Introduction to Acoustic Emission (AE) Monitoring

Principle and Terminology

- AE = stress wave caused by internal material fracture
- Passive method (as opposed to NDT, e.g. ultrasonic testing)
- Piezo-electric sensors on surface record surface motion
- Analogous to seismic activity on nano-scale
- Multiple sensors to estimate source locations and mechanisms

Reference: Grosse and Ohtsu, 2008

Figure 3. Principle of Acoustic Emission (AE) monitoring

Monitoring of Reinforced Concrete Highway Bridges under Service Conditions Using Acoustic Emission Techniques

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Background and Motivation

Challenges for bridges:
- Nationwide: 12% of bridges structurally deficient (ASCE, 2009)
- $71 billion needed to fix problem (Transportation for America, 2011)
- Many have reached 50-year service life (average age: 43 years)
- Increasing traffic volume and loads
- Deficiencies in codes used to design bridges
- Increasingly aggressive environment (acid rain, air pollution, salts)

Figure 1. Reinforced concrete deck girder (RCDG) bridges in Oregon

Needs in bridge management and maintenance:
- Means to better estimate remaining life of bridges
- Methods for real-time monitoring and overloading alarm system

Research Approach
- Stress wave based monitoring method
- Use of method that can detect localized and distributed damage
- Two full-scale highway bridge girders with realistic details
- Laboratory test representative of in-service conditions
- Create baseline
- Verification on in-service bridges (ongoing)

Full-Scale Laboratory Test

Figure 4. Generalized loading protocol (A = sensor array as in Fig. 2)

Application 1: Continuous Monitoring for Detection of Overloads
- Use of mean of lowest b-values estimated from all AE sensors

Example application 1

Example application 2

Full-scale test girder in the laboratory with AE sensor array

Proposed b-Value Analysis using AE Data

History and Principle
- Adapted from seismology (Gutenberg and Richter, 1949):
  \[ \log_{10}(N) = a - b \frac{\sqrt{dBN}}{X} \]
  \( N \) = Cumulative number of AE amplitudes \( \geq A \)
  \( a \) = Empirical constant to be estimated
  \( b \) = 'b-Value' = Slope to be estimated
  \( X = 20 \), constant to produce similar b-values found in seismology
- Hypothesis: b-value drop marks onset of macro-cracking
- b-Value estimated using 50 AE amplitudes back in time
- Least-squares estimation over mean ± 1 standard deviation
- Reference: Schumacher et al., 2011

Figure 5. Example plots from data analysis

Conclusions
- Can be used for real-time monitoring of bridges
- Can help estimate current operating load conditions

Acknowledgments

This work was carried out in the Structural Laboratory at OSU. The sponsorship of ODOT under SPR 633 is greatly appreciated.