DRISI
CALTRANS DIVISION OF RESEARCH, INNOVATION AND SYSTEM INFORMATION
TRANSFORMING IDEAS INTO SOLUTIONS

Research Notes

Estimating the residual fatigue life through a novel integrated system-component-material-based process

Develop fatigue models for concrete and reinforcing steel that are suitable for evaluation of existing bridge decks, and that could enable reasonable prediction of the residual life of existing bridges.

Geotechnical/ Structures

May 2025

Project Title:

Estimating the residual fatigue life through a novel integrated system-component-material-based process

Task Number: 4280

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Task Manager:

Colman Cronin
Senior Technical Engineer
colman.cronin@dot.ca.gov

WHAT IS THE NEED?

Many of California's bridges have been in service for several decades and are approaching the end of their "design" life. Asset managers must decide when replacement of such bridges will be required. Optimizing service life needs a reasonable prediction of residual life of existing bridges. Such predictions are usually based on the fatigue resistance of the various bridge components. Bridge decks are the single component most vulnerable to fatigue.

Bridge engineers rely on AASHTO's Manual for Bridge Evaluation when performing strength and fatigue evaluation of existing bridges. The AASHTO Manual for Bridge Evaluation provides little guidance for the evaluation of existing bridge decks because of an underlying assumption that "there is significant reserve strength in concrete decks designed by AASHTO LRFD Bridge Design Specifications." Given the lack of guidance for evaluation of fatigue life of existing bridge decks, engineers rely on current bridge design code fatigue provisions. Code provisions are intended to produce conservative designs for new bridges. Using such provisions for the evaluation of existing bridge decks will likely overstate the fatigue vulnerability of existing bridge decks, which can lead to costly and perhaps unnecessary work. We should strive to get the most use out of existing bridges and do it in a safe and cost-effective manner. Asset managers need information that will insure the most effective use of resources. Developing a realistic service life of existing bridges fits well within this goal. This, in turn, will avoid project delays and advance efforts to reduce GHG emissions associated with concrete materials.

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WHAT ARE WE DOING?

The research work will be broken into seven tasks. The first task will involve conducting data retrieval and analysis of state bridges to find an archetype bridge for the study. The focus of this task will be on multi-girder bridges. Task 2 will involve testing of 4 to 6 specimens of rebar with 4 to 5 stress variation amplitudes with an aim to understand how localized crack patterns induce fatigue stresses, consequently reducing the allowable number of cycles before failure. A regression analysis of the test results will be applied to build S-N curves.

Task 3 will involve the deployment of instrumentation on the bridge selected in Task 1 to monitor fatigue "hot spots". The measurements and curves obtained in Task 2 & 3 will be used to correlate and validate the non-linear finite element model (N-L FEM) of the bridge that will be created in Task 4. Task 4 has two parts: one focused on the probabilistic traffic load characterization, and the second part involves numerical simulations using the N-L FEM that will generate strain histories at critical points on the bridge under controlled and random traffic conditions. Task 5 will involve constructing and testing an 18 ft x 18 ft component model of a portion of a bridge deck with details similar to those of the chosen in-situ monitoring bridge for additional validation of the analytical results. Task 6 involves a parametric analysis, and the development of a simplified method for estimating concrete bridge deck residual fatigue life utilizing a linear FE bridge model calibrated to the N-L FEM.

A final report, following the standard PEER format, will be produced in Task 7. The report will be structured into three parts. Part 1 will provide a summary of the key research outcomes derived from the novel integrated system-component-material methodology. Part 2 will elaborate on the procedure for the Linear Finite Element Method (L FEM) model and its associated traffic loading scenarios. The report will conclude with the application of the procedure to the instrumented bridge.

WHAT IS OUR GOAL?

The following are the key products to come out of the proposed research:

- Fatigue models for concrete and reinforcing steel that are suitable for evaluation of existing bridge decks.
- Finite element modeling guidelines and procedure for the analysis of existing bridge decks.
- Guidelines and procedures for efficient/simple instrumentation of existing bridge decks that can be used to calibrate analysis models.
- Guidelines and procedures for collection and post processing of weigh-in-motion data.

WHAT IS THE BENEFIT?

Simplified analytical tools that enable reasonable prediction of the residual life of existing bridge decks and assists bridge maintenance designers and asset managers in maintaining bridge decks in a way that ensures safety, functionality, and durability, while optimizing service life.

WHAT IS THE PROGRESS TO DATE?

The contract for this task order was executed on October 08, 2024, and the kick-off meeting was held on October 28, 2024. The deliverable for sub-task 1 has been submitted. The research team are currently drafting the monitoring plan for field testing at the candidate bridge.