Project Summary

Texas Department of Transportation

0-4096: Evaluation and Monitoring of Texas' Major and Unique Bridges

Background

Within the past twenty-five years, several important bridges have been constructed within the State of Texas that utilize relatively uncommon structural systems. Because of their unique designs, the Texas Department of Transportation (TxDOT) is concerned that the structural response of these bridges may differ from that of the vast majority of bridges in the state and that standard inspection techniques may not be sufficient to detect the onset of structural damage. TxDOT project 0-4096 was funded to identify and evaluate monitoring technologies that could provide information about the behavior of these unique bridges that is not available during routine inspections.

What the Researchers Did

The investigation was divided into two phases. In the first phase, the research team evaluated two monitoring technologies in the laboratory. The first system was designed to collect rainflow data from the response of a steel bridge under service loads. The data acquisition units are small, independent, and battery powered. Therefore, installation can be completed in the field in a few hours. The rainflow data can be used to calculate the fatigue life of the structure without measuring the response to vehicles with known axle loads. The second system used GPS data to identify changes in the long-term response of a bridge and was designed to capture abrupt movements that could be attributed to bridge scour or structural damage caused by impact.

After discussing the advantages and disadvantages of both systems with TxDOT personnel, it was decided to test the first system on two fracture critical bridges. The second phase of the research focused on installation of the miniature data acquisition units, collection of rainflow data, and evaluation of the measured rainflow data to determine the remaining fatigue life of the fracture critical bridges.

Both bridges were considered to be fracture critical because the superstructure was supported by only two longitudinal girders. However, the structural systems and traffic loads on the two bridges were very different. The Medina River Bridge is the older of the two and carries northbound I-35 across the Medina River south of San Antonio. The bridge was constructed in 1935, the longitudinal girders are riveted, built-up sections, and each girder is statically determinant. An average of 4,000 trucks travel northbound on this section of I-35 each day.

The 12th Street Exit Ramp from southbound I-35 is located in downtown Austin and carries primarily passenger vehicles. The longitudinal girders are welded boxes. The north abutment of the bridge is skewed by more than 60°, while the south abutment is square. As a result, the west girder is nearly twice as long as the east girder.

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Project Completed:
8-31-05

What They Found

The miniature data acquisition units were not as robust as anticipated based on the results of the preliminary laboratory tests. Several of the units malfunctioned during the rainflow collection periods, and failure of the battery led to unreliable data. As a result, more careful evaluation of the measured rainflow data was required than originally anticipated. Development of fairly detailed analytical models of the bridges is also required before deploying the data acquisition units in the field. The research team also selected too small a bin size for several of the strain gages, and the maximum live-load stress range was not captured.

The measured rainflow response included strain cycles from three sources: electrical noise, temperature changes, and live load. The user specifies a noise threshold when programming the data acquisition units to reduce the number of cycles that are counted due to electrical noise. Procedures were developed to identify large-amplitude strain cycles caused by thermal changes and remove them from the measured data. Although it was not possible to remove all cycles attributed to electrical noise and temperature changes from the measured rainflow response, the calculated fatigue life of the bridges was not sensitive to these low-amplitude cycles.

It was not possible to reproduce the measured rainflow response of the Medina River Bridge using an analytical model and the spectrum of trucks that passed the nearby weigh-in-motion station. The model was successful in reproducing the ranges of live-load strains measured by the data acquisition units, but the total number of loading cycles was underestimated and the number of large-amplitude cycles was overestimated. As a result, the fatigue life calculated based on the results of the analytical model of the bridge was considerably shorter than the fatigue life calculated from the measured rainflow data.

The measured rainflow response indicated that the effective stress ranges induced in the 12th Street Exit Ramp by vehicular traffic were much lower than those induced in the Medina River Bridge. The Medina River Bridge was found to be more vulnerable to fatigue damage than the 12th Street Exit Ramp. While this conclusion is expected given the ages of the bridges and the level of truck traffic, without the measured rainflow data, the differences in fatigue life would be impossible to quantify.

What This Means

The recent collapse of the I-35W bridge across the Mississippi River in Minneapolis highlighted the consequences of failure of structural members in a fracture critical bridge. While it is not recommended that the miniature data acquisition units be integrated into the regular inspection of all fracture critical bridges, the units should be considered for inspection of the older fracture critical bridges. By measuring the rainflow response of these bridges directly, the Texas Department of Transportation will be able to identify the most vulnerable bridges using quantitative data and establish priorities for inspection and replacement of bridges that are approaching the end of their service life. The information obtained using the recommended methodologies will assist the Department in ensuring the safety of bridges throughout Texas.

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