Resilience-based design and damage-resistant technologies for an enhanced seismic performance of bridges

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Abstract

Seismic codes do not currently focus on earthquake resilience. Resilience can be broadly defined as the ability of a system to quickly recover after a large earthquake. Traditionally, the main code objective has been only to prevent collapse and ensure life safety. Performance-based design (PBD) is a supplement to force-based design (FBD) and intends to demonstrate that pre-identified earthquake performance objectives for the structure are satisfied. Yet, neither FBD nor PBD include explicit verification of the expected functionality of the structure after the earthquake. Resilience-based design (RBD) appears as a holistic design process which identifies and mitigates earthquake-induced risks to enable rapid recovery in the aftermath of a major earthquake. Resilience explicitly requires design of structures to sustain less damage in earthquakes, therefore, damage-resistant technologies are a key component of RBD. This paper gives an overview on low damage design and the latest damage-resistant technologies; and subsequently, presents a framework for the quantification of seismic resilience for damage-resistant technologies for bridges. The framework introduces reparability as a key design criteria and resilience as a key performance indicator for seismic design. Applying the proposed framework on the design phase allows the estimation, by defining different recovery strategies, of final recovery times and preliminary costs of the bridge after an earthquake. Finally, since resilience allows the benefits of mitigation technologies to be translated into concise meaningful terms to owners and decision makers, such as expected closure time, RBD concepts can lead to an increased confidence in implementing low damage technologies as a method for reducing damage to bridges in an earthquake.

Keywords: resilience, bridge, pier, rocking, damage resistance, seismic design

1 Introduction

It is clear that an engineering approach that focusses solely on the concept of life-safety will not ensure resilient structures nor communities. To achieve truly resilient facilities, earthquake engineering needs to embrace a modern definition of seismic risks that considers a number of important factors such as financial losses associated with repair, disruption to business and the time lost to clean up and reinstate services and activities. Therefore, a new more general design methodology is proposed, resilience-based design (RBD), which can be considered as an extension of performance-based design (PBD) which is just part of the total design effort. The goal of RBD is to make individual structures as resilient as possible, by developing technologies and actions, as will be discussed shortly, that allow each structure to regain its function as promptly as possible.

Several bridge systems have been developed by past research to reduce construction time, minimize residual displacements, reduce seismic damage and increase reparability in comparison with the conventional cast-in-place construction. Low damage technologies for bridges have been

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