RESEARCH NOTES

Contract: 59A0689

October 2011

Utilization of Strong Motion Data for Toll Bridge Damage Assessment

RESULTS: Various vibration-based damage assessment methods are investigated for post-event damage assessment from noisy and incomplete measurements. Output-only and input-output system identification techniques are respectively applied for identification of modal properties of the bridge from ambient vibrations and responses to high amplitude earthquake excitations

Background

Post-event damage assessment in structures typically requires a detailed and time-consuming visual inspection and evaluation. This project explores the utilization of the strong motion data for automated, remote, real-time damage assessment of bridges immediately after a destructive event.

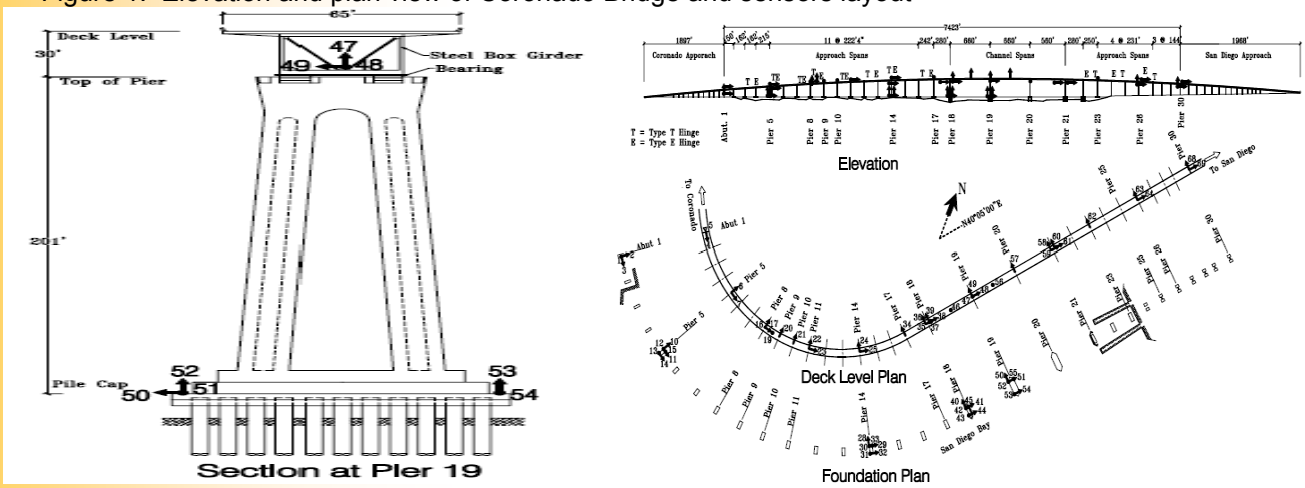
Why We Pursued This Research

Lack of information about damage in highway bridges, particularly the important toll bridges, can cause safety hazards, halt mobility of the transportation network and disrupt emergency response. Therefore a need exists to implement various vibration based damage assessment methods to explore the usage of strong motion data for automated, real-time damage assessment of bridges immediately after a destructive event.

What We Did

Various vibration-based damage assessment methods are investigated for post-event damage assessment. The first part of this report is devoted to experimental modal analysis. Output-only and input-output system identification techniques are respectively applied for identification of modal properties of the bridge from the measured ambient vibration data and responses to earthquake excitations. The second part of the report deals with identification of structural damage characteristics in critical structural elements using an optimization-based finite element (FE) model updating methodology. In the final part of the report, two vibration-based procedures are presented and applied for investigation of the consequences of damage in collapse capacity and functionality status of a damaged bridge. A new approach for generation of FE model realizations of the seismically damaged structures is proposed and applied. Generated FE realizations of the damaged bridge are employed to estimate the collapse capacity of the structure.

Figure 1: Elevation and plan view of Coronado Bridge and sensors layout



Research Results

The vibration-based structural health monitoring procedure for estimation of residual collapse capacity was applied to the San Diego Coronado Bay Bridge using the strong motion data collected during the 2004 San Clemente Earthquake. A five-step procedure was applied for residual capacity estimation and functional status update of the bridge. More specifically, this included: (1) estimation of collapse capacity of the pre-event bridge; (2) experimental modal analysis of the damaged bridge; (3) generalization of finite element (FE) realizations of the damaged bridge; (4) development of incremental dynamic analysis (IDA) curves for the damaged bridge; and lastly, (5) functional status of the damaged bridge was determined using seismic hazard properties at the bridge site and loss of collapse capacity. Figure 2 shows the results for the San Diego Coronado Bay Bridge. The dashed line shows the bridge specific relationship between loss capacity and mean annual frequency of ground motion exceedance. Based on this theoretical formulation, the seismic event must be twice as great as the mean event for the bridge to experience a significant loss (i.e., greater than 15%) of structural capacity [WN-3].

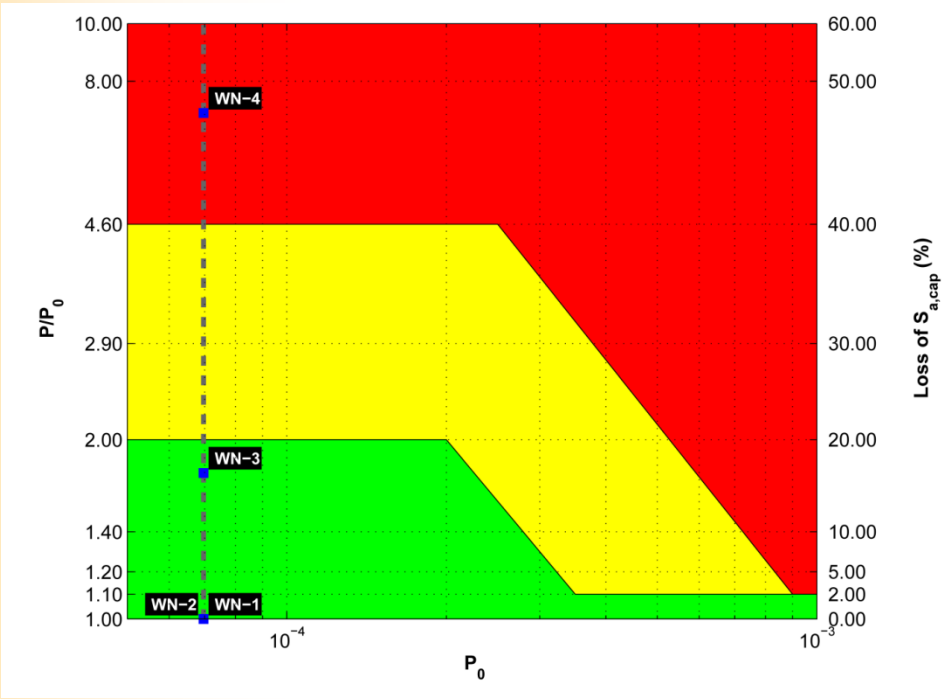


Figure 2: Estimation of capacity loss as a function of ground motion frequency

Recommendations

In conclusion, the project has proposed, investigated, and experimentally validated methods for post-event damage assessment of seismically instrumented bridges using its vibration measurement data. The performance of these methods for the real world bridges with challenges such as higher modeling uncertainties, unknown environmental conditions, incomplete and noisy measurements is yet to be evaluated.

Reference

Maria Q. Feng: "Utilization of Strong Motion Data for Toll Bridge Damage Assessment", Final Report, October 2011, 147 pp.

Principal Investigator:

Maria Q. Feng
Engineering Gateway E4139
University of California, Irvine
Irvine, CA 92697
Tel.: (949) 824-2162
Email Address: mfeng@uci.edu