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Promotion of Seismic Behavior of Mass Concrete Piers Using External Post-Tensioning Technique

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Bridge mass concrete piers had widely been used during past decades. This kind of pier is very vulnerable to earthquake excitations due to its excessive weight and inadequate reinforcement. A convenient way to promote the performance of this kind of pier is to apply a prescribed compressive stress using post-tensioning technique. The present paper is to investigate the seismic response of a typical mass concrete pier rehabilitated using this method. In the numerical case study carried out in the paper, it is shown that a prescribed compressive stress about five percent of the piers axial strength can promote the lateral load-carrying capacity by 60 percent. Moreover, the piers with originally brittle behavior can show ductility using adequate post-tensioning. The capability of the rehabilitated piers to reveal stable non-linearity is resulted in a seismic response modification factor of 2.9, approximately. This value is comparable with unity considered for the existing piers. The nonlinear analysis conducted under cyclic loading confirms that the efficiency of this method does not considerably degrade during the loading excursions. Finally, a simplified method is proposed to estimate the prescribed compression needed to achieve required strength and ductility.

Keywords: Seismic rehabilitation; Mass concrete pier; Post-tensioning technique.

1. INTRODUCTION

Bridge mass concrete piers with no or inadequate reinforcement are highly susceptible to brittle failure during a major excitation. Such piers undergo the earthquake actions while the overturning moment of the lateral forces does not dominate resisting moment due to gravitational loads. The equilibrium condition is often not met owing to the excessive weight of the piers, and its subsequent earthquake forces. Accordingly, the rehabilitation of this sort of pier is mandatory, especially in the high risk seismic zones.

To improve the seismic behavior of mass concrete piers, two strategies may be traced. First, strengthening of the pier to reach more lateral load-carrying capacity; and second, increasing the piers ductility to attain capability to dissipate a part of input energy induced by earthquake. These strategies may be resulted through traditional methods such as steel and concrete jacketing [1]. However, since the dimensions of mass concrete piers are commonly large, the jacketing methods do not work efficiently unless massive details are employed. Such details are often expensive and difficult to use.

In the first method, the pier must be so strong to tolerate any probable severe excitations. The second method is aligned to the current design codes in which the piers are allowed to experience inelastic deformation during severe earthquakes. There is a major drawback with this philosophy, which is unavoidable damage of piers after earthquake, leading to high expenditure needed to bring the bridge into the service. This has encouraged researchers to find more sophisticated methods.

One recent improvement in this regard is the Damage Avoidance Design (DAD) philosophy. This concept was first introduced as Rocking Systems [2-4]. In the original usage of this system in bridges, the piers acted as a rigid block, freely rotating about their base toe. Mander and Cheng [5] showed that the performance of this system can be improved using post-tensioned anchorage connecting the pier to its foundation. This method has been improved using supplemental energy dissipation devices [6-10].

The DAD concept may well be adapted to precast piers in which a separation interface exists between the pier and its foundation. For the case studied in this paper, the inadequate reinforced concrete piers are available, and there is no possibility to provide a separation surface. However, the main idea may still be employed. The main idea is to apply a prescribed compressive stress on the piers to prevent the concrete