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New Jersey Department of Transportation
Bureau of Research

Technical Brief

Monitoring the Construction of the Doremus Avenue Bridge Structure

This report looked at various means to validate the American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factored Design (LRFD) Bridge Design Specifications through field-testing of the Doremus Avenue Bridge- New Jersey's first AASHTO LRFD (1998) design. In addition, long-term monitoring of the bridge fatigue life was also implemented. In particular, the study evaluates the AASHTO criteria for live load distribution, effective flange width of the deck slab, deflection limits, dynamic amplification factors, and truckload data using a permanent Weigh-In-Motion (W IM) system.

Background

The AASHTO LRFD Bridge Design Specification was mandated by the Federal Highway Administration (FHWA) in the year 2007. All new bridges are to be designed and constructed according to AASHTO LRFD Specifications to be eligible for federal funding. New Jersey committed itself to adopting the AASHTO LRFD Specifications in January 2000. The AASHTO LRFD Specifications consider and ascertain the variability in the behavior of structural elements through extensive statistical analyses; therefore they continue to be refined. Many of the code's design approaches and methodologies have been adopted with limited or virtually no experimental validation. Therefore, it is believed that there is a need to validate the new design procedures and models as well as the AASHTO LRFD bridge structure designs. Figure 1 shows the Doremus Avenue Bridge that was instrumented and monitored using vibrating wire strain gages (VWSG). In addition, Figure 1 shows a typical finite element model used in the analysis of the bridge.

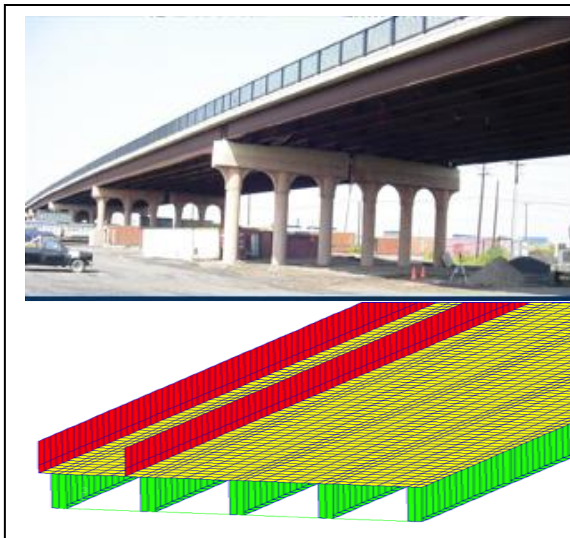

Figure 1. View of the Doremus Avenue Bridge and Finite Element (FE) model used in the analytical study.

Research Objectives and Approach

The primary objective of this study is to validate the LRFD Specifications (1998) by means of instrumentation, field-testing, and condition monitoring of the new Doremus Avenue Bridge. The following six main objectives are considered:

1. Verify the LRFD live-load distribution factor specification and develop new simplified equations.
2. Evaluate and develop a prediction model for the effective flange width in the bridge deck.
3. Verify New Jersey Department of Transportation's deflection limits and develop provisions for designing and formulating deflection and related serviceability limit states.
4. Verify the LRFD dynamic amplification factor specification.
5. Develop a truckload model using a permanent WIM system. Compare the live-load spectra to other WIM sites in New Jersey.
6. Develop a fatigue load mode to estimate the remaining service damage.

Figure 2 shows typical sensor network that were used in the instrumentation of the Doremus Avenue Bridge. Moreover, figure 3 shows a comparison between measured and predicted girder strains.

Findings

The following conclusions and recommendation are made from this study:

- The Research Team (RT) has proposed new equations that are a modified version of the AASHTO Standard Specification LDF simple "*S*-over" formula. However, rather than dividing *S* by a constant *D*, an equation is proposed to replace the constant. The following equations represent the denominator of the "*S*-over" equation for girder bridges (e.g., steel I-beam, prestressed concrete I-beam, and concrete spread box beam). For one lane loaded: $D = 8.4 + \frac{S}{1.4} + \frac{L}{C}$ while for two lanes loaded: $D = 7.0 + \frac{S}{3.0} + \frac{L}{C}$, where *L* is the span length (ft) and *C* is given as 28 for the steel I-beam, 50 for the prestressed concrete I-beam, and 20 for the concrete spread box beam. It is recommended that the proposed equation be adopted in NJDOT design specification as an alternative to AASHTO LRFD.
- Based on the data collected from the field study and using the extreme value theory, it is predicted that the deflection limit set by NJDOT will not be exceeded in 75 years.

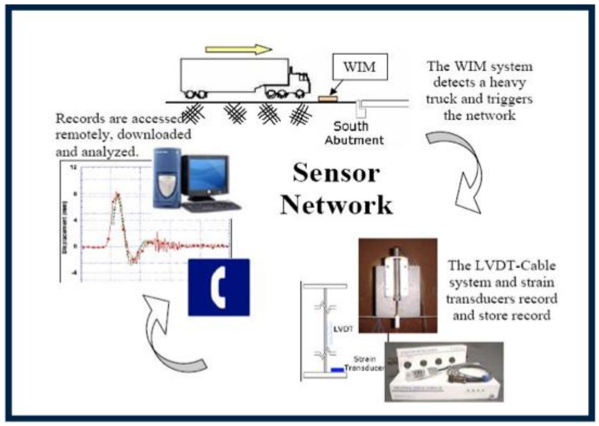

Figure 2. Typical sensor network used in the field instrumentation.

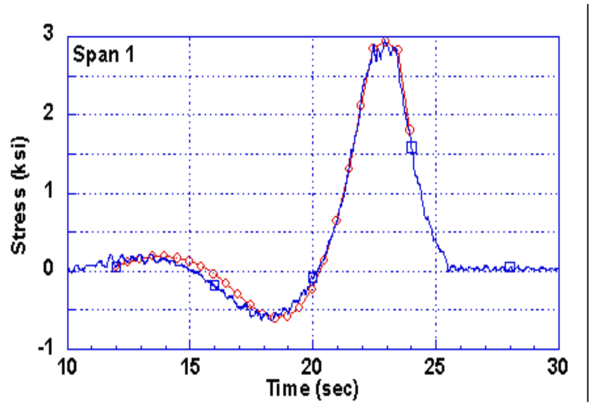

Figure 3. Typical results for measured and predicted girder strains

The reason for this is quite obvious as deflection limits used by NJDOT and many other states are based on human perception of vibration rather than on a serviceability limit state. The NJDOT deflection requirements should be retained at a minimum of $\frac{L}{800}$ to control the bridge deck flexibility.

- In this study, a linear equation for the effective flange width, b_e, is proposed as follows: $b_e / b_s = 1 - 0.5\left(\frac{b_s}{L}\right)$ for $b_s / L > 0.25$ where $= b_s$ for $\left(\frac{b_s}{L}\right) \leq 0.25$, b_s is the girder spacing, and L is the span length.
- WIM measurements provide a comprehensive description of site-specific live load information. According to the collected WIM data, a significant number of overloaded trucks are crossing the bridge. Trucks with GVW exceeding 200 kips were recorded as crossing over Doremus Avenue. Thus, further work is needed to develop new load models for bridge rating analysis that would take these overloads into account.
- For all tested bridges, the dynamic impact factor does not exceed 20 percent for trucks with a minimum gross vehicle weight (GVW) of 60 kips.
- Fatigue resistance depends on type of detail, degree of corrosion and other deterioration. Load analysis requires the knowledge of load history (accumulated damage), current load spectra and prediction of future loads. The effect of measurement duration is also studied to determine the minimum sample size needed to make stable and accurate fatigue life estimation. The procedures developed could be extended to simulate bridge live loads using site-specific weigh-in-motion (WIM) data applied to structural models. The resulting simulated stresses are then extrapolated, reducing or eliminating the need for labor-intensive field instrumentation.

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A final report is available online at: http://www.state.nj.us/transportation/refdata/research/.
If you would like a copy of the full report, send an e-mail to: Research.Bureau@dot.state.nj.us.

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