SAFETY MARGIN OF CAPACITY OF SHEAR PANEL DAMPERS IN SEISMIC DESIGN

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1. Introduction

Since the recent destructive earthquake in Kobe (1995), the seismic vulnerability of steel bridges with non-ductile design is clearly realized, researches on seismic performance upgrading methods for steel structures have been numerically studied, and plenty of fruits are harvested in recent years. However, big earthquakes in nearer time, famous ones in Kocaeli, Turkey (1999) and Sichuan, China (2008), show that multiple aftershocks (M=4~6) also accelerate the destruction of structures. The importance of seismic safety margin design is demonstrated for structures which might experience multiple earthquakes and aftershocks during their service life. In this research, Shear Panel Damper (SPD), as one of the structural control devices, which absorb and dissipate earthquake-induced energy to decrease the damage of main important structure, is studied by applying 3 times of earthquake ground motions to a rigid-frame bridge pier installed with SPDs designed in various parameters, as shown in Fig.1. And by calculating the demand of SPD in each time of earthquakes, the required performance and safety margin are proposed.

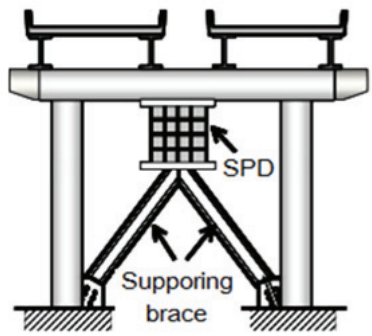

Fig.1 SPD Applied in Frame Bridge Pier

2. Analytical Model

In this research, the portal ramen pier frame shown in Fig.2 is used as the main structural model in which SPD is set up. Steel grade SM490 is used as main structural steel material, the constitutive rule of the beam element uses the modified two surface model developed in Nagoya University. For the failure judgement of the main structure, the axial strain generated in the critical member segments marked as S1~S6 in Fig.2 is used. To satisfy the member damage level 2, the average compressive strain of critical member segments are expected to be restrained within $2\varepsilon_y$ as the target limit.

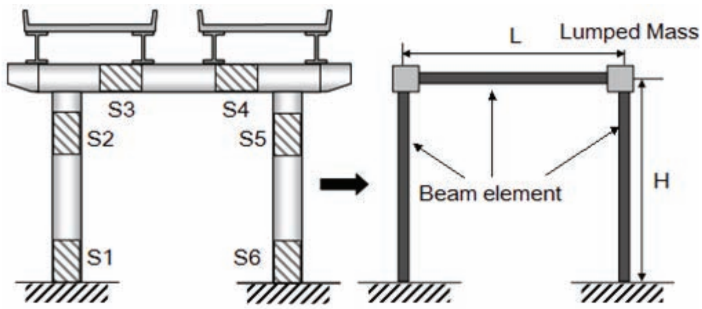

Fig.2 Analytical Model of Target Portal Frame

On the other hand, to obtain the response of SPD set up in the structure, the analytical model of SPD is simplified with two truss elements and one spring element (Chen et al., 2007). As shown in Fig.3, each element is connected to the main frame by roller and is movable independently. The two horizontal trusses, imitate the relation of shear force and shear displacement of SPD subjected to horizontal force and for that force-displacement relation, a combined hardening model proposed by Kaneko (2007), which is composed of kinematic hardening part and isotropic hardening part, is applied as the restoring force model.

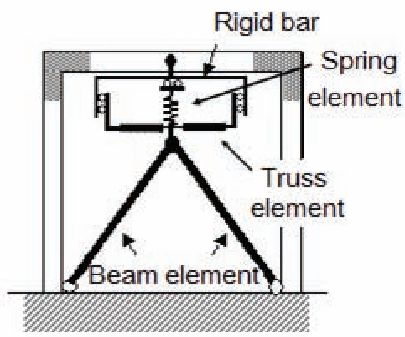

Fig.3 Analytical Model of SPD

3. Analytical Process

In this research, 3 kinds of level 2 type 2 earthquake motion for ground type 2 recommended by Specifications for Highway Bridge (2002) are used as input ground motions, which are labelled as JRT-EW-M, JRT-NS-M, FUKIAI-M. The damping ratio is assumed as 5%. These 3 ground motions are executed to the bare main structure first to judge whether it is necessary to install with SPD. With the installation of SPD, 3 ground motions are executed for the first time to exam the effect of SPD to the main structure. When the analytical result of the first time satisfy the member damage level 2, the second and third time of ground motions are executed in the same amplitude. By examine the demand of SPDs in each time of earthquakes, the required capacity and safety margin of SPD are calculated.

4. Analytical Result

For the 3 ground motions, $\varepsilon_{a)max}$, the compressive strain in critical member segments of main frame, are obtained as 23.4ε_y, 36.0ε_y and 20.0ε_y respectively, far away from the target level of 2ε_y, so it is necessary to install SPD for seismic performance upgrading.

There are two controlling parameters introduced in the design of SPD, which are defined as strength ratio α_F and stiffness ratio α_K (Chen, 2007). In Fig.4, the lateral line is the target value to keep the member damage level 2. It is shown that a part of cases in JRT-NS-M and JRT-EW-M are restrained below 2, but all the cases in FUKIAI-M have exceeded the level. So only the cases satisfy the member damage level 2 are executed for the 2nd and 3rd time of earthquakes.

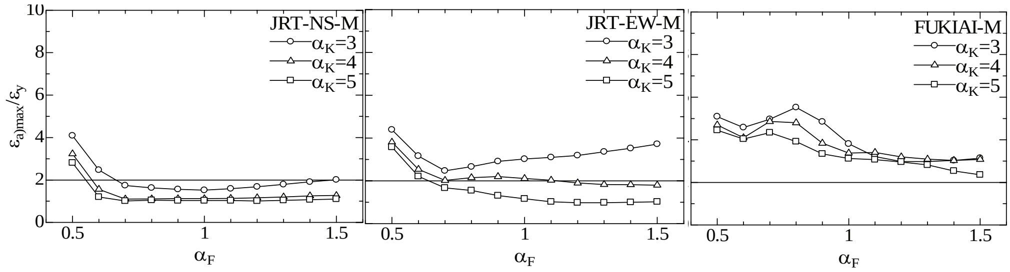

Fig.4 Seismic Response of Main Frame Installed with SPD in the 1st Time of Earthquake

The demand of SPD is evaluated for 2 indexes, the maximum shear strain γ_{max} and cumulative inelastic deformation CID. As shown in Fig.5, the shear strain of SPD have no obvious change in one time or 3 times of earthquakes, but in Fig.6, the CID of SPD has increased a lot in three times than in one time of earthquakes.

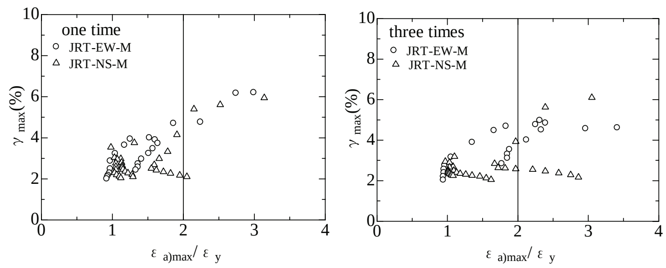

Fig.5 (compressive strain)-(shear strain) relation

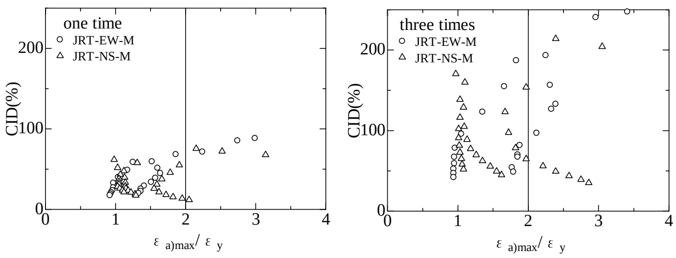

Fig.6 (compressive strain)-(cumulative inelastic strain)

5. Conclusion

Based on the results obtained in this research, the maximum value of necessary deformation for one time and three times of earthquakes are both about 5%, and the maximum value of necessary cumulative inelastic strain are about 60% for one time and 170% for three times of earthquakes, the safety coefficient to consider about multiple earthquakes is proposed as 3.

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References: 1) Chen, Z. Y., Ge, H. B., and Usami, T. (2007). Study on seismic performance upgrading for steel bridge structures by introducing energy-dissipation members. Journal of Struct. Engng. JSCE, Vol.53A, 540-549. 2) Kaneko, K. (2007). Experimental and analytical study on deformation performance of SPD. Graduation Thesis, civil engineering dept., Nagoya University (in Japanese).