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Report on Analysis and Design of Seismic-Resistant Concrete Bridge Systems

Reported by ACI Committee 341

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This report is intended for use by practicing engineers and provides a summary of the state-of-the-art analysis, modeling, and design of concrete bridges subjected to strong earthquakes. It is intended to supplement and complement existing documents from the American Association of State Highway and Transportation Officials (AASHTO), California Department of Transportation (Caltrans), and various building codes and guidelines. Procedures and philosophies of codes and guidelines are summarized. Linear and nonlinear seismic analysis methods are also discussed, and important modeling considerations for different bridge elements, including curved girders and skewed abutments, are highlighted. The report also includes a summary of general seismic-resistant design and construction considerations for concrete bridges, as well as analysis and design considerations for bridges with seismic isolation.

Keywords: abutment; bridge; column; connections; design; earthquake; footing; girder; hinge; restrainer; seismic; seismic analysis; seismic isolation.

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CHAPTER 1—INTRODUCTION

1.1—General

The stated objectives of seismic design provisions in major codes have evolved considerably over the last 20 years. The initial focus of preventing structural collapse under the design earthquake to prevent loss of life has shifted to broader design objectives, such as achieving a level of serviceability following a major earthquake that allows for emergency response and ensures that transportation lifelines remain operational. These newer design objectives focus on the need for structures to remain operational after an earthquake, particularly for structures important to emergency response and those housing emergency and high-risk facilities. Critical structures include bridges on key response routes, hospitals, public safety headquarters, communication centers, and nuclear power stations.

Bridge seismic design philosophies may use a traditional single seismic design level (AASHTO 2012; AASHTO LRFDSEIS-2-M) or a two-level approach (MCEER-ATC-49) where both functional-level and safety-level hazards are considered. Performance objectives for each level are composed of a performance level or functional requirement at a seismic hazard level. The functional-level event considered in this two-level approach is typically a lower-level event with relatively high probability of exceedance (PE), and the safety-level event is typically a major seismic event with a very low PE. The typical performance objectives for the two-level approach tolerate only slight damage to ensure uninterrupted service of the bridge under the lower-level event, and allow only easily repairable damage under the higher-level event to ensure minimal or no disruption of lifelines.

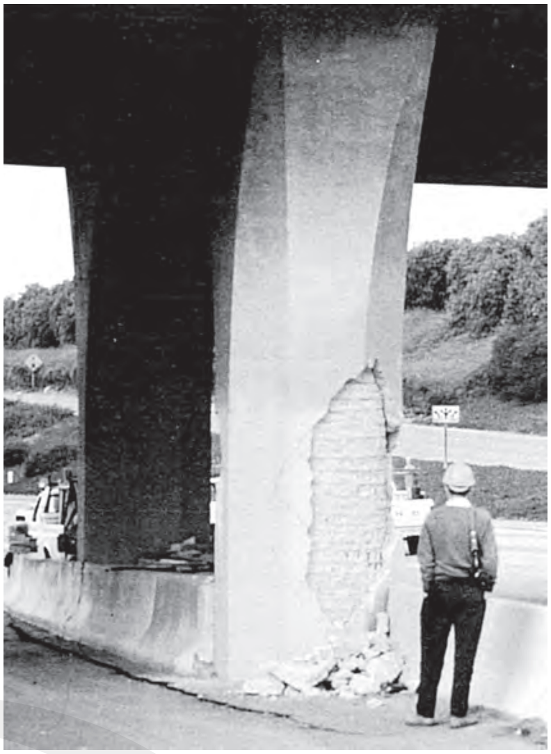

Fig. 1.1—Acceptable damage (spalling of cover concrete) to a bridge column for large earthquake.

In setting minimum performance standards, design codes recognize that it is not practical to design a structure to resist a large earthquake elastically; therefore, some degree of damage is typically permitted under the higher-level event (Fig. 1.1). For critical structures, however, depending on expectations of how quickly the particular structure can be put back in service and repaired, the damage can be further restricted by tighter requirements defined by the owner.

Design performance level requirements have become more general and are not always tied to traditional notions of force and strength. Thus, analysis requirements have also evolved beyond the traditional methods involving equivalent static forces representing the design event. The extent of damage in different bridge components is commonly quantified using performance quantities such as strains, curvatures, and displacements. Limiting damage requires imposing appropriate limits on these parameters in the critical sections of the structural members. In addition, the response of the structural system should be evaluated as a whole to assess functionality and operability. This requires a higher level of sophistication in both system modeling as well as sectional and material-level analysis. Reinforced concrete structural members, in particular, require greater attention to detail when moving beyond elastic or equivalent elastic analysis