COMPDYN 2011
3rd ECCOMAS Thematic Conference on
Computational Methods in Structural Dynamics and Earthquake Engineering
M. Papadrakakis, M. Fragiadakis, V. Plevris (eds.)
Corfu, Greece, 25–28 May 2011

# SEISMIC VIBRATION CONTROL OF IZADKHAST BRIDGE USING VISCOUS DAMPERS

**H.R. Anajafi[1], A.K. Ghorbani-Tanha[1], and M. Rahimian[1]**

[1] School of Civil Engineering, University of Tehran
P.O. Box 11155-4563, Tehran, Iran
e-mail: hra22_anajafi@yahoo.com, {ghtanha, rahimian}@ut.ac.ir

**Keywords:** Vibration control, Izadkhast Bridge, Viscous damper, Passive control, Earthquake

***Abstract.*** *Present study addresses the effectiveness of viscous dampers (VDs) in reducing the response of Izadkhast Bridge under earthquake ground motions. With the length of 485 m, Izadkhast Bridge is the longest box girder bridge in Iran and is located in Isfahan-Shiraz railway. The bridge is installed with VDs at the two ends. The Finite element model of the bridge is developed. Five pairs of representative earthquake records are selected and scaled using the earthquake code and applied to the model. Nonlinear seismic analyses of the structure without and with VD's are performed and the results are reported. Comparison of the results clarifies VD's effectiveness on seismic response reduction of the bridge. Sensitivity analyses are performed to demonstrate the effects of damper parameters on structural response.*

## 1 INTRODUCTION

The basic function of passive energy dissipation devices when added to a structure is to absorb and dissipate a portion of the input energy, thereby reducing energy dissipation demand on primary structural members and minimizing possible structural damage. Serious efforts have been devoted to the development and utilization of passive energy dissipation devices [1]. Viscous dampers (VD's) are a kind of these devices which significant efforts have been directed toward their application for structural vibration control. In VDs, energy dissipation occurs via conversion of mechanical energy to heat as a piston deforms a thick, highly viscous substance [1]. In present study, the effectiveness of VD's on response reduction of Izadkhast Bridge under earthquake ground motions is investigated.

With the length of 485 m, Izadkhast Bridge is the longest box girder bridge in Iran. This bridge is located in the central part of Iran, spanning Izadkhast valley on the railway line between Isfahan and Shiraz. The bridge is composed of five 77 m spans in the middle, two side spans having the length of 20 m and 40 m, six piers and two abutments, as shown in Fig. 1. The cross section of piers is shown in Fig. 2. With the width of 6.6 m, the deck is composed of two 4.5 m high box girders (Fig. 3). Seismic considerations were considered in the design of the bridge due to its location. The bridge is equipped with four 100 t VDs (stroke 25 cm) longitudinally directed at both ends (Fig. 4). According to the manufacturer catalogs and design documents, the governing equation of the dampers is $f = cv^{\alpha}$, where $f$ is force, $c$ is the damping coefficient, $v$ is the velocity, and $\alpha$ = 0.15 [2, 3]. Four 21.9×80×80 cm rubber bearings are placed at the top of each pier and two 35.7×80×80 cm rubber bearings at the top of each abutment (Fig. 5).

The Finite element model of the bridge is developed. Five pairs of representative earthquake records are selected and scaled using earthquake code and applied to the model. Nonlinear seismic analyses of the structure without and with VD's are performed and the results are reported. Comparison of the results clarifies VD's effectiveness on seismic response reduction of the structures.

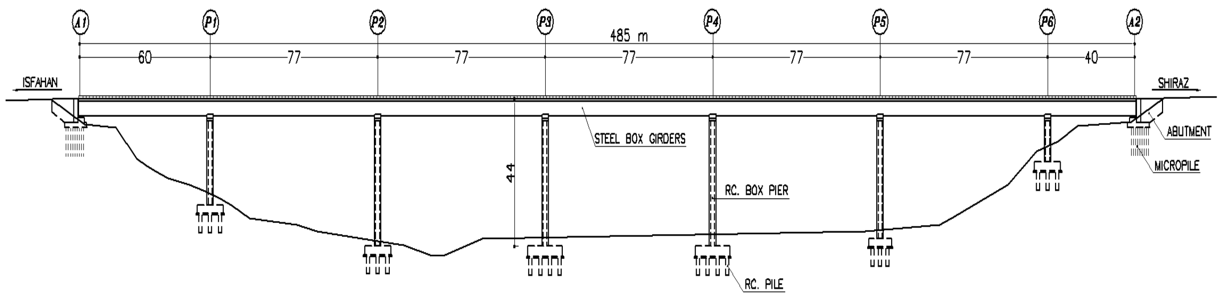



Figure 1: Izadkhast Bridge [2]

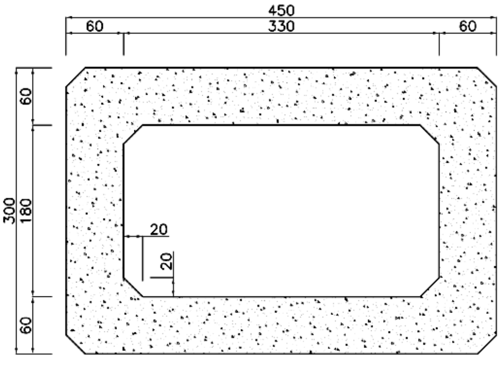



Figure 2: Cross section of piers [2]

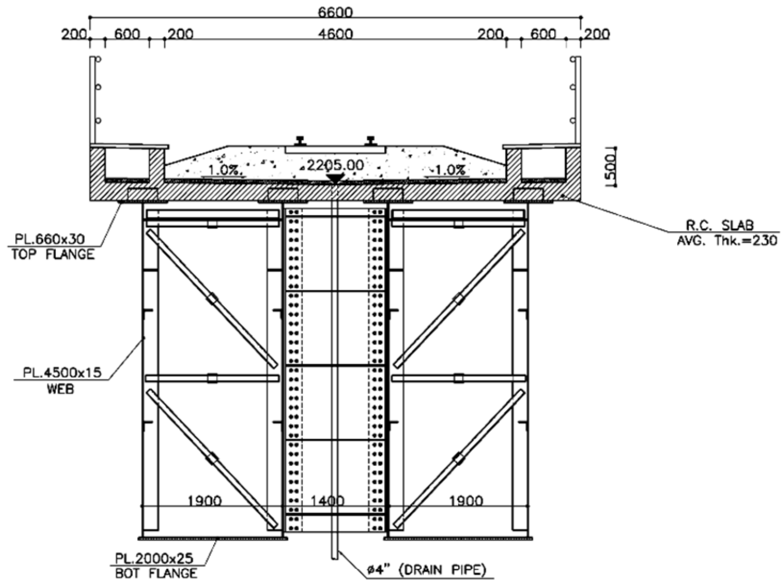
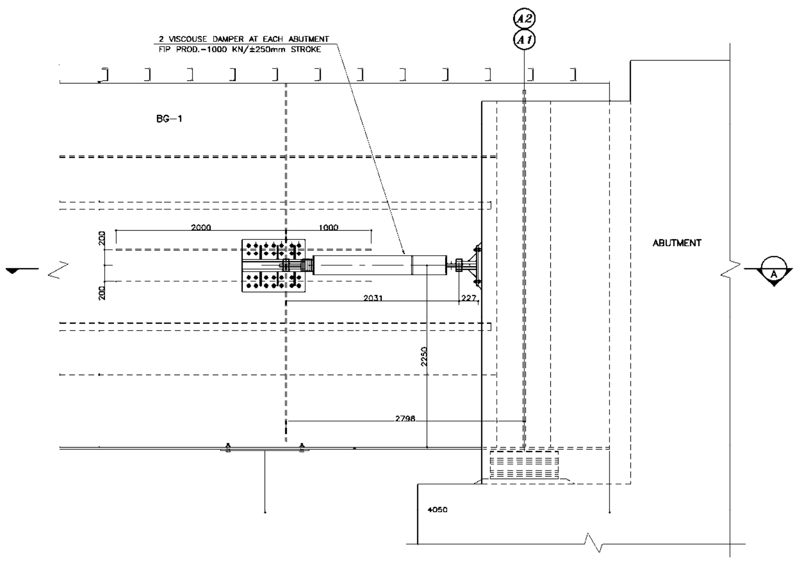
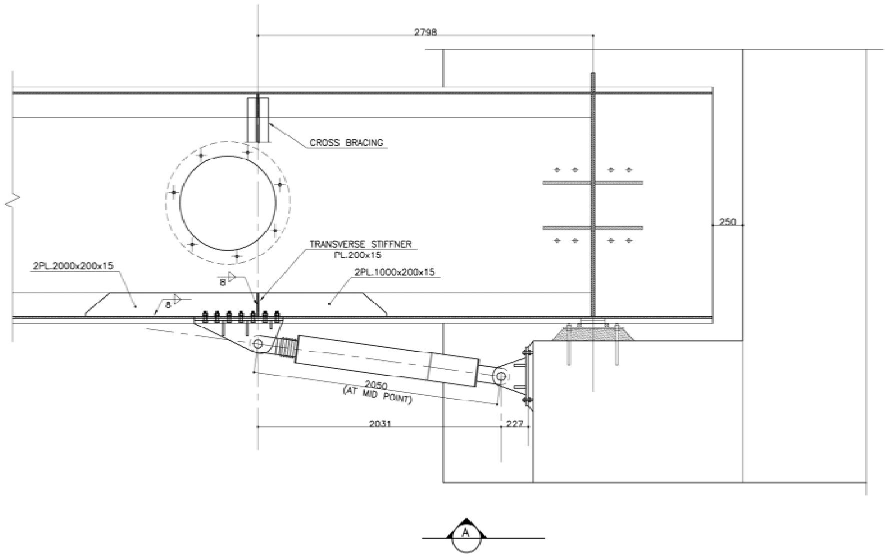



Figure 3: Cross section of bridge deck [2]



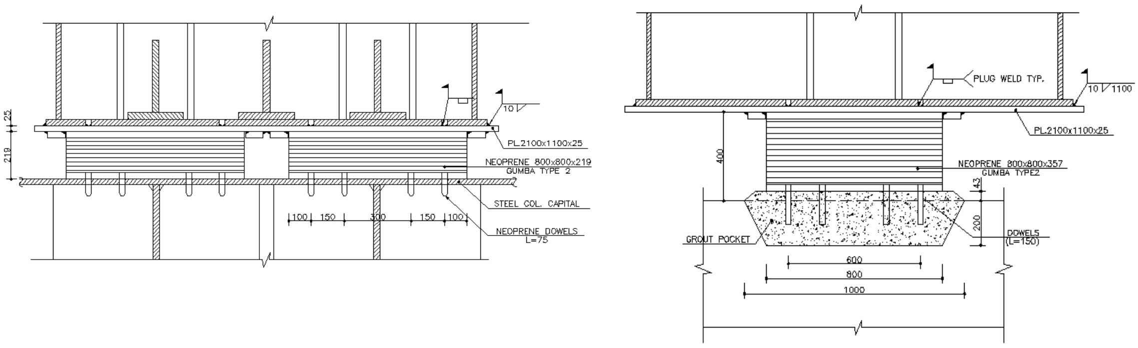

(a)

Figure 4: VDs placement [2]




(b)

Figure 4: VDs placement [2]




(a) (b)

Figure 5: Details of rubber bearings (a) at the top of piers, (b) at the top of abutments [2]

## 2 MODELLING AND ANALYSES

### 2.1 Finite element model of the bridge

A finite element model of the bridge is developed in PERFORM-3D [4]. Constraints are applied to restrict the deck from moving horizontally at Piers 2, 3, 4, and 5 and laterally at all piers. According to Caltrans [5], the displacement capacity of the rubber bearings are calculated as following

$$V_x = \mathrm{tg}\gamma\, T \tag{1a}$$

$$\frac{T}{a} \le 0.2 \ : tg\gamma = 0.7 \quad ; \quad \frac{T}{a} \ge 0.2 \ : tg\gamma = 0.9 - \frac{T}{a} \tag{2b}$$

where $T$ is the effective thickness of the rubber bearing which according to the manufacturer catalogs is 14.4 cm for piers and 25.2 cm for abutments; and $a$ is the minimum dimension of the cross section of rubber bearings. Under seismic loading, an increase of 50% should be applied to displacement capacity. As a result, the displacement capacity for the abutment bearings is 22 cm while this value for the pier bearings is 15 cm. The rubber bearing are modeled as non-linear springs whose initial stiffness are $k_s = GA/T$, where $G$ is shear modulus, $A$ is the area and $T$ is the effective thickness of bearings. This leads to $k_s = 43600$ N/cm for piers and $k_s = 24914$ N/cm for abutments. An increase of 50% to the stiffness should be applied for seismic loading. For the definition of plastic hinge in piers, the famous available models are employed. The length of plastic hinge, Priestley relation is used [6]

$$L_p = 0.08L + 0.0022 f_y d_b \quad \text{(MPa)} \tag{2}$$

where $L_p$ is the distance between critical section and inflection point of the member; $d_b$ is the diameter of longitudinal bars and $f_y$ is the yield stress.

According to design documents, the expansion joint between deck and abutments has a width of 25 cm which is taken into account in the model. If the longitudinal displacement of the deck is greater than this value, the deck knocks the abutments.

### 2.2 Earthquake records used

For the excitation of the bridge, five pairs of earthquake records are chosen (Table 1). These records are scaled according to UBC [7] and then applied to the structure.

Table 1: Earthquake records used

| No. | Record Name | Date | PGA(g) |
|---|---|---|---|
| 1 | IZMIT 1 | 17/8/1999 | 0.2195 |
| 2 | IZMIT 2 | 17/8/1999 | 0.1521 |
| 3 | ELCENTRO 1 | 19/5/1940 | 0.2148 |
| 4 | ELCENTRO 2 | 19/5/1940 | 0.3129 |
| 5 | K0BE 1 | 16/1/1995 | 0.5985 |
| 6 | K0BE 2 | 16/1/1995 | 0.8213 |
| 7 | NORTHRIDGE 1 | 17/1/1994 | 0.493 |
| 8 | NORTHRIDGE 2 | 17/1/1994 | 0.8283 |
| 9 | SAN FRANCISCO 1 | 18/10/1989 | 0.056 |
| 10 | SAN FRANCISCO 2 | 18/10/1989 | 0.105 |

## 3 RESULTS

### 3.1 Uncontrolled bridge

Dynamic analyses of the bridge without VD under scaled earthquake time histories are conducted. The first natural period of the bridge is 2.5 sec. The results show that the maximum longitudinal displacement of the deck occurs under scaled Izmit earthquake (PGA=0.546g) which is 51 cm. The time history of the longitudinal displacement response is shown in Fig. 6. The moment-curvature diagram for pier P6 is shown in Fig. 7. It is clear that the piers will exhibit nonlinear behavior. Fig. 8 shows the energy response of the bridge. A significant portion of the energy input to the structure is dissipated with both inelastic hysteretic mechanisms and viscous damping. In this case, the expansion joint will be closed and the deck will knock the abutments which can cause serious damages.

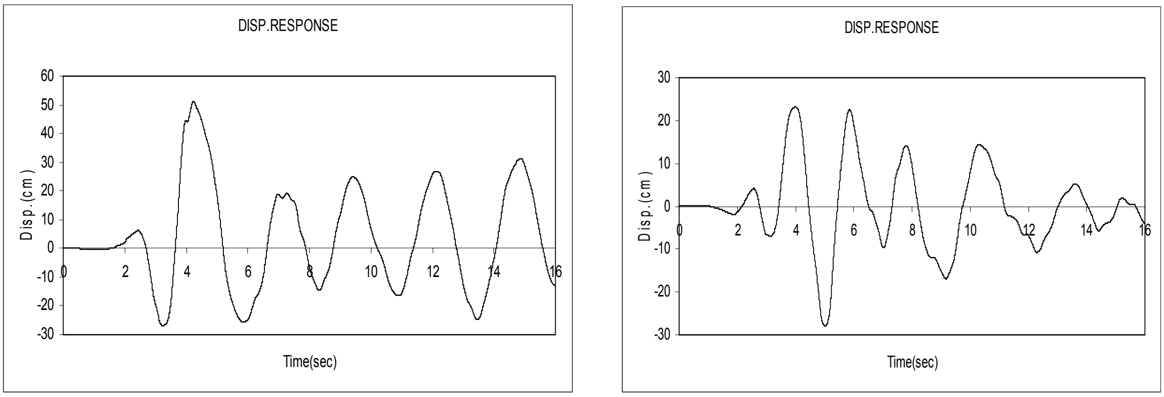



Figure 6: Longitudinal displacement response of the uncontrolled bridge under Izmit earthquake records

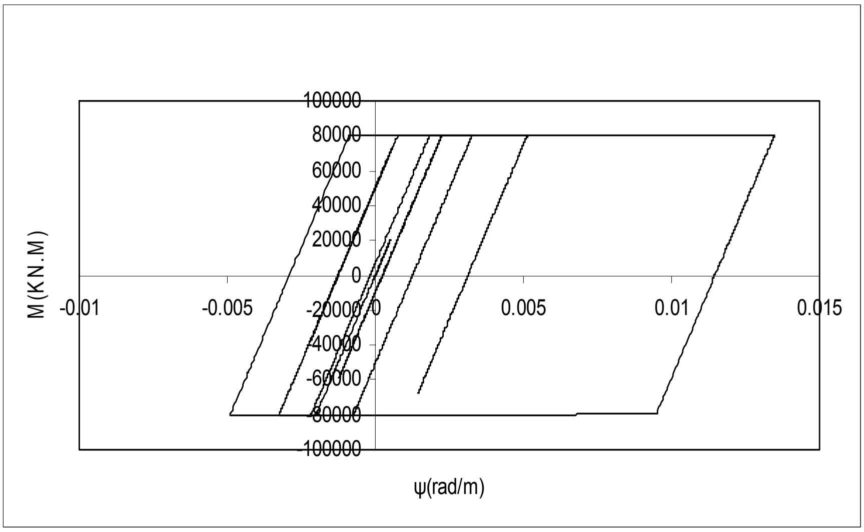



Figure 7: Moment-curvature diagram for pier P6 (shortest pier with the height of 11.9 m) for the uncontrolled bridge

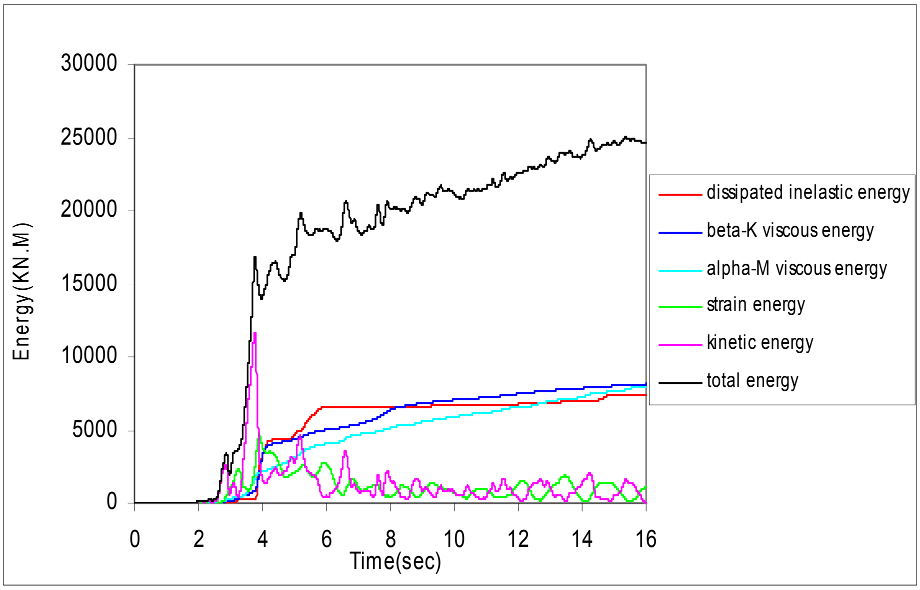



Figure 8: Energy response of the bridge under scaled Izmit earthquake

### 3.2 Controlled bridge

As mentioned before, the bridge is equipped with four 100 t VDs at both ends. Dynamic time-history analyses of the controlled bridge show that the maximum displacement of the bridge reduces to 38 cm but it is still greater than the width of expansion joint and the deck knocks the abutments (Fig. 9). However, a significant portion of the energy input is absorbed and dissipated by the dampers which reduces the nonlinear deformation of the structure. The moment-curvature diagram for pier P6 is shown in Fig. 10.

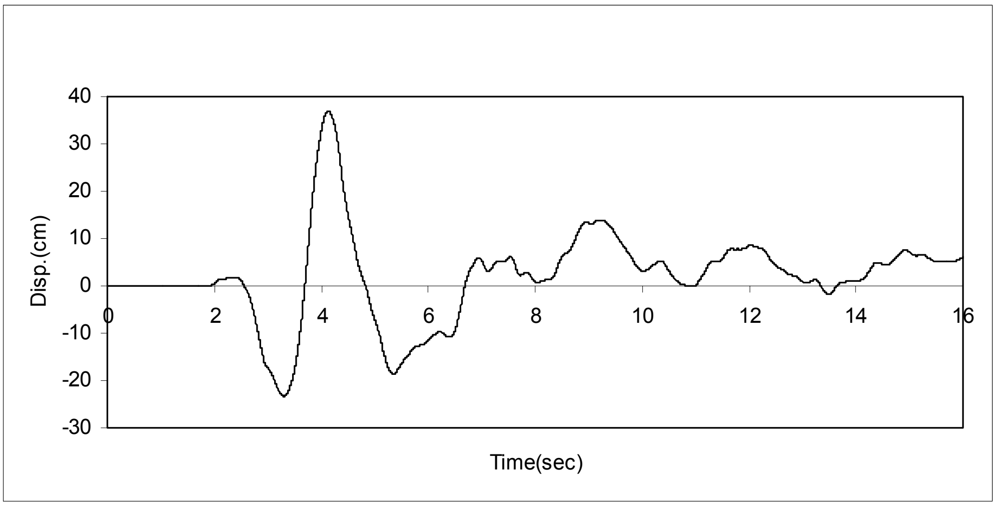



Figure 9: Longitudinal displacement response of the bridge fitted with four 100 t VDs under Izmit earthquake

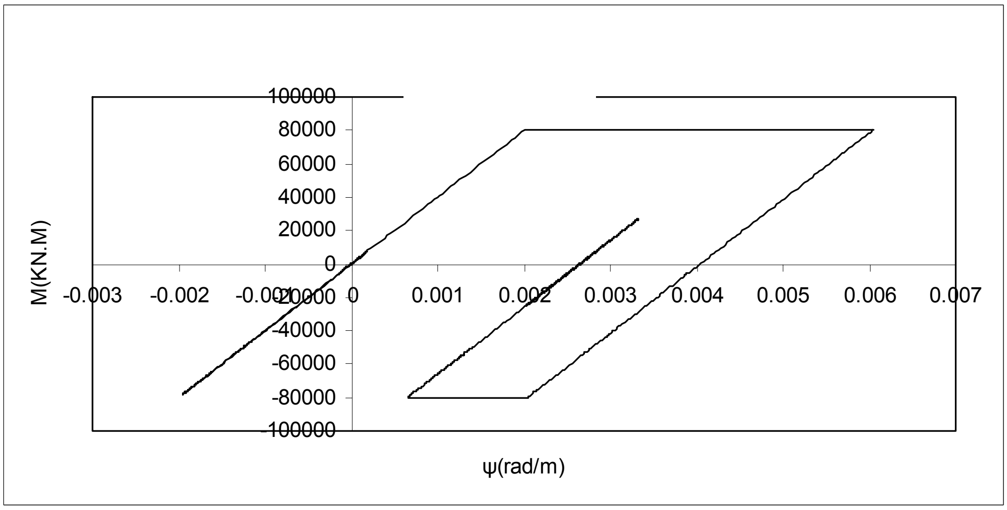



Figure 10: Moment-curvature diagram for pier P6 for the case that the bridge is equipped with four 100 t VDs

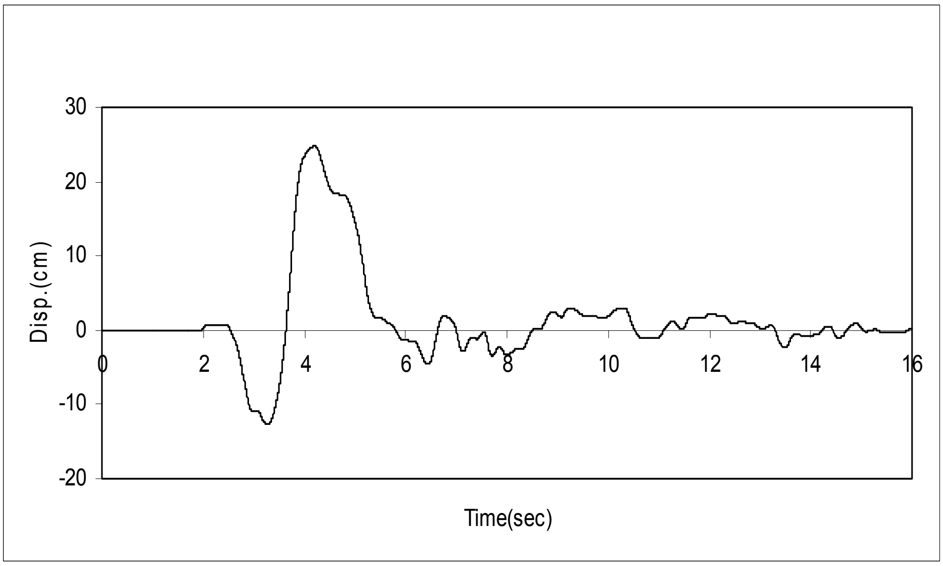



Figure 11: Longitudinal displacement response of the bridge fitted with four 250 t VDs under Izmit earthquake

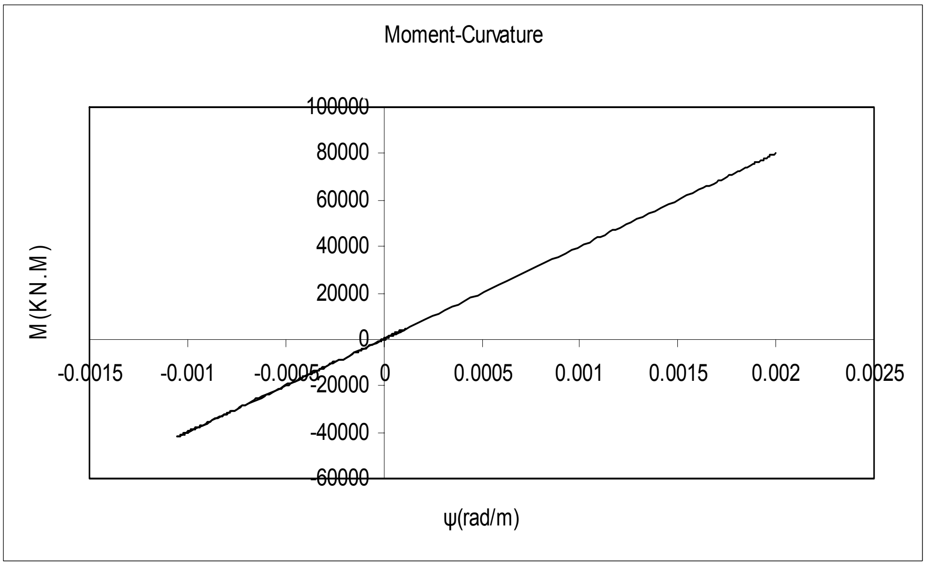



Figure 12: Moment-curvature diagram for pier P6 for the case that the bridge is equipped with four 250 t VDs

Proper VDs will prevent structural damages and does not let the deck knock the abutments. A trial and error procedure employed and finally it was concluded that if 100 t dampers are replaced by 250 t dampers, then the maximum longitudinal displacement reduces to 24 cm and piers will remain elastic (Figs. 11 and 12). These dampers are more expensive and off course apply higher values of reaction forces to the abutments which should be taken into consideration in design procedure.

## 4 SUMMARY AND CONCLUSIONS

- The inclusion of VDs enhances the seismic behavior of the bridge and the dampers dissipate a significant portion of the energy input to the bridge. This reduces the hysteretic energy dissipated by the sub-structural members and decreases damage to the structure and is favorable for earthquake resistant design.

- For the case that the bridge is fitted by 100 t VDs, the maximum longitudinal displacement under design earthquake is 38 cm which is more than the displacement capacity of the damper and expansion joint width and the deck knocks the abutments.
- To overcome the above-mentioned problems and improve aseismic performance of the bridge, 250 t dampers are recommended to be used. In this case the maximum displacement reduces to 24 cm.

## ACKNOWLEDGEMENT

The authors are grateful to Tazand Co. for providing them with the bridge design documents and data.

## REFERENCES

[1] T.T. Soong, G.F. Dargush, *Passive energy dissipation systems in structural engineering*, John Wiley & Sons, 1997

[2] Tazand Consulting Engineers, Design documents of Izadkhast Bridge, 2006 (In persian).

[3] http://www.fip-group.it

[4] CSI PERFORM-3D, V4.0.1, Computers and Structures Inc, Berkeley, California, Release 2006, Components and Elements.

[5] Caltrans, Seismic Design Criteria, V1.4, June 2006.

[6] T. Paulay, M.J.N. Priestley, *Seismic design of reinforced concrete and masonry buildings*, John Wiley & Sons, 1992.

[7] Unified Building Code, 2006.