Journal of Constructional Steel Research 120 (2016) 232–244

Contents lists available at ScienceDirect

Journal of Constructional Steel Research

ELSEVIER

Seismic retrofit of asymmetric structures using steel plate slit dampers

Jinkoo Kim *, Jaeyoung Jeong

Dept. of Civil and Architectural Engineering, Sungkyunkwan University, Chunchun-Dong, Jangan-Gu, Suwon 440-749, Republic of Korea

ARTICLE INFO

Article history:
Received 17 November 2015
Received in revised form 4 February 2016
Accepted 5 February 2016
Available online xxxx

Keywords:
Asymmetric structures
Steel plate slit dampers
Seismic retrofit
Ductility demand

ABSTRACT

A seismic design and retrofit procedure were developed for estimating the proper amount of steel plate slit dampers required to keep the seismic response of low-rise asymmetric structures within a given target performance level. Parametric studies for displacement response of a single story plan-wise asymmetric structure were conducted with varying eccentricities between center of mass and center of stiffness. Then a procedure was developed to distribute the damper based on the ductility demand of the structure. The procedure was applied to install slit dampers at proper locations of low-rise structures with horizontal and/or vertical irregularities subjected to an earthquake load. According to the nonlinear static and dynamic analysis results, the structure with hysteretic dampers installed in accordance with the proposed procedure showed satisfactory inter-story drifts in both the stiff and the flexible edges when they were subjected to the design level seismic load.

1. Introduction

It has been reported that asymmetric structures are especially vulnerable to earthquake-induced damage. According to the ASCE 7-13 [1], torsional irregularity is defined to exist where the maximum story drift at one end of the structure transverse to an axis is more than 1.2 times the average of the story drifts at the two ends of the structure. Many researchers have investigated the seismic response mitigation of asymmetric buildings using supplemental energy dissipation devices. Goel [2] studied the effects of supplemental viscous damping on seismic response of one-way asymmetric system and found that edge deformations in asymmetric systems could be reduced by proper selection of supplemental damping parameters. Kim and Bang [3] proposed a strategy based on modal analysis for an appropriate plan-wise distribution of viscoelastic dampers to minimize the torsional responses of an asymmetric structure with one axis of symmetry subjected to an earthquake-induced dynamic motion. They also found that the viscoelastic dampers were more effective than viscous dampers in controlling the torsional response of a plan-wise asymmetric building structure. Lin and Chopra [4] investigated the effectiveness of viscous dampers for elastic single story asymmetric system, and showed that the reduction in the seismic response achieved by a judiciously selected asymmetric distribution of viscous dampers can be significantly larger compared to symmetric distribution. De La Llera et al. [5] carried out analytical and experimental research of linear asymmetric structures with frictional and viscoelastic dampers, and showed that the energy dissipation devices prove useful in controlling the uneven deformation demand occurring in structural members of torsionally unbalanced structures. Petti and De Iuliis [6] proposed a method to optimally locate the viscous dampers for torsional response control in asymmetric plan systems by using modal analysis techniques. It was found that optimal damping eccentricity moves from the flexible edge to the mass center by reducing the structural eccentricity. Mevada and Jangid [7] investigated the seismic response of linearly elastic, single-story, one-way asymmetric building with linear and non-linear viscous dampers. It was shown that the non-linear viscous dampers were quite effective in reducing the responses and the damper force depends on system asymmetry and supplemental damping. Khante and Nirwan [8] applied a tuned mass damper for mitigation of torsional effect in an asymmetric structure subjected to seismic load, and investigated the optimum parameters for TMD with respect to the design variables such as eccentricity ratios, uncoupled torsional to lateral frequency ratios, mass ratios etc. Bharti et al. [9] investigated the seismic behavior of an asymmetric plan building with MR (Magnetorheological) dampers, and found that MR damper-based control systems are effective for plan asymmetric systems. They also investigated the influence of the building parameters and damper command voltage on the control performance through a parametric study. Almazána et al. [10] studied the response of asymmetrical linear and nonlinear structures subjected to unidirectional and bidirectional seismic excitations, equipped with one or two Tuned Mass Dampers (TMDs), and obtained the optimized parameters of each TMD by applying the concept of general torsional balance.

Most of the previous studies on mitigation of asymmetric behavior using energy dissipation devices were focused on elastic behavior of structures [2–9]. Paulay [11] suggested a rational design philosophy for performance-based seismic design of asymmetric structures subjected to inelastic deformation. He recommended a design procedure in which the ductility demand in each structural element does not exceed a given limit state. The same approach was applied in this study for application

* Corresponding author.
E-mail address: jkim12@skku.edu (J. Kim).

http://dx.doi.org/10.1016/j.jcsr.2016.02.001