Journal of Constructional Steel Research 79 (2012) 216–225

Contents lists available at SciVerse ScienceDirect

Journal of Constructional Steel Research

Optimal damper placement based on base moment in steel building frames

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ARTICLE INFO

Article history:
Received 14 February 2011
Accepted 25 July 2012
Available online xxxx

Keywords:
Optimal dampers
Base moment
Passive control
Viscous dampers

ABSTRACT

A new damper optimization method for finding optimal size and location of the added viscous dampers is proposed based on the elastic base moment in planar steel building frames. A Fourier Transform is applied to the equation of the motion and the transfer function in terms of the fundamental natural frequency of the structures is defined. The transfer function amplitude of the elastic base moment evaluated at the first natural circular frequency of the structure is chosen as a new objective function in the minimization problem. The damper coefficients of the added viscous dampers are taken into consideration as design variables in a steel planar building frame. The transfer function amplitude of the elastic base moment is minimized under an active constraint on the sum of the damper coefficients of the added dampers and the passive constraints on the upper and lower bounds of the added dampers. The optimal damper design presented in this paper is compared with other optimal damper methods based on top displacement, top absolute acceleration and base shear. A ten-storey steel planar building frame is chosen to be rehabilitated with the optimal dampers. The optimal damper allocation is obtained for the transfer function amplitude of the elastic base moment then compared with the other damper optimization methods in terms of the transfer function response. The results of the proposed method show that the method can also be beneficial to decrease both the base moment and the interstorey drift ratios in some frequency regions.

1. Introduction

Since the exact nature of the external forces such as earthquake, wind and impact excitations that affect structures is unknown structural control systems, such as passive, active and semi-active systems have been developed to protect the civil engineering structures from dynamic vibrations. Passive energy dissipation devices have been used to absorb dynamic external effects in new structures or for the rehabilitation of old structures. Passive energy devices are inserted in the bare structures to improve damping, stiffness and strength. Active control can also be effective with changeable features according to the variation of the excitation; however, this type of control requires large control forces and detailed state information, in this situation, active control can fail due to its instability. In passive control, this situation does not occur, but this type of control does not possess an adaptable mechanism to counter the variations of the external effects. The new semi-active control system has been proposed to protect structures from earthquake or wind excitations. These semi-active control systems have characteristics that can be adjusted and do not require the creation of large control forces. All such control systems are commonly used in practical applications in addition to designs using classical structural design methods. In recent years, the various studies have investigated the optimum placement of the different types of control devices in order to obtain the best distribution by the minimization or maximization of the defined structural responses.

A fluid viscous damper is one of the commonly known passive dampers. Fluid viscous devices that use a cylindrical piston immersed in a viscous fluid are extensively used in aerospace and military applications; in addition more recently they have been adapted for building applications as shown in Fig. 1 [1]. The primary characteristics of these devices for structural applications are the linear viscous responses achieved over a broad frequency range, insensitivity to temperature and compactness in comparison to the stroke and output force. The damper absorbs energy through movement of the piston in highly viscous fluid. If the fluid is purely viscous, then the output force of the damper is directly proportional to the velocity of the piston. Dampers are commonly used in steel structures to mitigate their seismic response. There are some investigations in connection with effects of linear viscous dampers in seismic response of steel structures [2–4].

1.1. Background of damper placement

When the passive dampers were begun to be used in buildings in 1980s, it was essential to ascertain the appropriate location and number of dampers within the structure. However, there are limited numbers of studies about damper allocation in structures. The following studies are relevant with this field. The results of reducing the seismic response of multi-storey shear type buildings with first storey damping were

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0143-974X/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jcsr.2012.07.011