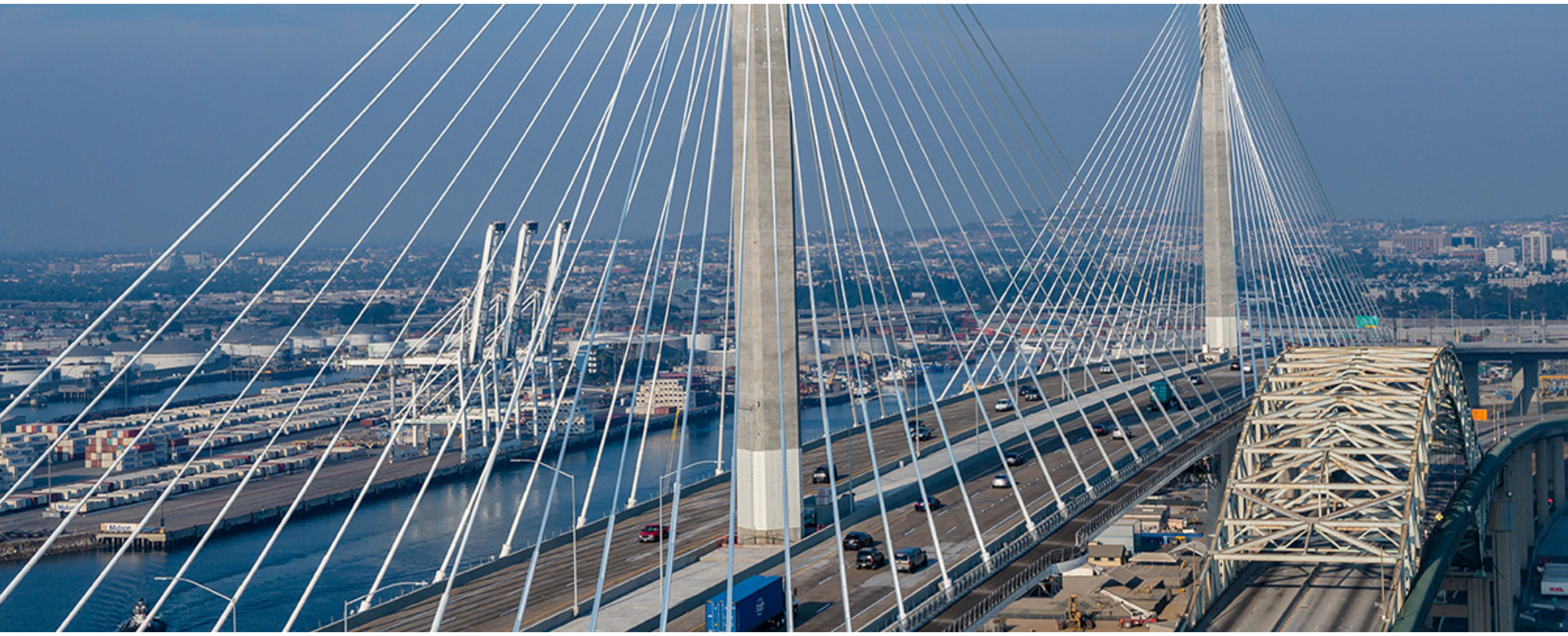
A Practical Framework for Component-Level Structural Health Monitoring of the Gerald Desmond Bridge

Mehran Rahmani, PhD, PE
Andrea Calabrese, PhD
Vesna Terzic, PhD
Brittany Campbell

Project 2155
December 2023



Introduction

This study presents a practical framework for instrumentation, data acquisition, and data aggregation for the new Gerald Desmond Bridge. The recommended instrumentation is intended to serve as the basis for remote condition assessment of the bridge's critical elements. The bridge, located at the Port of Long Beach and completed in 2020, is California's largest cable-stayed bridge that serves as a critical transportation link in the region. The iconic bridge features a unique 2,000-foot-long cable-stayed segment. This very large structure demands frequent inspection and monitoring to ensure the health of its critical elements, such as its towers, girders, and stay cables.

Traditional visual inspection involves several challenges for a complex and exceptionally large structure such as the Gerald Desmond Bridge. These challenges include (1) labor intensity, (2) time consumption, (3) cost, and (4) subjectivity. Considering these challenges, alternative methods such as monitoring the bridge's critical elements using sensory data and detecting damage or deterioration in its early stages are highly desirable for inspectors and operators. Remote monitoring of the bridge's elements also offers significant advantages in facilitating emergency responses in large cities.

Study Methods

As part of this study, a comprehensive literature review on best practices and recent advancements in both sensing technologies and instrumentation strategies utilized in similar cable-stayed bridges worldwide was performed. All the crucial factors associated with the design of a successful remote monitoring system have been thoroughly examined. We gathered a set of requirements that served as guiding principles for the design process, including (1) wireless sensing technologies and their advantages, (2) element-level local response monitoring, (3) scalability of the network, (4) cables' tension analysis, (5) energy saving and harvesting, (6) fatigue life estimation of fracture critical elements, (7) compensation of response for thermal effects, (8) decentralization of the data acquisition, and more.

The bridge's structural system and its design reports, such as load-rating reports, were reviewed, and the existing array of 44 accelerometers on the main span of the bridge, deployed by the California Geological Survey (CGS), discussed, including the bridge's response during a local earthquake (Carson 2021).

The key monitoring factors and bridge design information were carefully reviewed to ensure the establishment of a monitoring system for the bridge that is both reliable and resilient. Subsequently, the authors proposed element-specific instrumentation and layout designs that are tailored to the bridge's critical elements. This also included determining the optimal sensor placements and providing a consistent naming convention for all sensing channels across the monitoring network.

Findings

A comprehensive understanding of the load path and structural redundancy within the bridge allowed the authors to explain the failure mechanisms of critical elements and their potential impact on adjacent elements. The proposed instrumentation in this study will go beyond typical accelerometer arrays to encompass a wide range of cutting-edge and sustainable monitoring sensors, including Fiber Bragg Grating (FBG) friction strain gauges, displacement transducers, fiber optic temperature sensors, FBG tiltmeters, ultrasonic anemometers, and more.

For the monitoring system, a cluster topology approach with decentralization at the cluster head and sensor nodes is proposed. The sensing network is equally divided into four subnetworks (i.e., sensing clusters). Within each sensing cluster, the sensors communicate with their dedicated cluster-head sensor node, and further with a gateway node, which then transfers the data to a base station. The creation of subnetworks was motivated by the limited reception rate of wireless sensors over large distances, and this approach helps increase the number of responsive sensors. Subsequently, element specific instrumentation and layout designs tailored to the bridge's critical elements were proposed. The framework presented in this study will be effective in creating a foundation for real-time, or near real-time, remote health monitoring of the bridge.

Policy/Practice Recommendations

The recorded responses of members under the proposed sensing network must be reviewed, and the accuracy of the values should be confirmed. Calculated responses should be compared with results obtained from the finite element model of the bridge to verify and calibrate the sensor network and the post-processing algorithm based on actual on-site data. Furthermore, thresholds for healthy and anomalous responses at critical elements should be determined using the field tests. Variabilities in the parameter of interest (e.g., strain or displacement) and their sensitivity to various environmental, operational, or non-damage related phenomena (such as creep, shrinkage cracks, thermal expansion, or contraction) should be investigated and filtered out. These verifications and calibrations are crucial for enhancing the system's reliability and preventing future false positive alerts

About the Principal Investigator

Dr. Mehran Rahmani is an Associate Professor in the Civil Engineering and Construction Engineering Management Department at California State University, Long Beach (CSULB). He earned his PhD in Structural and Earthquake Engineering from the University of Southern California (USC) in 2014 and joined CSULB in 2017. He is a registered Professional Engineer (PE) in the state of California.

To Learn More

For more details about the study, download the full report at transweb.sjsu.edu/research/2155

MTI is a University Transportation Center sponsored by the U.S. Department of Transportation's Office of the Assistant Secretary for Research and Technology and by Caltrans. The Institute is located within San José State University's Lucas Graduate School of Business.