ON THE SPOT DAMAGE DETECTION METHODOLOGY FOR HIGHWAY BRIDGES DURING NATURAL CRISES

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TECH TRANSFER SUMMARY

A portable damage detection/prediction tool for infrastructure monitoring will assist bridge engineers in their decision making and provide significant ingredients for management and planning.

OBJECTIVES

The objective of this work was to develop a low-cost portable damage detection tool to assess and predict damage areas in highway bridges.

The proposed tool was based on standard vibration-based damage identification (VBDI) techniques but was extended to a new approach based on operational traffic load. The methodology was tested using numerical simulations, laboratory experiments, and field testing.

PROBLEM STATEMENT

Infrastructure health conditions and monitoring have been an active area of research and development due to the urgent demands for safer and longer-life structures. Many novel ideas have been developed and have shown success using simulations and lab testing, but have difficulties in detecting damage on large civil structures. This is attributed to the complexity of these structures and the presence of noise and environmental effects/interferences. The introduction of low-cost, portable, damage detection tool for highway bridges will add significant input for current and future maintenance, planning, and management.

RESEARCH DESCRIPTION

Vibration-based Damage Identification

In addition to numerical simulation, experimental methods that were used to evaluate the ability of VBDI techniques to identify damage include:

1. Laboratory experiments on an I-beam with two damage locations (Figure 1).

Figure 1 Laboratory I-beam with two damage locations simulated with masses

KEY FINDINGS

- In lab experiments with simple structural members (I-Beam) and boundary conditions, VBDI schemes can locate damage accurately.
- However, they have difficulties quantifying magnitudes of damage (Figure 2).

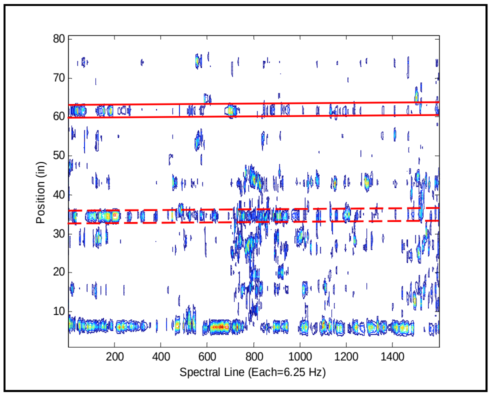

Figure 2 Damage-index properly locating both masses with each mass location represented by the two parallel red lines.

2. Field testing using a controlled excitation and roving acceleration responses from points on the beams (Figure 3).

Figure 3 Snooper truck used to access the superstructure of the field bridge during controlled vibration tests

KEY FINDINGS

- In field testing with controlled excitation on one beam, VBDI schemes can only show zones with variable stiffness on that beam (Figure 4).
- VBDI algorithms may indentify extensive damage areas but are too global to show localized low damage areas due to transducer sensitivity, boundary conditions, etc .
- Tests ran with other excitations (controlled excitation on multiple beams and operational vibration) yielded similar results.

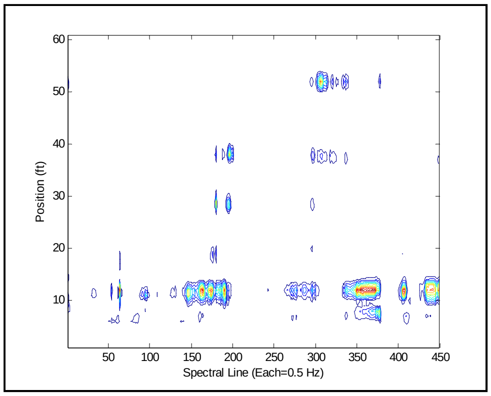

Figure 4 Damage index for the impacted exterior beam (#4) clearly showing the impact location at position 12 and regions of high stiffness near the diaphragm members at positions 20 and 40

Operational-Response & Waveform Analysis

A novel methodology called **Operational Response & Waveform Analysis (ORWA)** is introduced in this work to correlate structural motion due to traffic loading with identified damage, using the following steps:

1. Field testing with operational (traffic) load and roving acceleration responses points on the beams, diaphragm and abutments (Figure 5).

Figure 5 Scaffolding used to access the superstructure of the field bridge using operational/traffic loads as excitation

2. Animation of the all response points to identify operating deflection shapes (Figure 6).

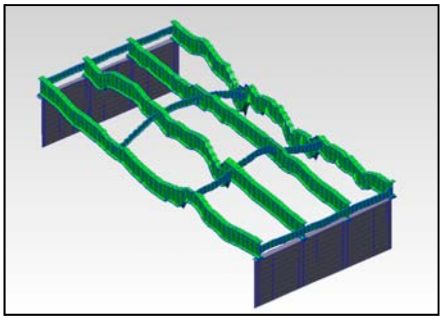

Figure 6 Operating deflection shape of the diaphragm members and beams, using ORWA

3. Analysis of all frequency waveforms from traversing vehicles to determine frequencies with most contribution to structural motion

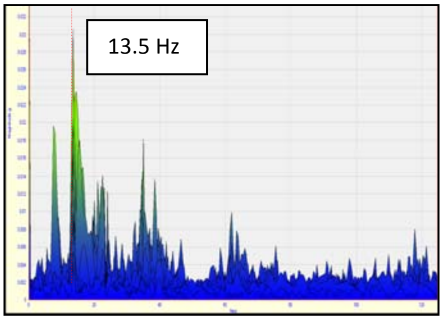

Figure 7 Frequency waveforms from 880 different vehicles showing large contribution at 13.5 Hz

KEY FINDINGS

- Largest frequency contribution from vehicular load was at 13.5 Hz, causing first mode bending (Figure 7)
- Significant torsional and compressive-tension action were identified at the ends of the exterior beams when animated at 13.5 Hz (Figure 8).
- This end beam motion can be can be correlated with actual damage in the abutment (Figures 9 and 10).

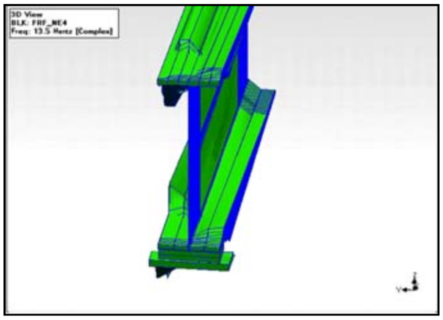

Figure 8 Operational response animation at 13.5 Hz showing compression-tension and torsional action in exterior beam end caused by first mode bending of beams and diaphragm members

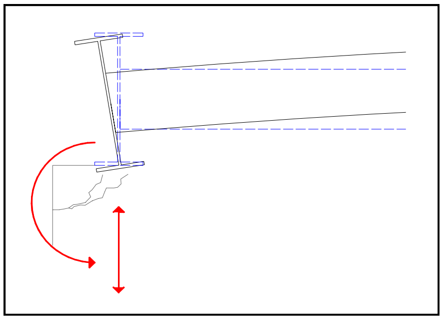

Figure 9 Schematic showing compression-tension action in abutment at 13.5 Hz

Figure 10 Photo showing actual cracking correlated with motion of exterior beams at 13.5 Hz

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