THE BEHAVOIOR OF A SEISMIC ISOLATOR IN BRIDGES

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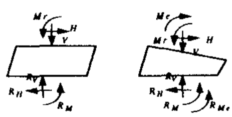
Objective

The main purpose of this paper is to propose a new concept of seismic isolator for bridges. In the present isolated bridges, there are some different mechanical characteristics as compared with an experimental condition; the changed stiffness and the different mechanical behavior in the isolator.

Concept of New Device

In case of buildings, it is very strong rigidity to the vertical direction so the effects of a bending in the bottom of buildings is negligible. But in case of bridges, it is more slender than buildings. Therefore, the effects of the moments and the rotations transferred directly to the device by superstructure must be considered in bridges. In Fig.1, two figures describe different load conditions in the rubber bearings. As removing the external moment, we may solve the problems; a changed stiffness, an unnecessary negative moment, an unbalanced shape in the isolator.



(a) Experiments (b) bridges
Fig.1 Haringx's Column

Numerical Model[1)]

Using the Total Lagrangian formulation, static analysis and dynamic analysis are represented by, respectively,

$$\left({}_0^tK_L + {}_0^tK_{NL}\right)\Delta U^{(i)} = {}^{t+\Delta t}R - {}^{t+\Delta t}_{\ 0}F^{(i-1)} \tag{1}$$

$$M\ {}^{t+\Delta t}\ddot{U}^{(i)} + \left({}_0^tK_L + {}_0^tK_{NL}\right)\Delta U^{(i)} = {}^{t+\Delta t}R - {}^{t+\Delta t}_{\ 0}F^{(i-1)} \tag{2}$$

where, ${}_0^tK_L$: linear strain incremental stiffness matrices, ${}_0^tK_{NL}$: the nonlinear strain incremental stiffness matrices, ${}^{t+\Delta t}R$: vector of externally applied nodal point loads at time $t+\Delta t$, ${}^{t+\Delta t}_{\ 0}F$: vectors of nodal point forces equivalent to the element stresses at time $t+\Delta t$, i : iteration. Strain-Energy relations is derived by Rivilin.

$$W(I_1, I_2) = \sum_{ij=0}^{\infty} C_{ij}(I_1 - 3)^i (I_2 - 3)^j \tag{3}$$

where, C_{ij} : the constants from an experiment. In this paper, the material is assumed to be of the Mooney-Rivlin type, for which experiments by Iding, R.H. gave, C_{11} is $1.518 kgf/cm^2$, C_{22} is $1.107 kgf/cm^2$. Steel shim is considered perfect plasticity.

Simulation Setup

We examine the two cases under vertical load only and under vertical and horizontal load. The shape factor, $S\left(= A_R / 2(a+b)t_e\right)$ is 20. Fig.3 shows the horizontal displacement of isolator under vertical load, 50tf and horizontal load, 10tf.

Verification of Modeling

As comparing the horizontal stiffness formula which is derived by Gent to FEM analysis, we can verify the modeling under vertical load 50tf.

$$K_h = \frac{\alpha\beta}{2\tan\left(\frac{\alpha l}{2}\right) - \alpha\beta l} = 1.430 \cong 1.394(F.E.M) \qquad (4)$$

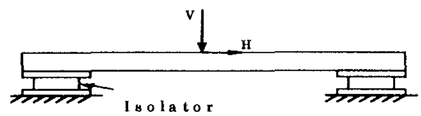


Fig. 2 Simulation Set up

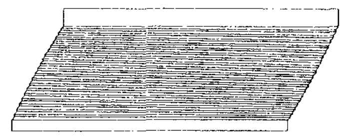


Fig. 3 Behavior of Device

Numerical Results(in the left-side isolator)

Static Analysis

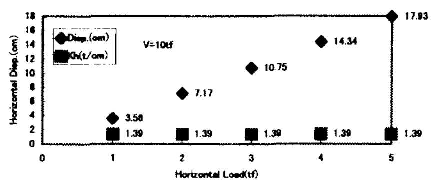


Fig.4 Horizontal Stiffness in Experiments

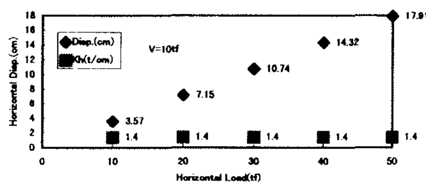


Fig.5 Horizontal Stiffness in Bridges

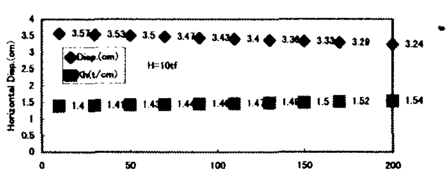


Fig.6 Horizontal Stiffness in Bridges

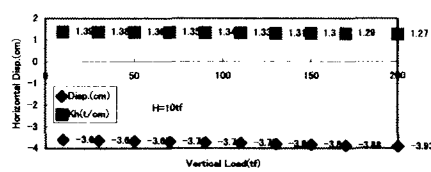


Fig.7 Horizontal Stiffness in Bridges

Dynamic Analysis(vertical load:30tf, horizontal load : El Centro 1940)

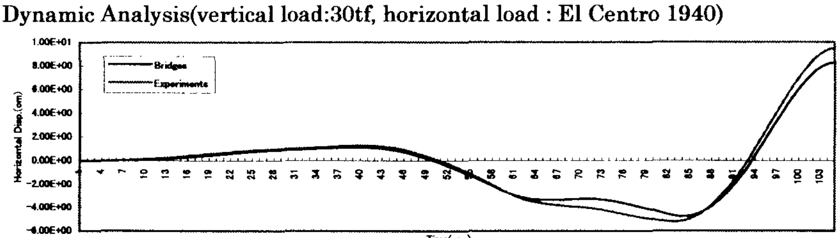


Fig.8 Horizontal Disp. Time History

Conclusions

We can find the horizontal stiffness of the isolator is changing in bridges and the horizontal stiffness is affected by a vertical load.

References

1) K. J. Bathe, *Finite Element Procedures in Engineering Analysis,* Prentice-Hall, 1982

2) James M. Kelly, Ian G. Buckle, and Chan Ghee Koh, "Mechanical Characteristics of Base-Isolation Bearings For A Bridge Deck Model Test", EERC-86/11, 1987, U.S.A