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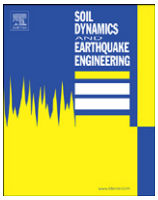

Example of application of response spectrum analysis for seismically isolated curved bridges including soil-foundation effects

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ABSTRACT

This paper presents seismic behaviour of isolated curved bridges in the earthquake prone regions.

For the seismic isolation of bridges, double concave friction pendulum bearings are placed between the deck and the piers, and the abutments as isolation devices. A curved bridge is selected to exhibit the application for seismic isolation. The mentioned bridge is a three-span featuring cast-in-place concrete box girder superstructure supported on reinforced concrete columns found on drilled shafts and on integral abutments founded on steel pipe piles. Additionally, the bridge is located on site underlain by a deep deposit of cohesionless material. The drilled shaft-soil system is modelled by equivalent soil springs method and is included in the finite element model. The soil modelled as a series of springs is connected to the drilled shaft at even intervals.

The multi mode method of analysis is typically implemented in a computer program capable of performing response spectrum analysis. The response spectrum specified for the analysis is the 5%-damped spectrum modified for the effects of the higher damping. Each isolator is represented by its effective horizontal stiffness with a linear link element.

As seen from the results of the outlined analysis, usage of the isolation devices offers some advantages for the internal forces on the deck for the considered curved bridge as per the non-isolated curved bridge.

The response spectrum analysis is substantially required to make a decision of the displacement capacity of the double concave friction pendulum bearings used in the study.

1. Introduction

For bridge applications, contemporary seismic isolation systems provide horizontal isolation from the effects of earthquake shaking to reduce forces. The main function of the seismic isolation system is to increase the period of vibration by increasing the lateral flexibility in the bridges or other structures.

The double concave friction pendulum (DCFP) bearing is an innovative and viable isolation system that is becoming a widespread application for the earthquake protection of structures. The DCFP bearings consist of two spherical stainless steel surfaces and an articulated slider covered by a Teflon-based high bearing capacity composite material. The concave surfaces may have the same radii of curvature. Also, the coefficient of friction on the two concave surfaces may be the same or not. Hyakuda et al. [1] presented the response of a seismically isolated building in Japan where DCFP bearings are utilized. Experimental and analytical results on the behaviour of a system having concave surfaces of both equal and unequal radii and both equal and unequal coefficient of friction at the upper and lower sliding surfaces were presented by Tsai et al. [2]. Constantinou [3] and Fenz and Constantinou [4–6] described the principles of operation of the DCFP bearing and presented the development of the force–displacement relationship based on equilibrium. The theoretical force–displacement relationship was verified through characterization testing of bearings with sliding surfaces having the same and then different radii of curvature and coefficients of friction. Finally, practical considerations for analysis and design of DCFP bearings were presented.

Few researchers have dealt with the dynamic response of straight and curved box girder bridges. Sennah and Kennedy [7] highlighted the most important references related to development of current guide specifications for the design of straight and curved box-girder bridges. DeSantiago et al. [8] analyzed a series of horizontally curved bridges using simple finite element models and reported that the bending moment in girders of a curved bridge can be about 23.5% higher than moments in girders of a straight bridge of similar span and design configuration. Mwafy and Elnashai [9] carried out a detailed seismic performance assessment of a multi-span curved bridge including soil–structure interaction effects. Constantinou et al. [10] manifested analysis and design procedures for seismically isolated bridges and examples of analysis and design of seismic isolation systems. Ates and Constantinou [11] carried out a parametrical study associated with the effects of the earthquake

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