The Ohio Department of Transportation Office of Research & Development Executive Summary Report

Predicting Fatigue Lifetime from Strain Histograms in an Abbreviated Time Window

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Problem

Details used in the construction of highway bridges are susceptible to fatigue failure. The present standard of practice associated with bridge fatigue considerations has ambiguities and assumptions associated with analytical stress predictions, number and magnitude of primary load response cycles and secondary vibrations. Furthermore, the variability of vehicle passage frequency over time in not addressed. Such inadequacies in current standards may detract greatly from the accuracy of fatigue lifetime evaluation procedures. A method of fatigue lifetime assessment that utilizes an observational procedure, which more closely captures actual in-situ strain cycle amplitudes and frequencies is suggested for more meaningful fatigue life estimations.

Objectives

The goal of this project was to develop an empirical methodology, based on short-term measurements from in-service bridges, for determining the expected fatigue life of a steel bridge. To do this it is necessary to characterize the manner in which fatigue damage accumulates over time. One of the primary objectives of this research was to characterize what will be referred to as the Strain Cycle Process (SCP). The temporal

characteristics of the SCP are used in the estimation of residual fatigue life. This methodology has been developed in a manner that allows timely implementation by bridge inspection personnel. To facilitate this, existing technology and standards of practice were incorporated whenever practical. The methods developed as part of this project utilize existing field instrumentation methods and equipment that have been shown to collect data appropriate to this task. The lifetime assessment calculations are formulated upon a stress-based approach to fatigue and the AASHTO code-prescribed S-N relationship.

Description

To develop the fatigue lifetime estimation methodology, the following objectives were accomplished:

- Gather histogram data over an adequate time period to represent the SCP for in-service bridges along roadways of different Functional Classifications (FCs).
- Develop a temporal model of the fatigue damage for respective functional classifications
- Develop a methodology to determine the expected time at which code-prescribed fatigue requirements will be achieved (i.e. the time at which expected fatigue life has ended)

Based on historical truck count data, the study was confined to FCs 1, 2, 6, 7, 11, 12, 14 and 16 as these were deemed most susceptible to unacceptable levels of fatigue damage within the design life.

Each of the twenty-four bridges studied in this project was monitored over an entire year. The data was resolved into an hourly *damage metric* representation. The damage metric data was analyzed to determine relative fractions of damage occurrence for hour-of-day, day-of-week and month-of-year time periods. The SCP for the FCs in this study was characterized using these relative fractions.

Fatigue life extrapolation for a site-specific detail is accomplished by applying the appropriate FC-specific relative fractions to the site-specific SCP measured during short term monitoring. This operation results in a *yearly damage metric*. A relation between the AASHTO fatigue detail constant and the yearly damage metric is used to estimate the year in which code-prescribed fatigue requirements will be achieved.

Conclusions & Recommendations

Based on the data and analyses acquired during this project, it appears that the occurrence of vehicle induced mechanical fatigue damage exhibits a general temporal structure. The general characteristics of this temporal structure have been characterized using a long-term data collection scheme. This characterization encompasses the Functional Classes studied in this project. In light of the comparison made between hourly data collected during this project and published hourly truck count data, the results of this work may have state wide applicability.

Short-term site-specific SCP data combined with long-term Functional-Class-specific

data will advocate a reasonable estimate of residual fatigue life. The method proposed in the final report may be applied to a broad class of bridges within the inventory as opposed to monitoring schemes that target a specific structure. The method of short-term data collection utilized in the proposed method may be implemented by existing bridge inspection professionals with little additional training.

It is recommended that the proposed methodology is further verified through additional long-term monitoring of in-service bridges.

It is also recommended that an Implementation Manual is developed prior to implementation of the fatigue life estimation methodology. Such a manual would outline data collection procedures, fatigue calculation procedures and trouble-shooting. The document would also facilitate training of personnel. The manual can serve as a platform to provide recommendations on how to best utilize the fatigue life assessment method for the purposes of strategic planning and budget justification.

Implementation Potential

The methods of data acquisition and fatigue life estimation presented in this project have been developed to be easily implemented with minimal additional training of either State or private bridge inspection professionals.

It was shown in this project that bridge inspection professionals, with no previous data collection experience (as required by this project), were readily trained to perform the tasks necessary for data collection. The consultant used in this project successfully collected the long term data for the bridges allocated on rural functional classes.

The long-term data collection operations for this project provide insight into the field effort required for implementation.

The fatigue life estimation calculation may be implemented using commercially available spreadsheet or mathematical software. The estimation procedure may also be incorporated into a self contained software package.

Based on the above discussion and experience gained during this project, the proposed fatigue life estimation methodology has the potential of immediate implementation. An “Implementation Plan” should include the development of an Implementation Manual and the subsequent training of personnel as needed to obtain the objectives set forth by the State.