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Seismic Performance and Failure Mechanism Study of Double Deck Bridges by Pushover Analysis

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Abstract

Double deck bridges are increasingly adopted to alleviate the overcrowded traffic in China. However, its seismic performance is more complicated and less well-studied, comparing with ordinary standard bridges. In this paper, pushover analysis is employed to investigate influence of structural parameters on the seismic performance of double deck bridges. Analysis results show that a relative small column reinforcement ratio is feasible for double deck bridges, as cap beams and joints are likely to damage if the column reinforcement ratio is too high. The failure mode of double deck bridges can be categorized into two types according to the height of upper column and columns. One type is that plastic hinges appear in both upper and lower columns, and the other type is that plastic hinge just appear in the upper or lower column. Cap beams with relative large cross section dimension are favourable, as the strong beam-weak column mechanism is achieved.

Keywords: double deck bridges; seismic performance; failure mode; column longitudinal reinforcement; height of the pier; beam cross section.

1 Introduction

Due to the advantages of economy and space-saving, double deck bridges are increasingly adopted to alleviate the overcrowded city traffic in China. However, comparing with ordinary standard bridges, double deck bridges are highly sensitive and vulnerable in earthquakes for the complicated failure mechanism. In the past earthquakes, double deck bridges in the USA suffered severe damage and even completely collapsed. For example, in the 1989 Loma Prieta Earthquake, a 1.4km part of the Cypress Viaduct collapsed and the upper deck of the bridge fell onto the lower deck [1].

After the Loma Prieta Earthquake, several studies have been conducted to explain the cause of the collapse of bridges[2,3]. According to the research results, the failure of Cypress might be attribute to the improper design and construction factors including inadequate shear reinforcement of the top end of the columns, unconfined shear keys, unconfined column steel, local conditions and etc. Bollo[4] conducted an in-situ experiment on a 3-span section of the Cypress Viaduct which did not collapse in the earthquake. The test result indicated that the shear failure of the pedestal between the upper and lower levels led the collapse. Kunnath[5] reaches the same result via numerical analysis. Priestley[6,7] studied the retrofit strategy of the double deck bridges which did not collapse by a pseudo static test. The result proved that those bridges satisfy the seismic requirement when they were well retrofitted.

The failure of the double deck bridges in the US was attributed to the design deficiency, rather than the structure type. Peng[8] designed a double deck

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