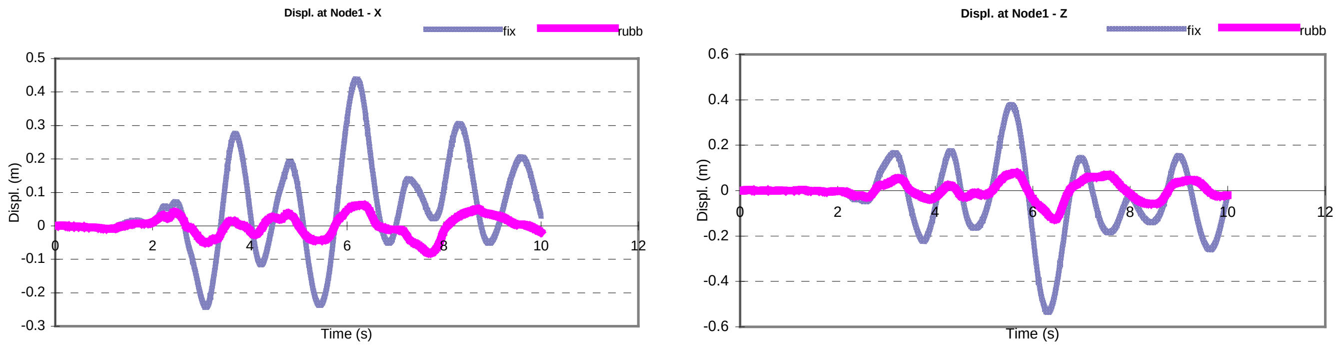

Fig. 3(a,b) Displ. of Node1 at X,Z – with cases of fix-support and rubber bearing

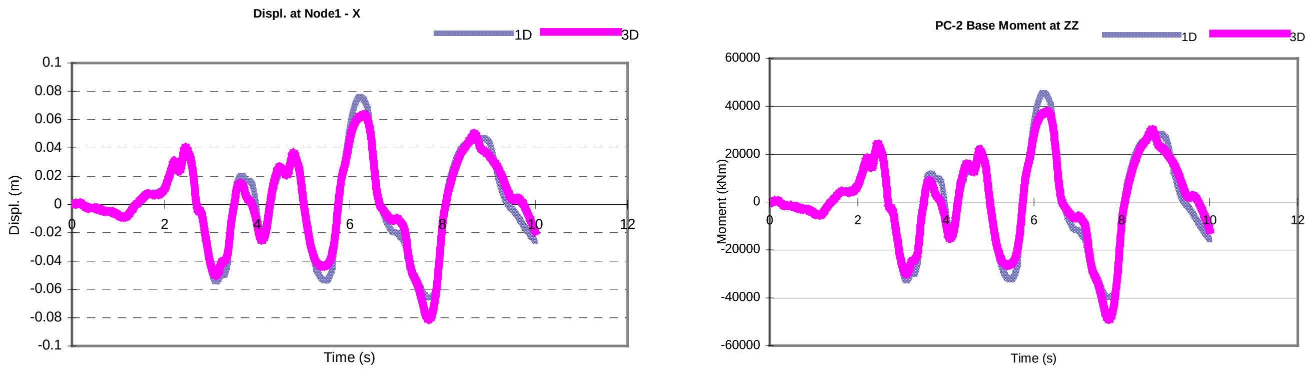

Fig. 4 / 5 Displ. of Node1 / Base moment of PC-2 - under 1D and 3D excitations (with rubber bearing)

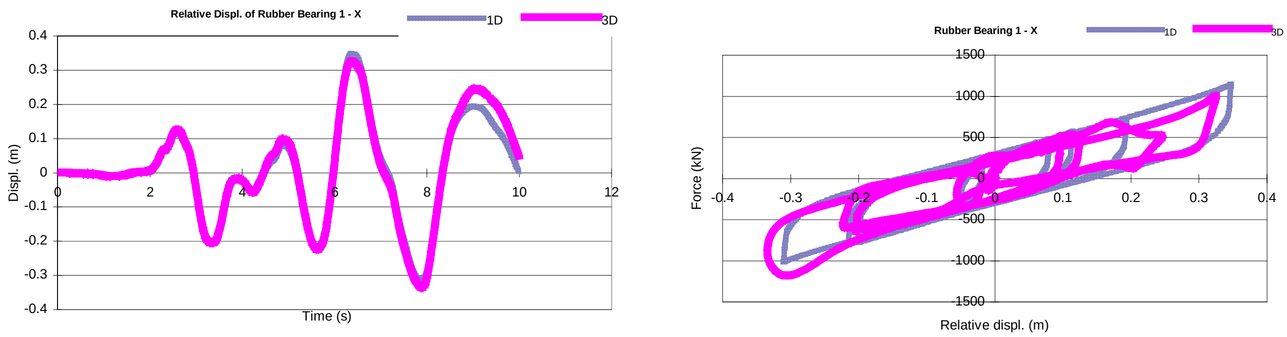

Fig. 6 / 7 Relative Displ. / F-D curve of Rubber bearing 1 - under 1D and 3D excitations

Conclusion

The utilization of rubber bearings reduces the seismic force at piers tremendously. While there are of nearly full yielding of piers of the bridge with no rubber bearing case, only slight yielding happens with piers after using rubber bearings. Using biaxial model, the analysis shows that though a response in one direction is dominated by the ground motion at this direction, the effect of ground motion in the other direction is also noteworthy. Responses may increase due to the couple effect of the structure as the analysis revealed.

Reference

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