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SEISMIC RETROFIT OF A TYPICAL HIGHWAY BRIDGE IN TEHRAN USING FLUID VISCOUS DAMPERS

Omid AFSHARIAN ZADEH
Structural Engineer, Deputy of Engineering, Ministry of Petroleum, Tehran, Iran
afshar599@yahoo.com

Seyed Mohammad RAZAVI
Earthquake Engineer, Iran Oston Consulting Engineers, Tehran, Iran
mrazavi90@yahoo.com

Mohammad Reza MANSHOORI
Earthquake Engineer, Deputy of Engineering, Ministry of Petroleum, Tehran, Iran
r.manshoori@gmail.com

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More than 600 bridges have been constructed in Tehran in three last decades, and studies of Tehran Municipality have shown many highway bridges do not have enough resiliency in a severe ground motion. The reports of past earthquakes have revealed that excessive lateral displacement of bridge piers is one of the most important causes of bridge vulnerability especially at fully operational and operational performance level.

During the last two decades, passive energy dissipation technologies have undergone great development, finding many applications in both new and old conventional bridges. Fluid Viscous Damper (FVD) is one of the most effective devices used in seismic retrofit projects of highway bridges in recent years all around the world especially in Japan and United States. FVD devices are designed to be installed at the deck-pier interface in all expansion piers and abutments. This technology has proven very helpful, particularly in retrofit applications where it is difficult to change service load static configurations and when there is a requirement for additional damping.

According to the FHWA Seismic Retrofitting Manual for Highway Structures, increasing the damping ratio of the retrofitted bridge structure is a passive method used for mitigating seismic damages and may be used in some types of bridges. Recent research activities and also past seismic events, have shown that dissipation devices such as FVDs, can significantly decrease seismic vulnerability of bridge structures.

In this study, a typical bridge in Tehran has been chosen for assessing the efficiency of FVD systems. The bridge has four simply supported spans with precast concrete girder superstructure. Substructure system includes multi column RC bents and open-type RC abutments. The bridge designed and constructed 25 years ago and performance-based seismic evaluations demonstrated that retrofit design is needed because longitudinal and transverse displacements of bridge bents exceed the capacity values according to D2 method of assessment in the FHWA manual. Assessment should consider two seismic hazard levels according to the manual with an upper level corresponding to 7% probability of exceedance in 75 years (return period of 1,000 years) as AASHTO specifications reaffirmed.

The site is near to more than two active faults and geotechnical studies have shown that site soil has low density and classified into soil type D according to the FHWA manual. 3D models of bridge structure have been developed and nonlinear time history analyses have been performed for seismic evaluations. FVD elements were designed and assumed between girders and cap beams with two different patterns. Analyses with seven ground motions adjusted to design response spectrum have been conducted to evaluate lateral displacement of bridge bents. Ground motions are selected based on soil type and near source issues. The resultant displacements were related to specifications of FVDs and their locations. With optimizing of the FVD elements and their arrangement, the best pattern has been found and the final scheme recommended.

Specifications of FVD devices have been selected based on Road Co. Catalogue as shown in Table 1. The FVD device is made of viscous medium, steel cylinder and piston with pores/gaps, and is a passive velocity-dependent damper. Silicone oil is adopted as the viscous medium, which has characteristic of small viscosity-temperature coefficient, stable performance in extremely low and high temperatures (-50 to +250°C), good electrical-insulation and water-repellent properties. The basic equation for this type of damper can be written as Equation 1:

$$F_d = C \times V^{\alpha} \tag{1}$$

in which:

F_d : Damping force (kN)
C : Damping factor (kN.(s/m)[a])
V : Velocity of the piston movement (m/s)
α : Damping exponential where selected 0.15 in this study

Table 1. Specifications of Selected FVD according to Road Catalogue.

Stoke	(mm/s) Velocity	α	Damping Coefficient (kN/(m/s)α)	Axial Capacity(kN)
300±	1500	0.15	1000	1000

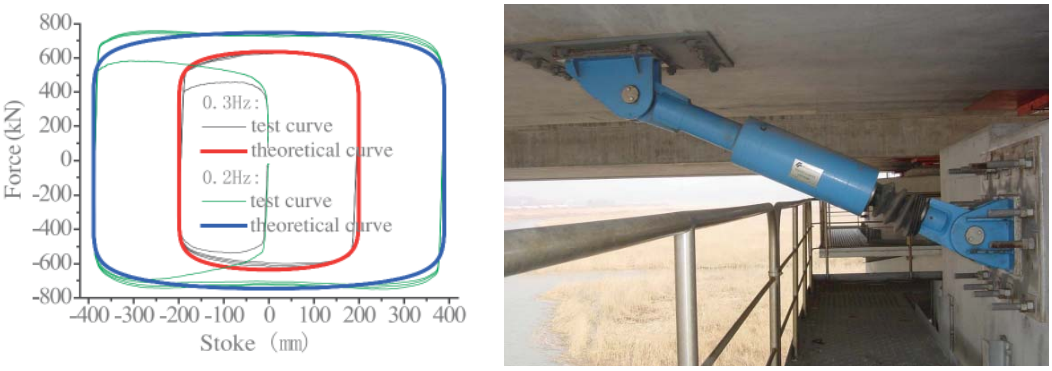

Figure 1. Force vs. Stoke behavior of FVD (Left Side), an installed FVD in a bridge (Road Co., 2017).

Finally, according to nonlinear time history analyses of retrofitted bridge with designed dampers, it is recognized that retrofitted bridge with mentioned strategy can absolutely tolerate the considered drift ratios and the FHWA criteria would be satisfied. The results of one of bents are shown in Table 2.

Table 2. Capacity/Demand Ratios of Retrofitted Bridge with FVD Devices (Afsharian Zadeh et al., 2018).

Capacity/Demand Ratio				
	100 Year		1000 Year	
	X direction	Y direction	X direction	Y direction
Demand	0.046	0.033	0.1336	0.082
Capacity	0.0782	0.0546	0.2014	0.1278
C/D	1.7	1.7	1.5	1.6

REFERENCES

Afsharian Zadeh, O. and Razavi, M. (2018). *Second Phase Report for Seismic Rehabilitation of Sanikhani Highway Bridge*, Rah-Ahan-Rah Consulting Engineers, Tehran Municipality, Tehran, Iran.

FHWA (2006). *Seismic Retrofit Manual for Highway Structures, Part I: Bridges*, Reston, VA.

Road Co. (2017). *Viscous Fluid Dampers, Changzhou City, China.* Changzhou Road Structure Damping Co. Ltd.