PEER
PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

In-Service Evaluation of Highway Box Beam Overhead Sign Structures

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1. Background and Motivation

Caltrans manages hundreds of steel Box-Beam Overhead Sign Structures (BBOSS), many of which are susceptible to corrosion at critical diaphragm connection details. Current condition assessment relies largely on visual inspection, which is subjective and difficult to translate directly into residual structural capacity. This project develops a quantitative framework linking observed corrosion to strength degradation in BBOSS. The work combines high-fidelity Finite Element (FE) modeling and optimization-based model updating with full-scale laboratory testing and vision-based corrosion detection. Using real BBOSS specimens, including a decommissioned corroded structure tested at the PEER Structural Laboratory and a corrosion-free reference configuration, the study establishes practical correlations between corrosion severity, load-path changes, and capacity loss to support risk-informed maintenance decisions.

2. Data Collection, Model Development, and Experimental Preparation

This study integrated field inspection, vibration testing, FE modeling, and laboratory test preparation to evaluate corrosion-induced capacity loss in BBOSS, refer to Figure 1. Field photographs and site measurements were collected to document corrosion conditions, while hammer-impact tests were conducted to identify natural frequencies for model calibration. High-fidelity FE models were developed from the measured structural configuration and observed corrosion damage. Corrosion information extracted using AI-based image detection was mapped into the Abaqus FE model. The model was then updated using dynamic properties obtained from field testing, including measured natural frequencies, to better represent the current structural condition.

A heavily corroded Seacliff overhead sign structure was removed from service and prepared for full-scale cyclic loading tests. In a later test stage, the corroded beam component was replaced with a non-corroded beam component for comparative evaluation. This paired testing strategy helped isolate the effect of beam corrosion on strength, energy dissipation, and damage progression.

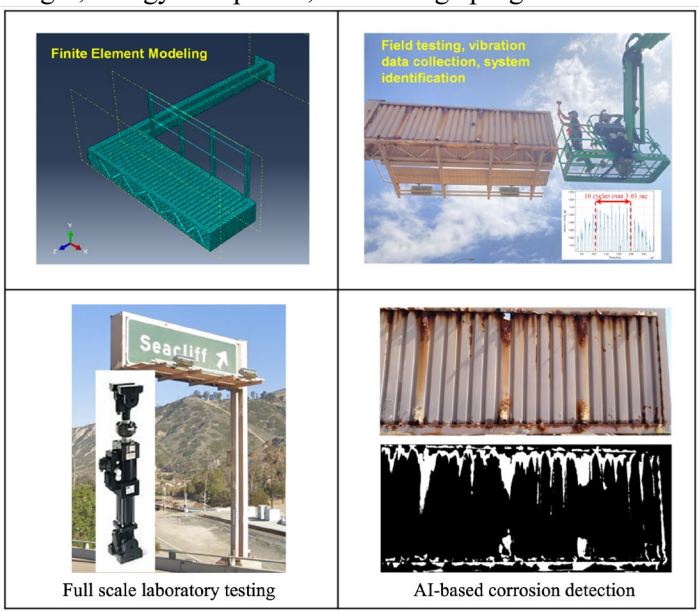

Figure 1. Integrated framework for corrosion assessment of BBOSS.

3. Key Experimental Findings: Capacity Loss and Failure-Mode Shift

Full-scale cyclic loading tests showed that corrosion significantly reduced the structural performance of the sign structure. As shown in Figure 2, the corroded specimen reached a similar peak strength in the pull direction, but its push-direction capacity dropped by nearly 50%, from about 30 kips to 15 kips. The

hysteresis response also exhibited clear pinching near the origin, primarily due to bolt loosening and local steel buckling during cyclic loading.

A key experimental finding is that corrosion did not simply weaken the structure; it changed the governing failure mechanism. In the corrosion-free specimen, damage was mainly concentrated in the post and post-beam connection region, while the ribbed sheet-angle connections remained largely intact. In contrast, corrosion weakened the ribbed sheet-angle connection in the corroded specimen, leading to earlier detachment and component separation. This shifted the load path and relocated the critical failure from the post-beam connection to the corroded ribbed sheet-angle connection. As a result, the energy dissipation capacity decreased from about 1,750 kip-in in the reference specimen to about 1,150 kip-in in the corroded specimen.

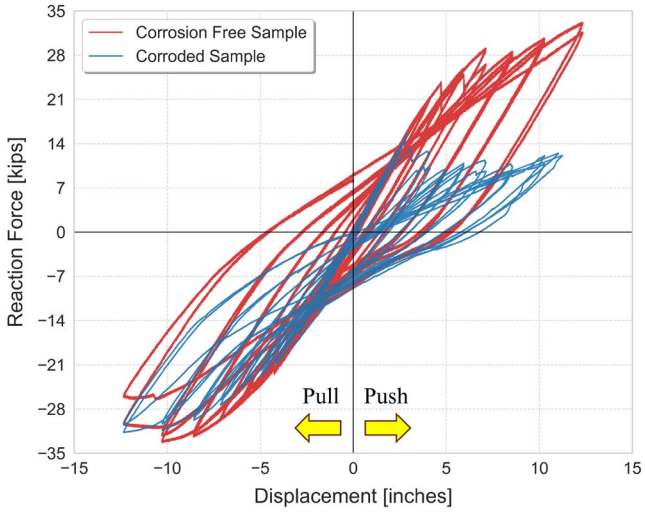

Figure 2. Force-displacement responses of corrosion-free and corroded specimens under cyclic loading.

4. Corrosion Index and Field-Ready Capacity Prediction

To avoid requiring a new FE simulation for every field inspection, the project developed a simplified, field-oriented capacity prediction method. A suite of Abaqus models with parametrically varied corrosion scenarios was used to fit a degradation curve relating a scalar corrosion index, based on the adjusted area ratio, to normalized force capacity (Figure 3). During field inspections, corrosion detected from photographs can be converted into a corrosion index and mapped onto the fitted degradation curve. This provides engineers with a rapid estimate of how observed corrosion may affect the structural capacity without the need for a detailed simulation for each inspected highway sign structure.

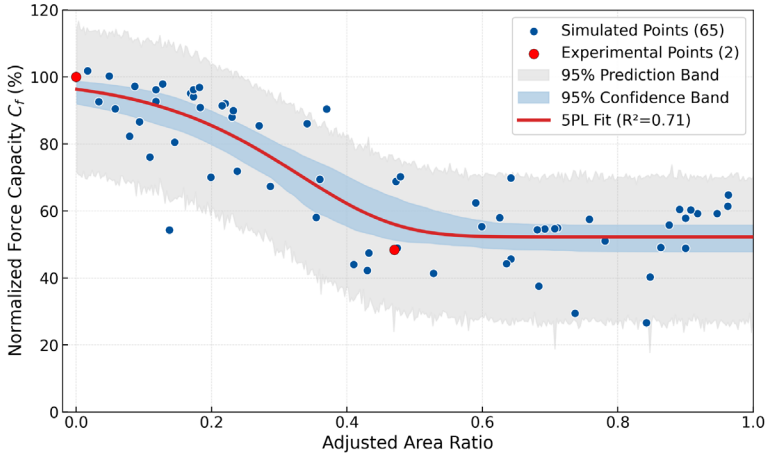

Figure 3. Relationship between corrosion area ratio and normalized force capacity.