

JOINT TRANSPORTATION RESEARCH PROGRAM

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Efficient Load Rating and Quantification of Life-Cycle Damage of Indiana Bridges Due to Overweight Loads

Introduction

Over the lifetime of a bridge, traffic loads cause numerous stress-strain cycles within bridge components, which in turn lead to the slow accumulation of damage. The rate of progression of this damage is affected by several human-induced and natural factors, such as volume and type of traffic loads, environmental conditions, and maintenance practices. Traffic volume and truck weights have been steadily increasing with the growth and technical development of the freight industry. Because further increased truck weight limits are anticipated in the future, this research focused on the potential detrimental effects of such increases on the durability of bridges, especially due to overweight trucks.

A computational approach to assess the effect of different load-related and environmental factors on the durability of bridge components is presented in this report. Detailed finite element models calibrated using data from inspection reports of real bridges were used for this study. The basic idea behind the durability model developed here is that repetitive loading and natural conditions cause damage to the bridge structure. Damage is represented as a degradation of the material properties of each and every point in a structure based on the level of stresses at that point resulting from repetitive traffic loading. In addition, an empirical relationship was used to represent degradation due to natural processes. Thus the finite element model of a representative bridge was subjected to a set of different vehicle loads to quantify the stresses (and hence the damage) at all the material points in the bridge. This damage was scaled by the annual daily traffic for each

vehicle class to account for damage occurring over a year, and the finite element model was updated to reflect this damage within its elements. The process was repeated successively to characterize the evolution of damage in the bridge over its lifetime.

Findings

It is shown that this computational approach, with certain assumptions, is capable of quantifying damage resulting from loading and environmental factors. The approach was also used to study different hypothetical scenarios of how this damage could potentially affect the life of bridge components as loading and environmental conditions were varied.

A challenging aspect of this research was the calibration of the durability models developed. A detailed study of all INDOT-owned bridges (approximately 6,000) and all Indiana bridges (approximately 18,000) using data from the NBI database was conducted. Three types of bridges were considered in this study: reinforced concrete (RC), pre-stressed concrete (PSC), and steel. The bridges were first classified into 25 different classes according to 5 different levels of loading conditions and 5 different levels of natural conditions. Then, using historical condition rating data from 1994 to 2014 for each of these bridges, a rate of deterioration corresponding to the 25 different classes of bridges was determined. An empirical equation to characterize the variation of these deterioration rates with loading and natural factors was postulated and calibrated with actual data. The relative importance of load-related and natural factors in terms of their effect on the durability of bridge structures was also determined for different bridge types.

A limitation of the current approach for calibration of durability models is that annual daily traffic is taken to represent the level of loading on a bridge. This is usually insufficient since the loading experienced by a bridge is characterized not only by the total number of vehicles, but also by the axle configurations and axle loads of each of those vehicles. Unless historical traffic data with vehicle weights and axle configurations is available for all bridges being investigated, a precise calibration of the load-related damage in this durability model may not be possible. Another limitation of the calibration approach adopted is that location (latitude) of a bridge is taken to reflect its natural condition. This does not account for local environmental conditions and maintenance practices that may affect the durability of bridges significantly.

Implementation

Action items from this research include implementing measures to collect more detailed vehicular data, possibly with the use of weigh-in-motion stations, across all major highways to allow a better characterization of the loads incurred by bridge structures. Further, it is recommended that during bridge inspections the environmental conditions affecting durability be characterized on a scale similar to that presented in Chapter 6 of this study. It is also recommended that a more detailed component-wise record of condition ratings be undertaken during bridge inspections. Not only will this reduce the subjectivity in the determination of these ratings, but it is also essential for effectively calibrating the

durability models constructed in this study. In addition, a database of maintenance activities performed on bridges should be maintained.

Despite some limitations, trends in the real data show that deterioration rate increases with increased loading and/or with worsening natural conditions. However, challenges remain with precisely calibrating the relative importance of load-related and natural factors on the durability of bridges with real data from inspection reports. Results from the durability analyses of different scenarios using the finite element models of representative bridges show that the effect of increasing trucks weight limits on these bridges can indeed be quantified and used to generate deterioration curves for the various bridge components. This information can also be used by INDOT to streamline permitting of overweight trucks and for bridge maintenance and operations.

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