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Research Article

Comparative Study of Non-Isolated and Isolated Bridge with TCFP Bearing Under Spatially Varying Ground Motions[#]

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Seismic isolation system
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Abstract: In this study, stochastic behaviours of non-isolated and isolated highway bridges under spatially varying ground motion are examined. The triple concave friction pendulum (TCFP) bearing is used as a seismic isolation system which is easy to be manufactured and stand out against severe earthquake more than traditional seismic isolation systems. The spatially varying earthquake ground motion model includes wave-passage, incoherence and site-response effects. The incoherence effect is examined by considering the Harichandran and Vanmarcke coherency model. Soft and firm soil types are selected for considering the site-response effect where the bridge supports are constructed. The mean of maximum element forces and displacements of deck are examined in the study. Results from stochastic analysis of isolated and non-isolated bridges subjected to spatially varying ground motion are compared with each other for the special cases of the ground motion model. It is observed from stochastic analysis that the TCFP bearing decreases element forces of bridge deck by 61% to 93%. Also, it is pointed out that increasing of difference between the soils types at support points generally increase element forces and displacements.

1. Introduction

When a highway bridge as an important engineering structure collapses during earthquake, transportation is effected and introduces various troubles. These types of structure are constructed against severe earthquake ground motion. Thus, using stochastic approach considering incoherence, wave-passage and site-response effect along with seismic isolation system should use on designing long span structure as a highway bridge.

TCFP bearing is used as an isolation system based on one of the most effective sliding isolation systems, namely friction pendulum system is invented by Zayas et al. (1989) [1]. TCFP bearing system consists of two facing concave stainless steel surfaces and an articulated slider is separately placed between the two spherical stainless steel surfaces. Namely, in the later system motions occur in three sliding surfaces. So the system is named as triple. The principles of operation and force-displacement relationships of the TCFP bearing are develop by Fenz (2008) [2]. There are some studies to indicate that TCFP bearing system is more effective than other sliding systems on severe earthquake ground motions [3-5]. Dynamic response analysis long span non-isolated and isolated bridges subjected to spatially varying ground motions were investigated by Harichandran and Wang (1988) [6]. Ateş et al. (2006) [7] performed a study of spatially varying ground motions on stochastic response of isolated bridge with friction pendulum bearing systems. Ates et al. (2009) [8] compared stochastic response of non-isolated and isolated cable-stayed bridge with double concave friction pendulum (DCFP) bearing subjected to spatially varying ground motion.

Although stochastic responses of cable-stayed and highway bridges isolated with different sliding systems have been investigated, TCFP bearing system exhibited more effective behaviour than other sliding systems is not taken into account so far. The purpose of this paper is to investigate the relative importance of using TCFP bearing for the isolation of the highway bridge system in the stochastic response analysis when the highway bridge system is subjected to the spatially varying earthquake ground motions.

2. Material and Method

In this study, TCFP bearing system is to be effective in severe earthquake used as an isolation device installed between deck and pier. To determine parameters of TCFP bearing, a sample design proposed by Constantinou et al. (2011) [9] is used in this study. Stochastic analyses of isolated and non-isolated bridge are performed under spatially varying ground motion by taking into account the incoherence, the wave passage and site response effects since the earth is inhomogeneity and complicated. The bridge model is subjected to spatially varying ground motions in the horizontal direction. The excitation is assumed to travel from left side to right side with velocities of 400 m/s, 700 m/s and 1000 m/s for soft, medium and firm soil types, respectively.

3. Numerical Example

In order to investigate the stochastic response of non-isolated and isolated bridges, a two-dimensional analytical model is selected as a numerical example (figure 1). For this aim, four different soil conditions sets are considered namely Cases A-D for the bridge supports. In Case A, all the supports are assumed to be founded on homogeneous medium soil. Wave passage and incoherency effects are considered between support excitations. In Case B, all the supports are assumed to be founded on homogeneous firm soil. Wave passage and incoherency effects are considered between support excitations. In Case C, while the side supports (1, 2, 5 and 6) are assumed to be founded on firm soil, mid supports (3 and 4) are assumed to be founded on soft soil. The incoherence, the wave passage and the site-response effects are considered. In Case D, while the side supports (1, 2, 5 and 6) are assumed to be founded on firm soil, mid supports (3 and 4) are assumed to be founded on medium soil. The incoherence, the wave passage and the site-response effects are considered.

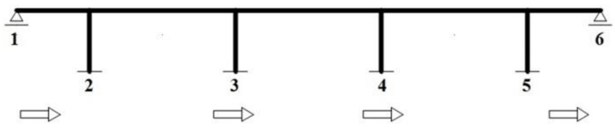

Figure 1. *The bridge system subjected to spatially varying earthquake ground motions for different soil case*

The non-isolated and isolated deck total normal force response components for Case A-D are presented in figure 2. TCFP bearing decreases total normal force of the bridge deck by 88%. This figure clearly indicates that case C is more effective than the other cases in both non-isolated and isolated.

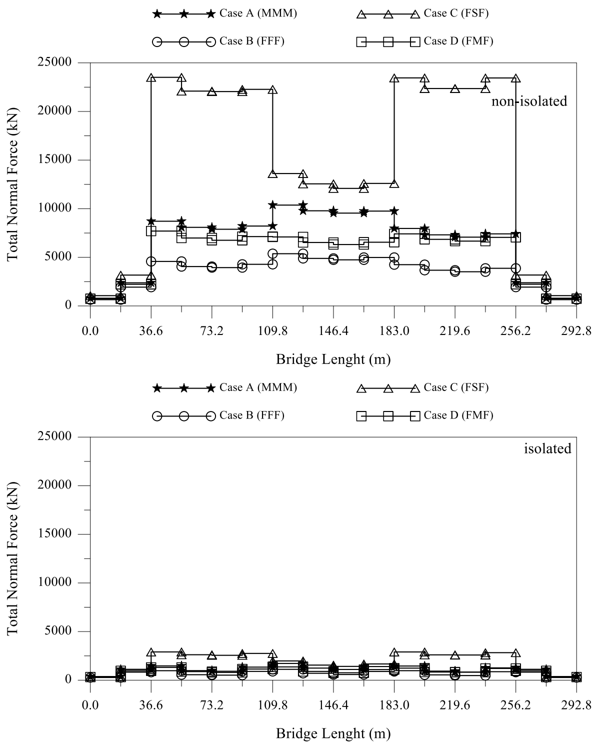

Figure 2. *Total normal forces of non-isolated and isolated bridges*

The non-isolated and isolated deck total shear force response components for Case A-D are presented in figure 3. TCFP bearing decreases total normal force of the bridge deck by 88%. This figure clearly indicates that case C is more effective than other cases in both non-isolated and isolated.

The non-isolated and isolated total deck bending moment force response components for Case A-D are presented in figure 4. TCFP bearing decreases total bending moment of the bridge deck by 88%.

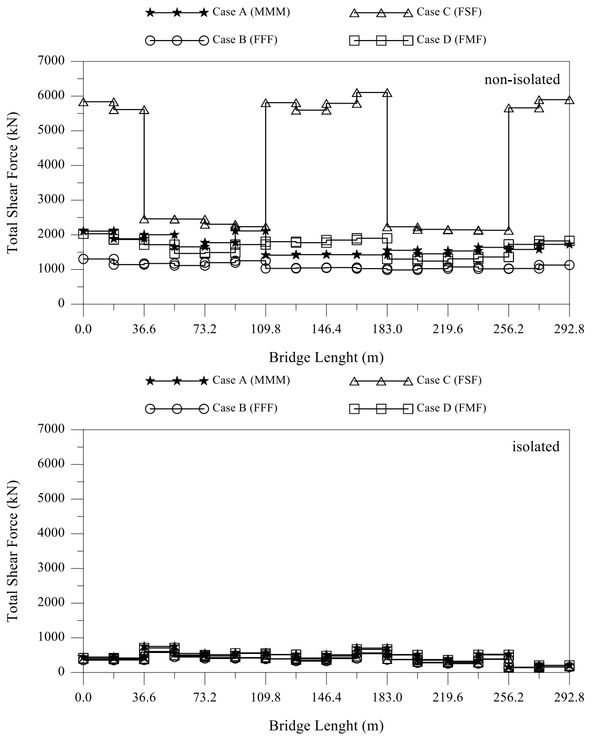

Figure 3. *Total shear forces of non-isolated and isolated bridges*

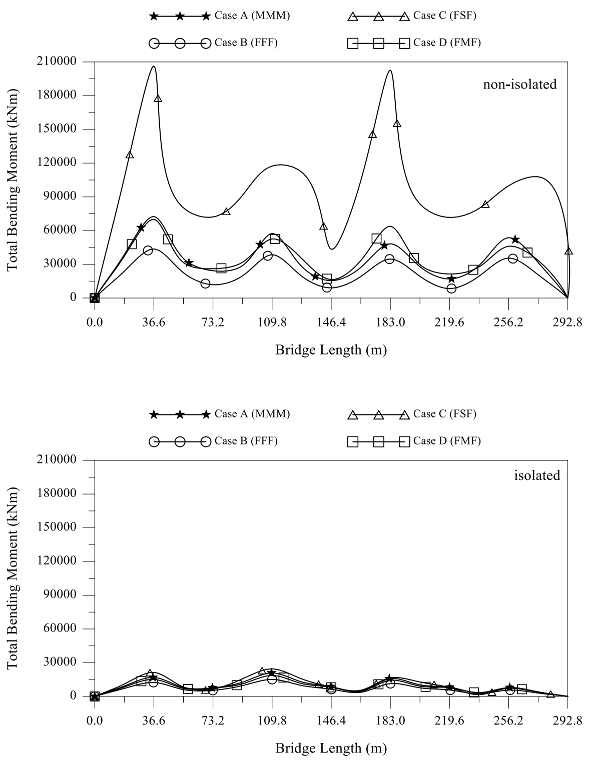

Figure 4. *Total bending moments of non-isolated and isolated bridges*

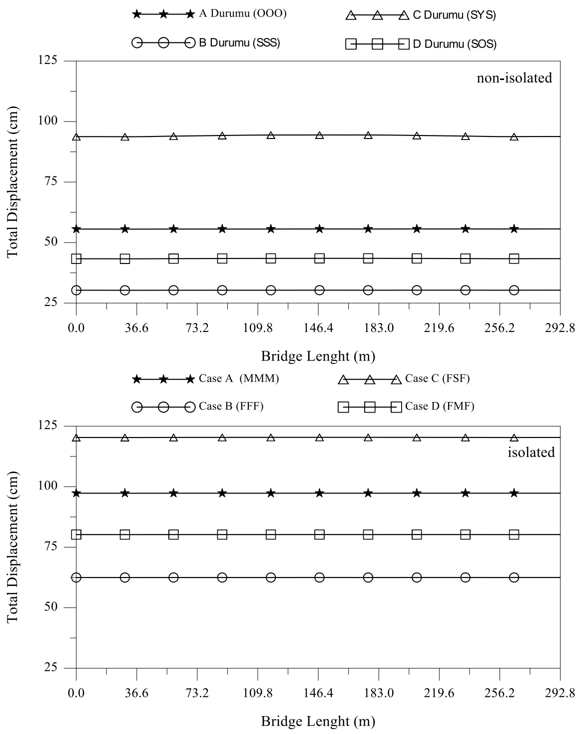

Figure 5. *Total displacements of non-isolated and isolated bridges*

This figure clearly indicates that case C is more effective than other cases in both non-isolated and isolated. The non-isolated and isolated total deck displacement response components for Case A-D are presented in figure 5. The value of total displacement in case C is bigger than the other cases in both non-isolated and isolated bridges. The value of total displacement in case B is the smallest.

4. Conclusion

In this study, means of maximum values of responses of non-isolated and isolated with TCFP bearing bridges are compared with each other for specialized conditions of the soil conditions. The changing of the local soil cases at the support points effects response values of isolated and non-isolated bridge decks. Increasing of difference between the soils types at support points generally increase element forces. The smallest values are obtained when the all piers are supported by firm soil condition. TCFP bearing decreases element forces of bridge deck by 61% to 93%. The most damaging effects occur in case C.

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