The Role of Technology in Managing Aging Highway Bridges

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February 21, 2003
The Role of Technology

• Objective
  • To make the case that quantitative data is essential for adequate management of the multi-trillion dollars worth of assets we refer to as the highway infrastructure.
The Role of Technology

Overview

• Present background on infrastructure management in the United States
• Present a few examples of how technology has been used in infrastructure management
• Discuss future directions and research needs for infrastructure management and the role of technology
Some National Highway Statistics

- 3.95 million miles of public roads
- 8.3 million lane miles
- 2.5 trillion vehicles miles in 1997
- 593,000 highway bridges
- 3.2 billion square feet of bridge deck
- 3 billion bridge crossing per day
$101.3 Billion expended on highways in 1997 by all levels of government

FHWA provided $20.1 Billion for Capital Expenditures
The Role of Technology

- Bridge management as example
  - History of national bridge program
  - Current bridge management practice
  - Limitations of BMS
  - Summary of recent R&D to address limitations
  - The technology in the management of bridges
Silver Bridge Collapse
December, 1967 46 Fatalities
FHWA Bridge Program

- NBI Program began in 1971
- Establishment of National Bridge Inspection Program and National Bridge Inventory
- Focused on Elimination of Deficient Bridges
National Bridge Inspection Program

- National Bridge Inspection Program
  - Bi-annual Inspections
  - 593,000 bridges
  - 116 fields of data collected
  - Inspectors provide condition and appraisal ratings
- Eligibility for HBRRP determined by deficiency
NBI Coding Guide
NBI Ratings
(Numeric Code 0 to 9)

• Condition Ratings
  • Superstructure
  • Substructure
  • Deck
  • Culverts

• Appraisal Ratings
  • Waterway Adequacy (Frequency of overtopping)
  • Structural Evaluation (Load rating)
  • Approach Alignment
  • Deck Geometry (Roadway Width)
  • Underclearances (Vertical and Lateral)
NBI Condition Ratings

• 9 - EXCELLENT CONDITION
• 8 - VERY GOOD CONDITION
• 7 - GOOD CONDITION
• 6 - SATISFACTORY CONDITION
• 5 - FAIR CONDITION
• 4 - POOR CONDITION
• 3 - SERIOUS CONDITION
• 2 - CRITICAL CONDITION
• 1 - "IMMINENT" FAILURE CONDITION
• 0 - FAILED CONDITION.
NBI Appraisal Ratings

- 9 - Superior to present desirable criteria
- 8 - Equal to present desirable criteria
- 7 - Better than present minimum criteria
- 6 - Equal to present minimum criteria
- 5 - Somewhat better than minimum adequacy to tolerate being left in place as is
- 4 - Meets minimum tolerable limits to be left in place as is
- 3 - Basically intolerable requiring high priority of corrective action
- 2 - Basically intolerable requiring high priority of replacement
- 1 - not used
- 0 - Bridge closed
NBI Bridge Deficiencies

Source: 1999 NBI
NBI Deficiencies

Culvert Condition
Approach Alignment
Underclearance
Deck Geometry
Waterway Adequacy
Structural Evaluation
Substructure Condition
Superstructure Condition
Deck Condition

Source: 1999 NBI
Reliability of Condition Rating?
NBI Data
Average HS Inventory Rating

<= HS 10
<= HS 15
<= HS 20
<= HS 25
> HS 25
Reliability of Load Ratings?

1999 SD Bridges (SA Only)
Method used to Determine IR

- NR (1028)
- LT (4)
- LRFD (11)
- AS (10224)
- LF (1458)
- ? (6417)
Shortcomings of NBIP

- NBIP adequate for administration of national HBRRP program
- Inadequate for bridge performance measurement
- Most states augment NBI data
- Condition Ratings based on subjective visual inspection
- Not adequate for owner level bridge management
Element Level Inspection

- PONTIS
  - Element level inspections
  - More discretized condition state data
  - More quantitative condition state data
  - Provides network (population) level decision support
- Significant advance
Typical Condition State Definition
Open Steel Stringer (Painted)

- Condition State 1
  - Sound paint, no corrosion, no section loss

- Condition State 2
  - Early distress of paint, little or no corrosion, no section loss

- Condition State 3
  - Paint not effective, surface rust, no section loss

- Condition State 4
  - Paint failed, surface pitting, section loss incidental

- Condition State 5
  - Paint failed, advanced corrosion, section loss sufficient to warrant analysis

- Quantity in each state recorded
Limitations of Element Inspections

- Condition states still based solely upon visual inspection
- Invisible deterioration, damage or distress not detected or measured
- Operational performance not measured
- Vulnerability and reliability not adequately considered
Detection and measurement needs

- Damage
  - Impact
  - Overload
  - Scour
  - Seismic
  - Fracture
  - Settlement
  - Loss of section
  - Inoperative bearings

- Movement
  - Lack of movement
  - Cracking

- Deterioration
  - Corrosion
  - Fatigue
  - Water absorption
  - Loss of prestress
  - Unintended structural behavior
Detection and measurement needs

• Operation
  • ADT
  • WIM
  • Stress
  • Strain
  • Deflection
  • Displacement

• Service
  • Congestion
  • Accidents
  • Side friction
  • Performance measures
Additional Data Needs

- Data to support life cycle cost analysis
- Data to support performance based specifications
- Data to support performance measures
R&D to meet these needs

- Global health monitoring
- Rapid measurement of load capacity
- Vulnerability
  - Fatigue and fracture
  - Flood and seismic
  - Overloads
  - Impacts
- Critical component monitoring
- Integration with BMS
Commodore John Barry Bridge Real Time Health Monitoring System

- Truck Weight & Weather Monitoring Station
- DAS
- Fiber Optic Local Area Network (LAN)
- Remote Wireless Component of LAN
- Internet
- LAN Server

Bridge Sensing Systems
- WIM
- Video Cameras
- Weather Station
- Typical DAS

Sensor Installation

Real Time Access via Web Browser

Integrated Legacy & Data Archive Databases
Laser Radar Measurement System

- Rapid non-contact measurement of structural deflections
- Range 2 to 30 meters
- Resolution ~0.1 mm
- Rapid measurement capabilities (100’s of points per minute)
- Totally portable
Recent Brittle Fracture
Milwaukee, WI December 2000
Wireless Strain Measurement

- Characterization of fatigue
- Measures random cyclic stress at several locations
- Battery powered

- Digital Spread Spectrum
- Adaptive wireless network
- Telemetry Range (~1.5 Km)
- Low Noise
- High Dynamic Range
Thermoelastic Measurement of Stress Concentrations

- Determine the stress concentrations at welded details in fatigue categories
- Correlate the apparent concentration with the fatigue category
- Might define fatigue categories more accurately – or differently - for un-catalogued details
Specimen w/ hole

IR Camera

Controller

Laptop computer
Passive Fatigue Load Measurement

Two aluminum coupons with manufactured fatigue cracks

Fully characterized fatigue crack growth behavior

Integrated continuous resistive crack length gage

Placed on in-service bridged for extended time
New AE System for Bridges

Battery powered
8 AE channels
11 Parametric channels
Totally Digital
Remote access and data download
Smart Bearings

Neoprene Pads

Prototype

Composite load cell using multi axis fiber optic strain sensors

*Images obtained from Blue Road Research
Wingwall Monitor

Eddy Current Displacement Sensor
Mianus River Bridge 1983
Pin & Hanger Failure
Monitoring Critical Bridge Components
High strength steel wires are susceptible to stress corrosion cracking.
Acoustic monitoring of wire breaks
Embeddable Corrosion Sensor

- 4-pin conductivity probe
- Steel working electrode (Corrosion Sensor)
- Force ERE20 reference electrode
- Ag/AgCl electrode (Cl-sensor)
- Counter electrode
- Casing for electronics
- Wireless RF power & telemetry
Smart Pebble Construction

- Coil with ferrite core
- Sensing electrode
- Reference electrode
- Polyurethane rubber enclosure
- Polyurethane cup
- Circuit board
- Epoxy sealant
- Cementitious plug

1.5 in.
Smart Pebble™
Infrared Defect Detection

- Inspection of concrete and concrete/composite structures
- Passive methods use heat contained within the intact concrete vs. heat in thin layers (delaminations)
System Description

Main System

Infrared Cameras
Infrared Data

Rt. 248 South of Rexville, NY

Northbound Lane

Approach Slab
Deck
Aluminum Tape
Infrared Data

NDEVC Test Bridge, Van Buren St

Long Wave

Short Wave

Video Image
Chain drag data:
Lake Anna Bridge deck
Green hatch=delaminated

PERES II data:
Surface reflection
Top layer of reinforcing steel
Bottom layer of reinforcing steel
Lowe’s Motor Speedway
North Carolina
Segmental Construction

Anchorage

Ducts
RADIOGRAPHY OF BRIDGES

X-ray source

Film loading
RESULTS

X-ray radiograph of duct
Detection of Broken Strands
Void

No Void

REF: Central Artery/Tunnel Project
Thousands of ‘intolerable’ U.S. bridges pose risk for drivers

No warnings on many defective spans

The Washington Times
TUESDAY, FEBRUARY 20, 2001
Technology will provide the basic information necessary to effectively manage civil infrastructure throughout its life cycle.
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Thank You!