History of Structure Inspection Program Development in the U.S. and the World

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Agenda

♦ Focus on the United States

♦ Focus on International Systems
Over **100,000** Railway Bridges

Over **570,000** Highway Bridges
“Bridge Construction Boom in the United States”

- Railways (1860’s)
- Highways (1950’s)
- Little emphasis placed on safety
- Little emphasis placed on maintenance

Maintenance and safety were the responsibility of the Owners
Ashtabula Railway Bridge

- Built in 1865
- Collapsed in 1876
- **Worst** Bridge Failure in U.S.
- 100 Died, 64 Injured
- Could Have Been Prevented by an **Inspection Program**
An Infant Inspection Program Is Born

- Interstate Commerce Commission (ICC) Was Developed to Regulate Safety of Railway Companies.
- U.S. DOT – Federal Railway Administration. (Later Developed Out of the ICC)

“Focus Was On Safety To The Traveling Public”
American Railway Engineering and Maintenance-of-Way Association (AREMA)

- Published Manuals from 1905 - Present

American Association of State Highway and Transportation Officials (AASHTO)

- Published Manuals from 1921 - Present
**Railway Bridge Inspections**

- Over 95% Bridges on Annual Basis (Min.) per AREMA Study
- AREMA also Published Book on “Structural Fatigue and Steel Bridges”

**Highway Bridge Inspections**

- Random Inspections Performed
- Very Little Consistency
Until…

December 15, 1967

Silver Bridge Collapsed

- Ohio River at Point Pleasant, West Virginia
- 46 people killed
This Catastrophic Failure Focused National Attention on Bridge Safety
December 15, 1967

1967 1967
Congress Asked

- How many bridges are there in the US?
- Where are they located?
- What is their condition?
- Is there another Silver Bridge waiting to happen?
Railroad Bridge Safety Committee
Formed on January 8, 1968

- 16 Days After Silver Bridge Collapse

- However, Final Publication of “Recommended Rules for Railroad Bridge Inspections” Not Finished until March 6, 1972
Merrillan Railway Bridge Collapse

Collapse of GBW Bridge E. Fork Halls Creek 8-68

AUG 68
Congress Took Action

Federal Aid Highway Act - April 27, 1971

• National Bridge Inspection Standards (NBIS)
  - All States must perform routine inspections of bridges (maximum interval 24 months)
  - Inspector qualifications defined
  - Inspector training program developed
  - Report formats developed
  - Inspection and rating procedures defined

• National Bridge Inventory (NBI) Development

“Focus Was on Safety to the Traveling Public”
Federal Funding for Replacement of Bridges in the Federal Aid Highway System Was Established
Manuals Were Developed for the Transportation Industry

- Bridge Inspector’s Training Manual 70 (BITM) (FHWA; 1970)
- Manual for Maintenance Inspection of Bridges (AASHTO; 1970)
- Recording and Coding Guide for the Structure Inventory and Appraisal for the Nation’s Bridges (FHWA; 1972)
- Bridge Inspector’s Manual for Movable Bridges (FHWA; 1977, Supplement to Manual 70)
As States Implemented the NBIS Program, Two Critical Issues Developed:

- Bridge Replacement Needs Exceed Available Funding
- No Incentive for States to Inspect Bridges Off the Federal Aid System
Congress Again Took Action

Surface Transportation Assistance Act

- Provided more funding to the States for all bridges for rehabilitation and replacement.
- Required all public bridges with spans equal to or greater than 20.0 feet in length to be inspected.

“Focus Was Still On Safety To The Traveling Public”
Manuals Were Updated

- *Manual for Maintenance Inspection of Bridges*  
  (AASHTO; Updated 1978)

- *Recording and Coding Guide for the Structure Inventory and Appraisal for the Nations Bridges*  
  (FHWA; Updated 1979)

State DOT’s now have “definite” guidelines for compliance with the NBIS
Mianus River Bridge Collapse

• Pin and hanger failure
• Collapse of main span carrying I-95 in Connecticut
• Several fatalities
• Disruption of traffic for months
Mianus River Bridge Collapse

FHWA Response

- National focus on “Fracture Critical Bridges”
- Expanded inspection data collection requirements
- Additional inspector training
- New fatigue research
- Supplement to Manual 70

*Inspection of Fracture Critical Bridge Members* (FHWA; Added September 1986)
Collapse of the U.S. Route 43 Bridge

- Occurred in April of 1985
- Over Chickasawbogue Creek – Mobile, Alabama
- Lead to FHWA issuance of memo stressing
  - The importance of Underwater Inspections
  - Ordering steps to ensure each state has a well-founded underwater inspection program
Culvert Failures

- Loss of Life Occurred
New York’s Schoharie Creek Bridge Collapse

April 1987
Schoharie Creek Bridge Collapse

- Center Pier Scour Failure
- Collapse of Main Span Carrying I-90 in New York
- 10 Fatalities and Significant Disruption of Traffic
- “Inspection 1 Week Earlier Did Not Detect Scour Due to Silt Infilling.”
Response to Schoharie Creek Bridge Collapse

- New focus on “Bridges Over Waterways” (approximately 86% of bridges on the NBI)
- Technical advisory published - *Scour at Bridges* - (FHWA; 1988)
- “Scour Critical” bridge inspections required
- Analytical procedures to predict bridge scour were published - *Hydraulic Engineering Circular No. 18* - (FHWA)
Scour

The Result of Erosive Action of Running Water, Excavating and Carrying Away Material From the Bed and Banks of Streams and Rivers.
Scour (Cont’d.)

Channel Cross-Section

Degradation
Scour Hole
Scour Hole
Undermining
Scour (Cont’d.)
Scour (Cont’d.)
Conducting the Field Investigation

• Purpose of Scour Investigation
  – Establish Existing Conditions
  – Obtain Data to Use in Engineering Analysis
Conducting the Field Investigation (Cont’d.)

• When to Conduct Investigation
  – During Major Flood is Desirable but Difficult
  – After Major Flood
  – As Part of Scheduled Inspection
Lead Lines and Sounding Poles
Disadvantages of Simpler, Traditional Methods

- Extensive Note Taking
- Current Problems
- Depth Limitations
- May be Misleading
Depth Sounders

- Sonar (50KHZ & 200KHZ)
- Black & White Chart Recorder
- Various Transducer Angles
- Simple to Elaborate Equipment ($500 - $15,000 +)
Accuracy of Soundings

- Depth
- Location
Advantages

- Accurate
- Fast & Simple
- Permanent Record
- Good Definition
Soundings

- Plot Plan
- Plot Cross Sections
  + Channel Bottom
  + Foundations
- Plot Historical Record
Post Processing

- Soundings
- Contour Lines
- Cross Sections
- Quantities
Scour

Scour Can Only be Measured With Certainty During High Flood Events;
Infilling may Occur During Lower Flows
Geophysical Methods

- Sonar Fixed-Tuned Transducer
- Swept-Frequency Continuous Seismic Reflection Profiling (CSP)
- Ground Penetrating Radar (GPR)
- CHIRP Color Sonar
- Side-Scan Sonar
3-D Bathymetric Contour Plot

Unprocessed CSP Data
Scour

“Detecting Defects Is Only the First Step”
S.R. 675 Bridge Over Pocomoke River

- Collapsed on August 17, 1988
- “Cause Determined to be Inadequate Response to Deficiencies Noted in the Underwater Inspection Report”
October 1988 Modifications to NBIS

- Based on requirements of “1987 Surface Transportation and Uniform Relocation Assistance Act”
- FHWA mandated development of “Master List” of all bridges that require “Underwater Inspections”
- Underwater inspection frequency maximum interval 60 months
- Mandated development of “Master List” of all bridges that require “Fracture Critical Inspections” (initially 60 months, now 24 months)
- NICET Level III and Level IV certifications allowed for bridge inspection team leaders
Hatchie River Bridge Collapse

- April 1989 – Covington, Tennessee
- 8 fatalities
- Disruption of traffic

Response

- Illustrated critical importance for Underwater Bridge Inspections
- Focused attention on taking appropriate corrective action when deficiencies are discovered

“Forensic Analysis Performed”
Miamitown Bridge Collapse

- May 26, 1989
- 2 Fatalities

“Failure Caused by Significant Lateral Debris Loading During Flood”
Bridge Inspection Program Continues to Evolve Through the 1990’s and Into the Next Millennium

- Bridge Inspectors Training Manual 90 (FHWA; Updated in 1990)
  - State of the art inspection techniques
  - Expanded coverage on culverts, fracture critical, cable-stayed bridges, prestressed segmental bridges, and underwater inspections


- Recording and Coding Guide for the Structure Inventory and Appraisal for the Nation’s Bridges (FHWA; Updated 1995)
NHI Courses

- NDT Methods for Steel Bridges (FHWA-HI-88-006, June 1986)
- Safety Inspection of In-Service Bridges (No. 13055, 1992/1994, “80-Hour Course”)
- Bridge Management Training (No. 13051)
- Fracture Critical Inspection Techniques for Steel Bridges (No. 130078)
FHWA Demonstration Projects

- Bridge Maintenance Training (1980’s)
- 80 – Underwater Inspection of Bridges (FHWA-DP-80-1)
- 98 – Underwater Evaluation and Repair of Bridge Components
- 84-2 – Corrosion Detection in Reinforced Concrete Structures
Underwater Inspection Issues

- Structural Deterioration (Cracks, Spalls, Splits, Missing Blocks, Corrosion, Etc.)
- Surrounding Environment (Scour, Undermining, Debris Accumulation, Etc.)
Means of Access

- Dry
- Scuba
- SSA
Underwater Structural Deterioration

- **Level I**
  Visual; Minimal Cleaning

- **Level II**
  Limited Cleaning & Measurement

- **Level III**
  High Detailed; NDT
Personnel

- Engineer-Divers – Team Leaders
- Construction Divers Reporting to Engineers – Team Leaders

Equipment

- Advancement in Technology
- Remote Operated Vehicles
- Geophysical/Graphical Display Operators
**Expectations of Team Leaders**

- Accurate assessments
- Understanding of structural significance and loading ramifications
- Formulate and prioritize repairs or replacement options
- Develop accurate reports, plans and specifications

The engineer’s knowledge of what to look for and the ability to recognize the structural significance of anomalous conditions greatly enhance the technical value of the inspection and often saves time and money.
Engineer-Diver

- Diving Skills
- Engineering Skills
  - Inspection
  - Testing
  - Evaluation
- Professional Responsibility
“Alligator Gar”

- 215 pounds, 7 ft. long.
- Caught May 3, 2003 in the Mississippi River.
- Second largest gar ever caught, Mississippi River record.
Engineering Requirements for Diving

- American Society of Civil Engineers – Underwater Investigations Standard Practice Manual
- U.S. Navy’s Worldwide Underwater Assessment Program
- U.S. Department of Transportation National Bridge Inspection Standards
Engineering Requirements for Diving (Cont’d.)

• Type and Frequency of Inspection

• Personnel Qualifications
  – Registered Engineer-Diver Conducts at least 25% of Diving
  – Inspectors
    • Graduate Engineer
    • Technician with 80-hour Structures Training
Safety, Accuracy, and Project Success
Remote Operated Vehicles (ROV’s)
Federal Railroad Administration

- Principles and Practices of Railroad Bridge Inspections (1992)
- Railway Specific and Very Comprehensive
Amtrak Railway Bridge Collapse

- September 22, 1993
- Mobile, AL
- 47 Deaths
1993 Great Midwest Flooding

- Several Railway Bridges Washed-Away
- BNSF Railway Bridge on Mississippi Exhibited Half of Pile Length

“Scour Up To 50 Feet Deep”