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Seismic response of a continuous bridge with bearing protection devices

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ABSTRACT

Unseating of bridges during earthquakes results from the failure of bearings and insufficient seat length. In case of elastomeric bearings, large deformations of the superstructure occur, under severe earthquake ground motions and additional protection measures are necessary. The combination of a displacement restraining device with the elastomeric bearing can prevent bearing failure. This paper evaluates the performance of four different types of protection devices to limit the displacement of the superstructure during earthquakes: (1) rigid stopper device, (2) yielding stopper device, (3) steel restrainer, and (4) superelastic shape memory alloy (SMA) restrainer. Analytical models for all the protection devices have been developed and seismic response of an existing bridge with elastomeric bearings and different protection devices has been evaluated for five strong ground motion records scaled in the frequency domain. The results show that all the protection devices have comparable performance in preventing the failure of bearing during an earthquake.

1. Introduction

Failure of bridges due to excessive displacement of superstructure or inadequate seat length at the pier or abutment is a common phenomenon during earthquakes. In case of elastomeric bearings [1–3], which do not have any energy dissipating characteristics, the displacement during a severe earthquake is quite large and may exceed the capacity of the bearing, resulting in failure of the bearing [4] and unseating of the superstructure. Measures to reduce the chances of collapse due to unseating at the supports have been available for many years [5]. But, in spite of that, the collapse of the bridges due to unseating continues and the Chi–Chi [6], Kobe [7], San Fernando [8] and Northridge [9] earthquakes have shown several examples. Therefore, there is a definite need to explore better methods of protection of bridges against unseating failure during earthquakes.

Restrainers and stoppers are used as the protection devices to prevent the failure of bridges due to unseating [10,11]. Various design approaches for restrainers are available in literature [12–14] and design codes [15–17]. In all the approaches, the focus is on the prevention of falling of the superstructure and no attention is given to the prevention of the failure of bearings. In the present study, the possibility of restrainers designed to prevent failure of the bearings during severe earthquakes has been explored. Using this approach, the bearing protection devices can be designed for new bridges, as well as, for existing bridges. In case of existing bridges, this method can be used if the existing bearings are not able to accommodate large displacement due to strong earthquake. In case of older bridges, the most widely used bearings are elastomeric bearings and these are generally designed only for movements arising due to temperature, creep and shrinkage. Use of restrainers/stoppers can be an effective technique to prevent failure of these bearings during earthquake.

The proposed method can also be useful for new bridges, if the designer does not have confidence in the use of isolation or energy dissipation devices and is inclined to use conventional elastomeric bearings. If the elastomeric bearing is designed for severe earthquake (MCE) it may lead to very large size of the bearing which is not practically acceptable in respect of required pier cap dimension. Reduction of the size of the elastomeric bearing may lead to failure, during an MCE level of earthquake. Therefore, restrainers/stoppers can be used with the elastomeric bearings to prevent failure of the bearings during severe earthquake.

Several types of devices, such as, steel rods, steel cables [18,19] and dampers have been used as the unseating protection devices for bridges. Shape Memory Alloy (SMA) has also been used in bridges as an unseating protection device [20–25]. Various devices have relative merits and the designer has difficulty in selecting the most appropriate device.

In this paper, the comparative performance of different types of unseating protection devices has been studied for a continuous bridge. All the devices have been designed to prevent failure of bearings. Four types of devices have been considered in the study: (1) rigid stopper, (2) yielding stopper, (3) traditional steel

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