ODOT RESEARCH

HIGHLIGHTER

UNDERSTANDING THE BEHAVIOR OF PRESTRESSED GIRDERS AFTER YEARS OF SERVICE

October 2017

OVERVIEW The state of Oklahoma has the goal of eliminating all structurally deficient bridges within the state by the year 2020. To address shear capacity concerns related to additional bridges not currently classified as deficient, this research effort was initiated by the Oklahoma Department of Transportation (ODOT) and it focused on a comprehensive study of a bridge with 47 in-service years. The shear capacity of the prestressed girders used for this bridge and others built during the same time period is a concern because the AASHTO Standard Specifications used in the design of these girders employed a less conservative design methodology, often referred to as the "quarter-point rule", than what is specified in the current AASHTO LRFD Specifications. Approximately one fourth of the bridges (not including culverts) in Oklahoma are precast prestressed concrete girder and slab bridges, and of these, approximately 10% (400) were designed and put into service using the so called "quarter-point rule", leaving them potentially vulnerable to concerns with shear capacity. Bridges designed earlier, in the 1960s and 1970s, are potentially more vulnerable since they used lower strength Grade 40 shear reinforcement. Therefore, it is important to have a clear understanding of the actual capacity of in-place bridges designed under the past specifications when rating using the current specifications. This understanding could potentially have a major influence on whether a particular bridge requires load posting or replacement.

RESULTS A comprehensive study including detailed analysis and shear testing to failure was conducted on two AASHTO Type II girders obtained from the I-244 bridge over the Arkansas River in Tulsa after approximately 47 years in service (shown right). Small-scale girders with a matching design were also tested both individually and as a composite bridge section to evaluate the effects of composite behavior in resisting shear. Additionally, inverse techniques and non-destructive testing methods were evaluated to determine their applicability for determining material properties and detecting damage in prestressed concrete bridges.

Methods were evaluated for determining properties of aged girders and monitoring structural health. A simple yet effective 1-D model was established by leveraging an existing initial value problem model for concrete creep and strand relaxation in post-tensioned concrete and Guyon's instantaneous elastic shortening analysis based on a boundary value problem to predict time-dependent behaviors of pretensioned concrete. By directly utilizing draw-in time history measured from a pretensioned concrete beam and other section and material properties, many facets of bond-transfer

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FINAL REPORT ~
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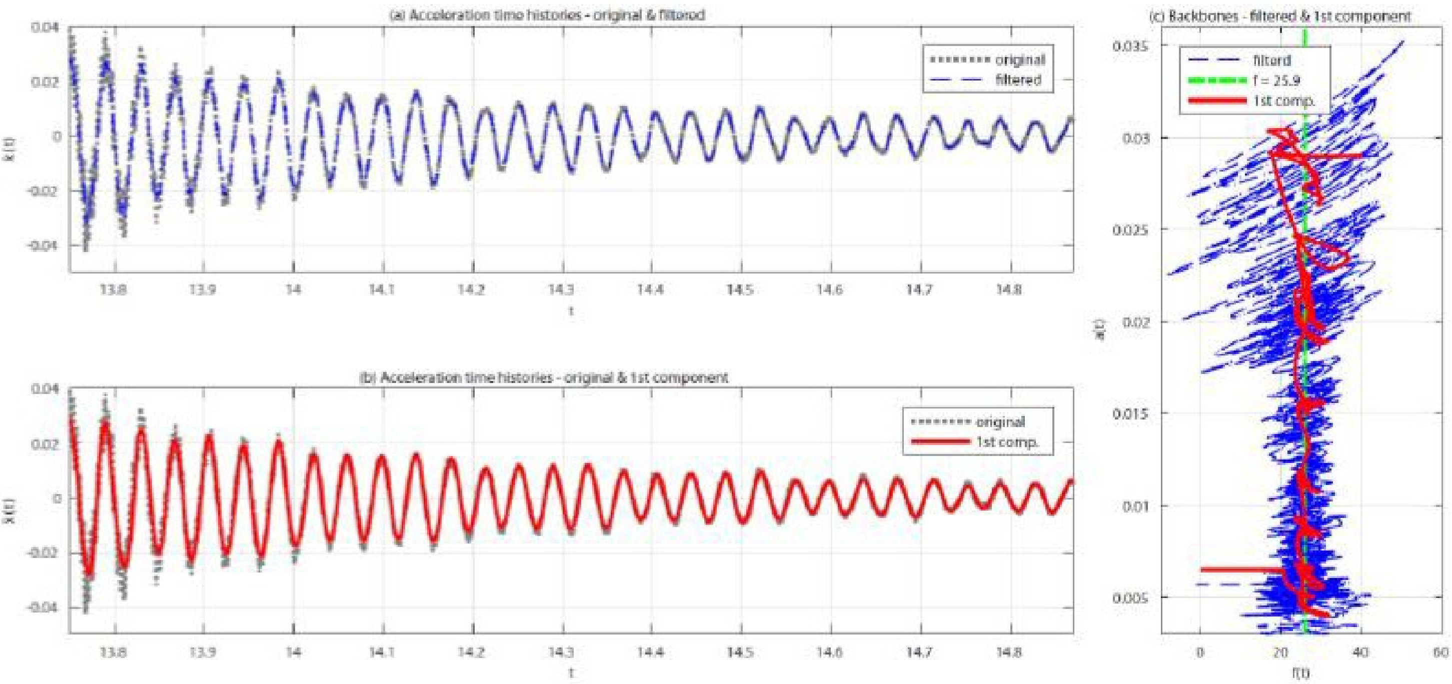
behavior can be predicted, revealing the insights into the time-dependent interaction of strand and concrete that would otherwise be obscure in current literature. Backbone analysis methods for free vibration data (graph shown below) were substantially advanced through work on the project and have great potential for nonlinear system identification and damage detection purposes in prestressed concrete bridges. System identification of flexural rigidity based on elastic flexural testing data and using cracking moment to evaluate effective prestress force were also shown to be effective methods.



The two girders examined in this project are representative of separate designs for 30-ft and 46-ft spans. Both girders were subjected to (1) non-destructive tests to assess the effects of damage over time and (2) destructive shear testing at each end. The project included a detailed study of the contribution of the bridge deck and entire bridge system to shear capacity through testing the real-world girders with a section of the original deck and diaphragms intact, through construction and testing of a scaled composite bridge section, and through detailed structural analysis. This research provided important information on the structural and composite behavior of aged prestressed girder bridges critical to shear and on methods for identifying properties of aged members, structural health monitoring, and damage detection.

As reported in the literature, shear capacity calculations can vary dramatically and the results described in the report indicate limited agreement between different methods. The girders that were tested showed good ductility and a large amount of cracking before failure, despite being in service for more than 45 years. Corrosion at the ends did cause some issues, especially at high loads. Spalling was often initiated by the corrosion cracking at the ends, potentially leading to bond loss. Bond loss behavior due to corrosion is important since similar deterioration is common in simply supported precast concrete girder bridges in Oklahoma. The 2012 AASHTO LRFD simplified method was not a conservative method to calculate shear capacity for the bridge girders tested, and this research indicated that the Modified Compression Field Theory methods of 2004 AASHTO LRFD provide the best balance of accuracy and conservativism. In all tested cases however, the applied loads exceeded expected loads determined from shear capacity calculations or flexural capacity by strain compatibility depending on the failure type. Experimental loads also exceeded demands calculated using the current design loads and load distribution factors. Testing of the scaled bridge girders and scaled composite bridge section indicated that the composite section added significant shear capacity compared to an individual girder.

POTENTIAL BENEFITS This work provided important information on the structural and composite behavior of aged prestressed girder bridges critical to shear and on methods for identifying properties of aged members, structural health monitoring, and damage detection and will allow potential influence on whether a particular bridge requires load posting or replacement.