Soil Dynamics and Earthquake Engineering 31 (2011) 1171–1181

Contents lists available at ScienceDirect

Soil Dynamics and Earthquake Engineering

journal homepage: www.elsevier.com/locate/soildyn

An experimental study on using MR damper to mitigate longitudinal seismic response of a suspension bridge

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ARTICLE INFO

Article history:
Received 6 January 2011
Received in revised form
17 April 2011
Accepted 18 April 2011
Available online 7 May 2011

Keywords:
Suspension bridge
MR damper
Mechanical model
Seismic response reduction experiment

ABSTRACT

In this paper, the seismic response reduction performance of magnetorheological (MR) damper is experimentally investigated for a suspension bridge. First, the force–displacement and force–velocity curves under a range of excitation frequencies, amplitudes and currents are obtained by mechanical behavior test of the RD1097 type MR damper. Then a new non-linear hysteretic model is proposed to model the mechanical behavior of the MR damper and the model parameters are identified from test data. An experimental method, as well as a set of testing setups with the MR damper for longitudinal seismic response reduction of a SDOF generalized system representing the fundamental longitudinal mode of suspension bridge, is developed. Finally, the seismic response reduction experiment subject to three kinds of earthquake excitations, including the Pingsheng Bridge earthquake wave, the El-Centro wave and the Taft wave, is carried out, and nine control cases, including uncontrolled, six passive control schemes with different input currents and two semi-active Bang–Bang control schemes, are tested. The results verify that the seismic response reduction experimental method is feasible and the good performance of seismic longitudinal response reduction of the suspension bridge can be achieved by MR damper. It is also shown that the passive control with optimum input current outperforms the semi-active Bang–Bang controls.

1. Introduction

Suspension bridge is widely adopted in long-span bridges since the internal force can be effectively reduced owing to a long period of fundamental longitudinal vibration mode. However, the excessive longitudinal displacement of the girder subject to seismic loading may also cause many problems such as destruction of expansion joint, fatigue fracture of short cable, pounding between the girder and adjacent approach bridge and so on [1]. These problems certainly lead to considerable difficulties in bridge maintenance, and even affect their normal operation. It is of vital importance to restrain the excessive longitudinal displacement of the girder.

Magnetorheological (MR) damper has been mainly applied in vibration control of stay cables and high-rise buildings [2–4] because of the excellent intelligent characteristics of low power requirement, large damping force, fast response, simple structure and continuous adjustable damping force. Therefore it is worthy of studying the performance of MR damper for seismic response reduction of suspension bridge.

A lot of mathematical models are available for modeling the non-linear mechanical behavior of MR damper, and can be generally grouped as parametric models and non-parametric models. Models of the first kind include the Bingham model [5], the viscoelastic–plastic model [6], the Bouc–Wen model, the phenomenological model [7], the improved Bouc–Wen model [8], the modified Dahl model [9], the double-sigmoid model [10], the hyperbolic tangent function model [11] and many others. The non-parametric models include the polynomial model [12], the neural network model [13] and the fuzzy logical model [14]. Among these models, the application of the non-parametric models is limited due to lack of physical conception and need to perform considerable data training; on the other hand, some of the parametric models do not capture the force–velocity non-linear behavior of the damper well, such as the Bingham model and the viscoelastic–plastic model, and some other parametric models described with multi-parameters differential equation are too complicated to be identified and conveniently applied in practice, such as the Bouc–Wen model, the phenomenological model, the modified Dahl model and so on. So it is very necessary that a new model, which can portray the non-linear behavior well and also ease in model parameter identification, should be developed for seismic response reduction control of suspension bridge.

At present, some theoretical researches on using MR damper to mitigate seismic response of the cable-supported bridge have

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doi:10.1016/j.soildyn.2011.04.006