UPGRADING OF EARTHQUAKE-INDUCED RESPONSES OF AN EXISTING ARCH BRIDGE

Kumamoto University	Student Member	Elif Cagda Kandemir
Kumamoto University	JSCE Member	Taiji Mazda
Kumamoto Prefecture		Hidenori Nurui
Eight-Japan Engineering Consultants Inc.	JSCE Member	Hirokazu Miyamoto

1. INTRODUCTION

This paper presents the selection and application procedures for viscous damper due to several earthquakes. The methods are applied to the arch bridge system using three-dimensional nonlinear dynamic response analysis. Consequently, the effectiveness of viscous dampers is obtained comparing the structures with and without dampers and the methods to find out viscous damper characteristics are confirmed.

2. THE BRIDGE PROPERTIES

The arch bridge investigated in this paper is Kusakabe Yoshimi Bridge located in Kyushu Island in Japan. It is a conventional upper-deck type steel arch bridge with reinforced concrete (RC) deck slab designed according to the regulations of 1980 Japan Highway Bridge Specification. The general configuration of the bridge is presented in **Fig 1**. The total length of the deck and available width between bearings are 90.0 m and 8.1 m, respectively. The twin arch ribs that are connected by lateral steel bracings have a span of 60.0 m and a rise at the crown of 12.0 m which gives a rise-span ratio of 1:5. RC deck slab is supported by two main longitudinal girders with transverse girders and diagonal members. The connection between main longitudinal girders and arch ribs are supported by 11 piers at the intersection joints of the main ribs and transverse bracings. The side piers are strengthened by diaphragms and transverse bracings.

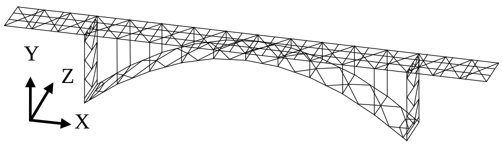


Fig 1 The configuration of the bridge

Table 1 Boundary conditions

	X	Y	Z	θ_x	θ_y	θ_z
Abutment	F	R	R	R	F	F
Pier	R	R	R	R	F	F
Foundation	S	S	S	S	S	S

The boundary conditions of the bridge are as seen in the **Table II**. The abutments are movable along the longitudinal axis without rotations and displacements to other directions. All piers are restraint to the displacements can rotate about to Y and Z axis. (F: Free, R: Restraint, S: Spring).

3. THE VISCOUS DAMPING CHARACTERISTICS

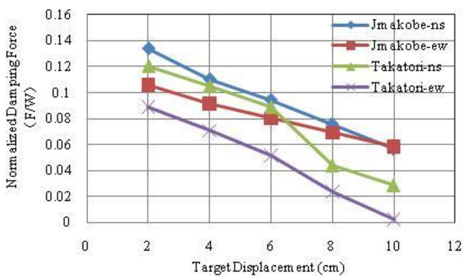


Fig 2 The normalized damping force-target displacement relationship

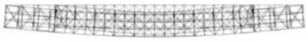
To determine the damper characteristics such as damping coefficient, damping force etc. and to figure out its behavior due to seismic loading, a single degree-of-freedom system with viscous damping was taken into consideration. Allowing different displacements to the system several damping forces are obtained. **Fig 2** shows the relationship between the damping forces (F) normalized by the weight of mass point (W) and target displacements for each type of earthquake. Damping force decreases for smaller values of target displacement. In present study the damper which has the lowest damping force obtained under Kobe-ew at the target displacement of 10 cm was attached to the bridge to be economical as well as mitigating the responses induced by Kobe-ns, Takatori-ns and Takatori-ew earthquakes.

4. DYNAMIC ANALYSIS OF BRIDGE

4.1. Eigen Value Analysis

The predominant eigenmodes which were obtained in accordance with the largest effective mass ratios are 1st, 4th and 13th along longitudinal axis, 2nd and 25th modes along transverse axis. **Table 2** shows predominant modes, frequencies, natural periods and effective mass ratios and the predominant mode shapes.

Table 2 Predominant eigenmodes

Mode	Frequency (Hz)	Natural Period (sec)	Effective Mass (N)		Effective Mass Ratio (%)	Mode Shapes
			Tx	Tz		
1	1.521	0.657	439.5	0	15	
2	1.847	0.541	0	986.5	33	
4	2.645	0.378	747.2	0	24	
13	4.768	0.210	563.9	0	18	
25	6.620	0.151	0	707.9	23	

4.2. 3D Nonlinear Dynamic Response Analysis

The dynamic responses were found out for two bridge structures; with and without dampers to make the efficiency of dampers clear. As it is seen from the figures below, the target displacement of 10 cm damper which has lowest damping force provides necessary seismic response reduction.

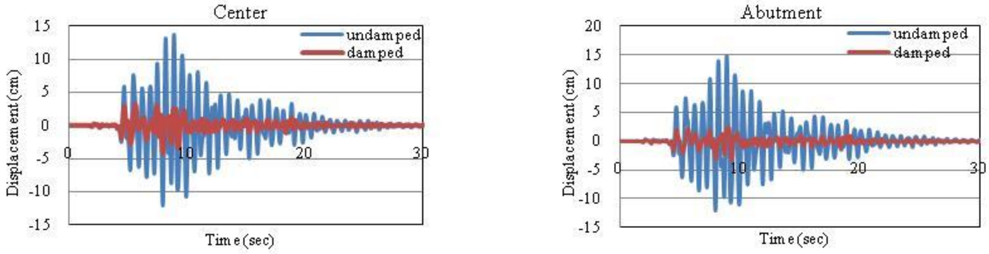


Fig 3 The displacements at the center and end of abutments (Kobe-ns)

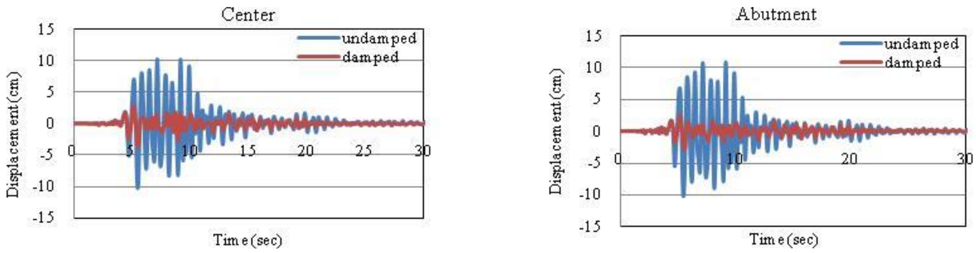


Fig 4 The displacements at the center and end of abutments (Kobe-ew)

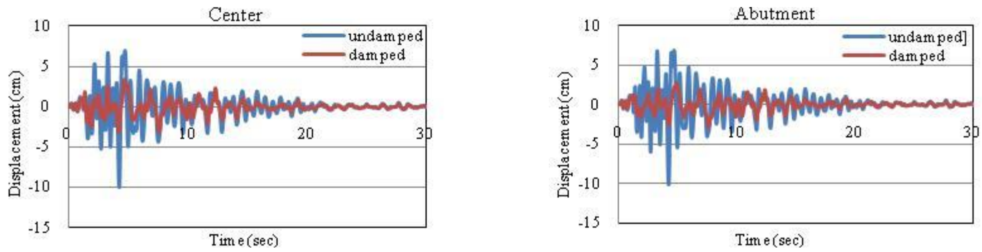


Fig 5 The displacements at the center and end of abutments (Takatori-ns)

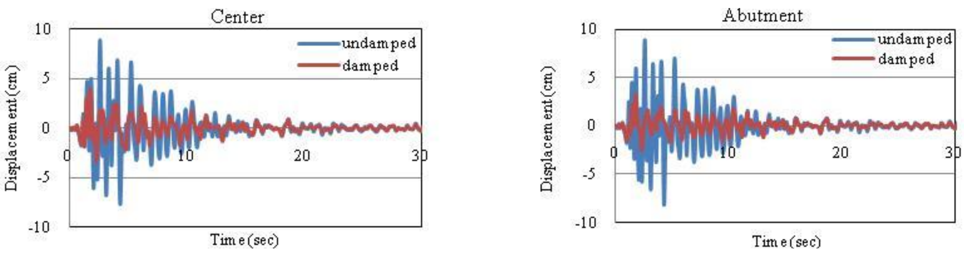


Fig 6 The displacements at the center and end of abutments (Takatori-ew)

4. CONCLUSIONS

The single degree of freedom system to obtain the viscous damping characteristics was confirmed by this research. In addition to this as it can be understood from dynamic response results the damper is highly effective to reduce the earthquake induced responses along bridge axis.

REFERENCES

- Japan Road Association, Specifications For Highway Bridges, Part V Seismic Design, 2002.