DEMAND OF SEISMIC BRACE DAMPERS INSTALLED IN STEEL ARCH BRIDGES UNDER MULTIPLE EARTHQUAKES

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1. Introduction

Regarding the destructive earthquakes in recent years, famous ones in Kocaeli, Turkey (1999), Sichuan, China (2008), and Papua, Indonesia (2009), strong aftershocks (M=4~6) are liable to occur frequently, which accelerate the destruction of structures after the main shocks. And the importance of seismic safety margin design is demonstrated for structures which might experience multiple earthquakes and aftershocks during their service life. As one of the seismic performance upgrading method for structures against severe earthquakes, structural control devices have attracted wide attention during recent years. This strategy is to decrease the damage to the principal structure as much as possible by limiting it to the energy dissipation dampers. In this research, Buckling-Restrained Brace (BRB), as one of the structural control devices, is studied by applying 3 times of severe earthquake motions to a steel arch bridge structure installed with BRBs well-designed for one time of earthquake. And by examining the demand of BRBs in each time of earthquakes, the required capacity with a safety margin to against multiple earthquakes are proposed as the purpose.

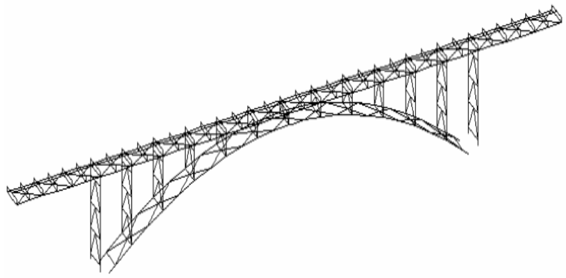

Fig. 1 Analytical Model of Steel Arch Bridge

2. Analytical Model

In this research, an upper-deck steel arch bridge shown in Fig.1 is used as the main structural model in which the BRBs are installed. By executing one time of dynamic analysis on the arch bridge with Level 2 Type Ⅱ ground motions for Ground Type Ⅱ, BRBs are designed to install in the bracings of the side piers and the arch rib (Ge et al., 2005) as shown in Fig.2. The labels of the BRBs are marked as side pier BRBs ①~⑥ and arch rib BRBs ①~⑥ separately.

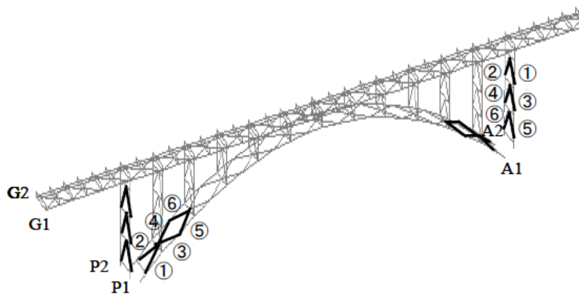

Fig. 2 Layout of BRBs Installation

3. Analytical Process

6 patterns of Level 2 earthquake motions for Ground Type Ⅱ are used as the input ground motions, among which 3 patterns of Type Ⅰ motions are Marked as ITA-LG-M, ITA-TR-M, ONN-TR-M, and Type Ⅱ as JRT-NS-M, JRT-EW-M, FUK-Y-M. These input motions are executed for 3 times, and the serviceability of the arch bridge is evaluated in each time of earthquake to satisfy member damage Level 2 ($\varepsilon_{max}<\varepsilon_y$), and then the maximum compressive strain and cumulative inelastic strain of BRBs are calculated as the demand values.

4. Analytical Results

The results of serviceability check of the arch bridge in each time of earthquakes are shown in Table 1. It can be seen that except for JRT-NS-M, the damage of the arch bridge can still be restrained in acceptable range in 3 times of earthquakes.

Keyword: Arch Bridge, Buckling-Restrained Brace, Demand, Multiple Earthquakes, Dynamic Analysis
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Table 1 Serviceability Evaluation of Arch Bridge in 3 times of Earthquakes

Ground Motion	ITA-LG-M	ITA-TR-M	ONN-TR-M	JRT-NS-M	JRT-EW-M	FUK-Y-M
1st time	○	○	○	×	○	○
2nd time	○	○	○	×	○	○
3rd time	○	○	○	×	○	○

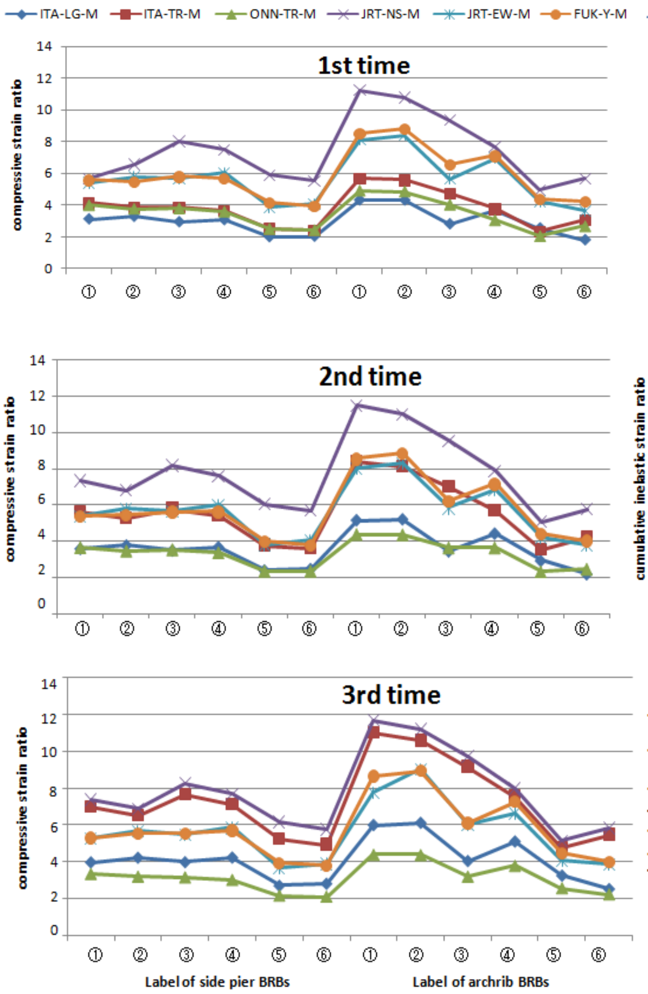

Fig.3 Compressive Strain Ratio of BRBs

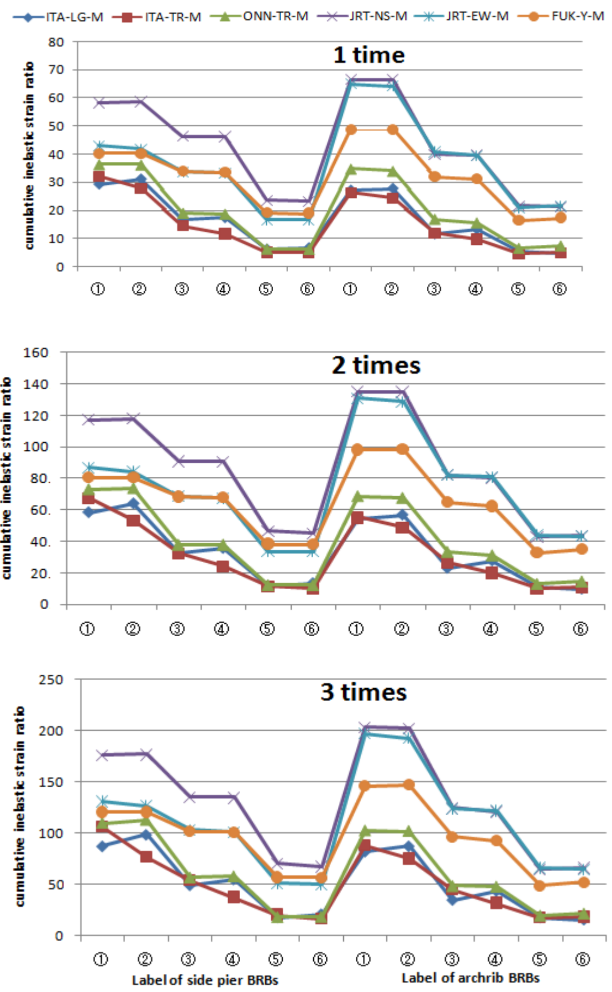

Fig.4 Cumulative Inelastic Strain Ratio of BRBs

The compressive strain ratios of BRBs ($\varepsilon/\varepsilon_y$) in each time of earthquakes are shown in Fig.3. It can be seen that No.① ,② of arch rib BRBs always show the largest values. In the 3 times of earthquakes, JRT-NS-M, JRT-EW-M and FUK-Y-M experience no obvious changes, but ITA-LG-M and ITA-TR-M increase dramatically and ONN-TR-M decrease in opposite tendency. The cumulative inelastic strain ratio ($\Sigma\Delta\varepsilon_{pi}/\varepsilon_y$) are shown in Fig.4 as cumulated values by 1 time, 2 times, and 3 times of earthquakes. Different from Fig.3, the values simply grows as time grows. While the effective lengths of BRBs are actually half of the analytical length, all the results should be timed by 2.

5. Conclusion

Based on the results obtained in this research, the maximum values of necessary compressive strain are about $8.79\times2\,\varepsilon_y = 2\%$ for one time and $11.0\times2\,\varepsilon_y = 2.4\%$ for three times of earthquakes. The safety margin is about 1.2. Similarly, the maximum values of necessary cumulative inelastic strain are about 14% for one time and 43% for three times of earthquakes, and the safety margin to consider about multiple earthquakes is calculated as 3.

6. References

Ge, H. B., Hioki, K., and Usami, T. (2005). Demand of seismic brace dampers installed in steel arch bridges. J. Earthq. Eng., JSCE, Vol.28, No.190, 2005.3.