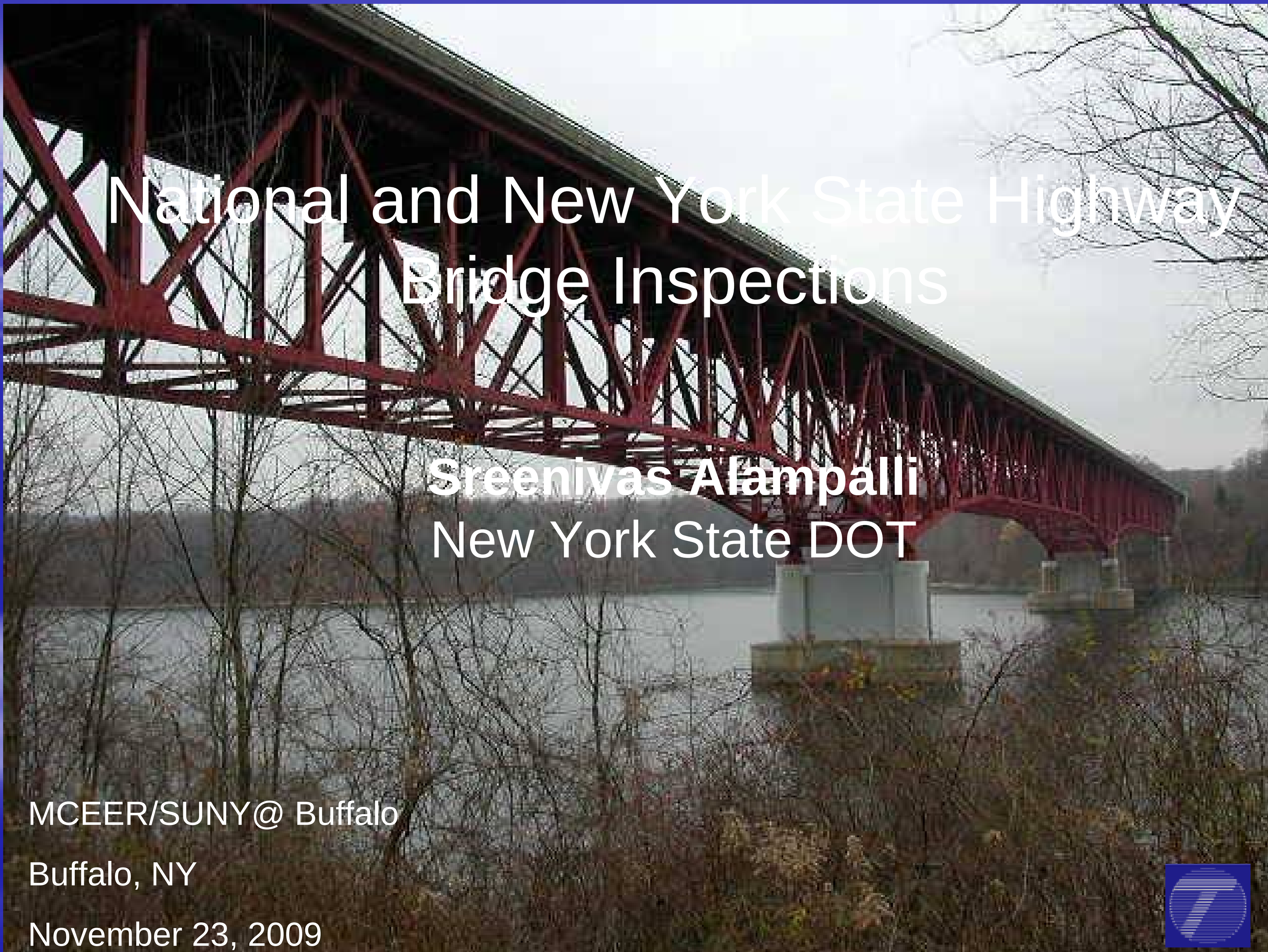

National and New York State Highway Bridge Inspections

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Buffalo, NY

November 23, 2009

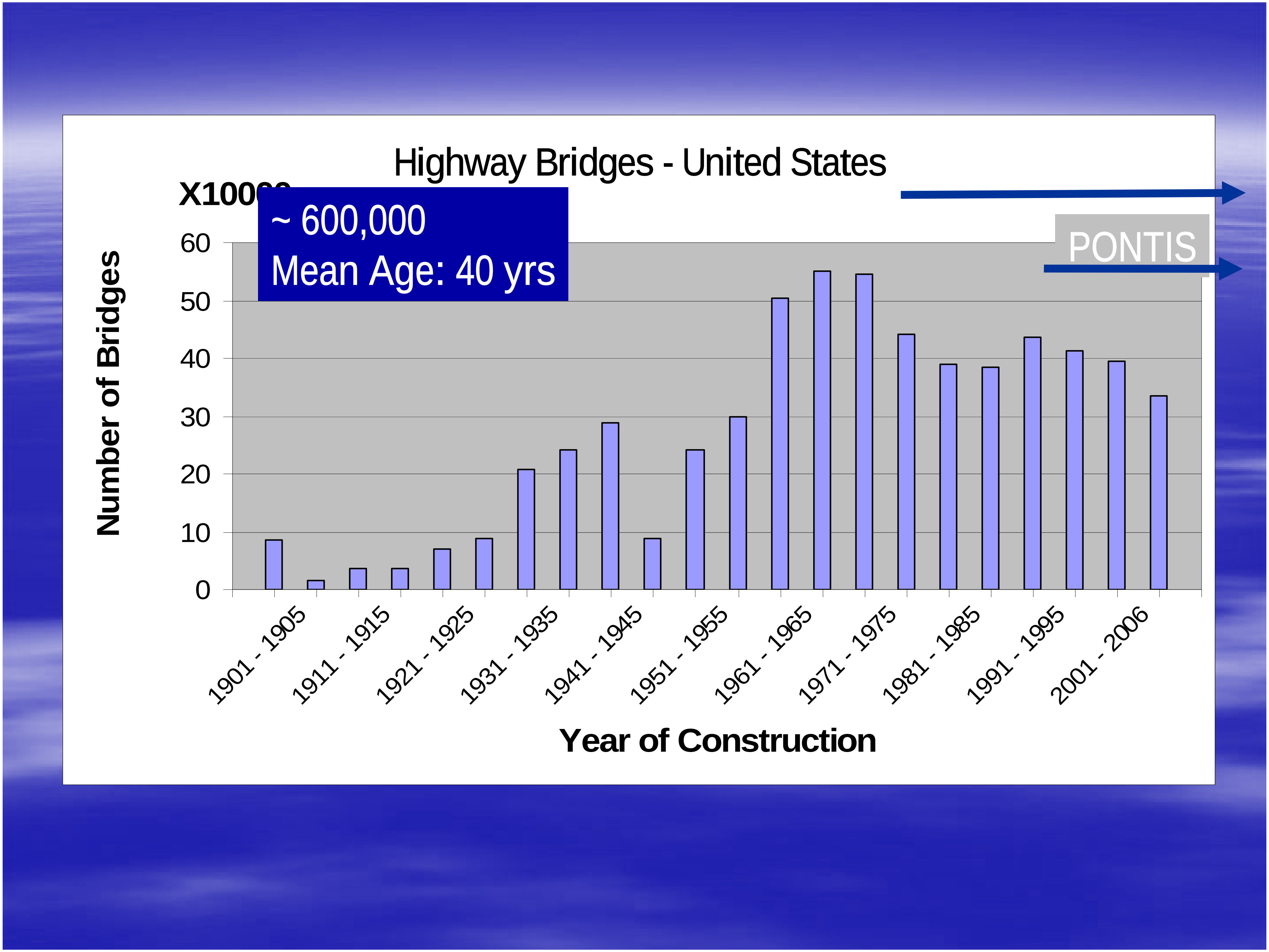
Outline

- National Bridge Inspections
  - History
  - Current status
- New York State Bridge Inspection Program
  - History
  - Highlights and differences with National Program
- Looking into the Future

Current National Bridge Inspection Program
What is a bridge?

- It must be over a depression or an obstruction, such as water or a highway

- It must carry traffic and have an opening (span) of more than ***<u>20 feet</u>***

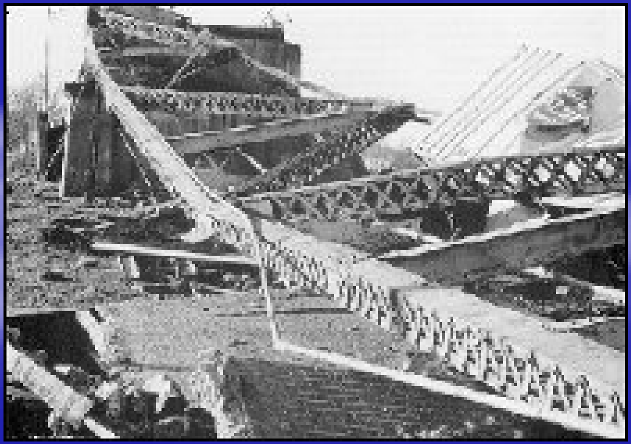


Highway Bridges - United States
X1000
~ 600,000
Mean Age: 40 yrs
PONTIS
Number of Bridges
60
50
40
30
20
10
0
1901 - 1905
1911 - 1915
1921 - 1925
1931 - 1935
1941 - 1945
1951 - 1955
1961 - 1965
1971 - 1975
1981 - 1985
1991 - 1995
2001 - 2006
Year of Construction

NBIS History

- 1916 Act: Federal Aid to Highways
  – Inspections of highway structures was part of maintenance work by states and others
  – More detailed program under Public Roads Administration during 1930-40s
- 1967: Ohio River Bridge Collapse
  – President Johnson formed a task force charged to determine procedures available to preclude future disasters and implement changes, if needed

Silver Bridge Collapse



NBIS History

- March 1968 FHWA Memo
  - Initiated review and inventory of all existing structures, to be completed by January 1970
  - All structures reviewed once in five years
  - Two-year inspection interval for important structures
  - Need qualified personnel
  - 1964 AASHTO "Information Guide for Maintenance Personnel"
  - Resulted in complete inventory
  - Identified and fixed serious deficiencies

NBIS History

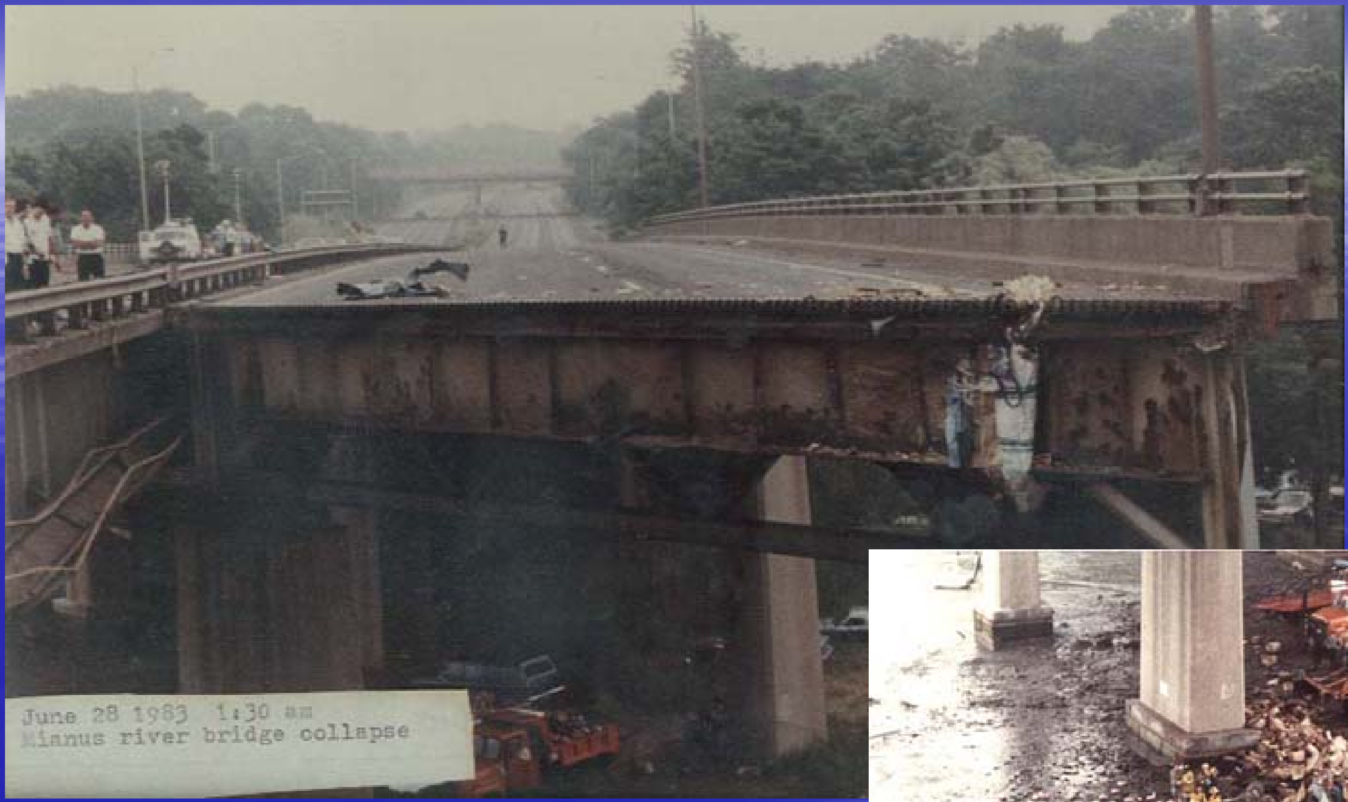
- 1968 Act: Required establishment of NBIS
  - Limited to Federal-aid Highway System
  - Inspection Frequencies
  - Inspector Qualifications
- 1970: Manual Development
  - AASHTO Manual for Maintenance Inspection of Bridges
  - FHWA Bridge Inspectors Training Manual
- 1970 Act: Establishment of NBIS in 1971

NBIS History

- 1971 NBIS: Uniform guidelines and criteria
  - A licensed engineer in each organization
  - 2-year inspection cycle (first cycle by July ’73)
  - Detailed reporting format, appraisal ratings (present vs. current desirable), and sufficiency ratings
  - Inspection types: inventory, routine, damage, in-depth, and interim
  - Rating and measurements

NBIS History

- 1978 Surface Transportation Act:
  - Establishment of HBRR Program
  - Improve significantly important and unsafe bridges
  - R&R based on structural deficiencies, physical deterioration, and functional obsolescence
  - Extension of inspection program to non-federal aid system
  - Classification of bridges for prioritization



Mianus River Bridge Span Collapse, 1983 due to Hanger-Pin Failure

NBIS History

- 1988: NBIS revised
  - States can vary frequency of routine bridge inspections when certain conditions are met
  - Establishment of fracture and scour critical bridges requiring 2-yr max inspection interval
  - Special requirements for fracture critical member inspections and appropriate NBI designations
  - Underwater bridge inspection requirements

Schoharie Bridge Collapse

NBIS History

- 1988: NBIS revised
  - Alternative procedures for certifying bridge inspection Team Leaders and required competence levels
  - Change in reporting requirements: 180-days for local bridges
- 1992 US Court of Appeals, D.C. Ruling
  - 1993 NBIS Revision: Maximum inspection interval of 4 years

NBIS History

- 2004 NBIS Revisions: Effective Jan. 2005
  - State DOT is responsible for making sure inspections are done within the state
  - More ways to qualify to be a Team Leader
  - Two year interval defined as 24 months
  - Max inspection interval cannot exceed 48 months
  - Max interval for underwater inspection is 72 months
  - Follow-up on critical findings
  - Complex bridges
  - QC/QA
  - Training for Divers
  - Refresher training

Current National Bridge Inspection Program

- All publicly owned highway bridges are covered
- Most bridges inspected at least once in two-years
- Diving inspections at least once in five years
- Team Leaders' qualifications are defined
- Refresher training required

Current National Bridge Inspection Program

- Evaluate the entire structure to as-built condition
- Rate few elements, indicative of entire structure, not for localized deterioration
  - Superstructure
  - Deck
  - Substructure
  - Channel and channel protection
  - Culverts
  - Capacity

Need a global understanding of structural behavior and failure mechanisms

Current National Bridge Inspection Program

- Federal ratings (0 to 9 Scale)
  - 9 Excellent; 7 Good; 5 Fair; 3: Serious; 0 Failed
- Structurally Deficient
  - Typically requires significant maintenance and repair to remain in service
  - Need eventual rehabilitation or replacement to address deficiencies
  - In order to remain in service, are often posted with weight limits
- Functionally obsolete
  - Refers to a bridge's inability to meet current standards for managing the volume of traffic it carries, not its structural integrity
  - For example, a bridge may be functionally obsolete if it has narrow lanes, no shoulders, or low clearances

Current National Bridge Inspection Program

- Sufficiency Rating
  - Indicator of bridge sufficiency to remain in service → Varies from 0 to 100
  - 100 → Entirely sufficient bridge
  - 0 → Entirely insufficient or deficient bridge
- Depends on
  - Structural adequacy and safety (55%)
  - Serviceability and obsolescence (30%)
  - Essentiality for public use (15%)
  - Special Reductions (-13%)
- Used for determining HBP funding eligibility

Current National Bridge Inspection Program

- Several states go beyond FHWA requirements and conduct element level inspections
  - Varies from state to state significantly
- Condition Ratings
  - Generated directly through inspection
  - State data converted through translator

NYS Bridge Population

- New York State is home to more than 17,000 highway bridges
  - About 44 percent of them owned by the State Department of Transportation (NYSDOT)
  - Roughly 50 percent owned by municipalities
  - The rest are owned by state and local authorities (such as the State Thruway Authority), commissions (such as the Capital District State Park Commission), and railroads (such as CSX Corporation, Inc.)
- Total NYS highway bridge area: 136 million square feet (about 5 square miles or over 3,100 acres)

Brooklyn Bridge

Manhattan Bridge from Brooklyn Bridge

George Washington Bridge

Twin Arches

Latham, NY

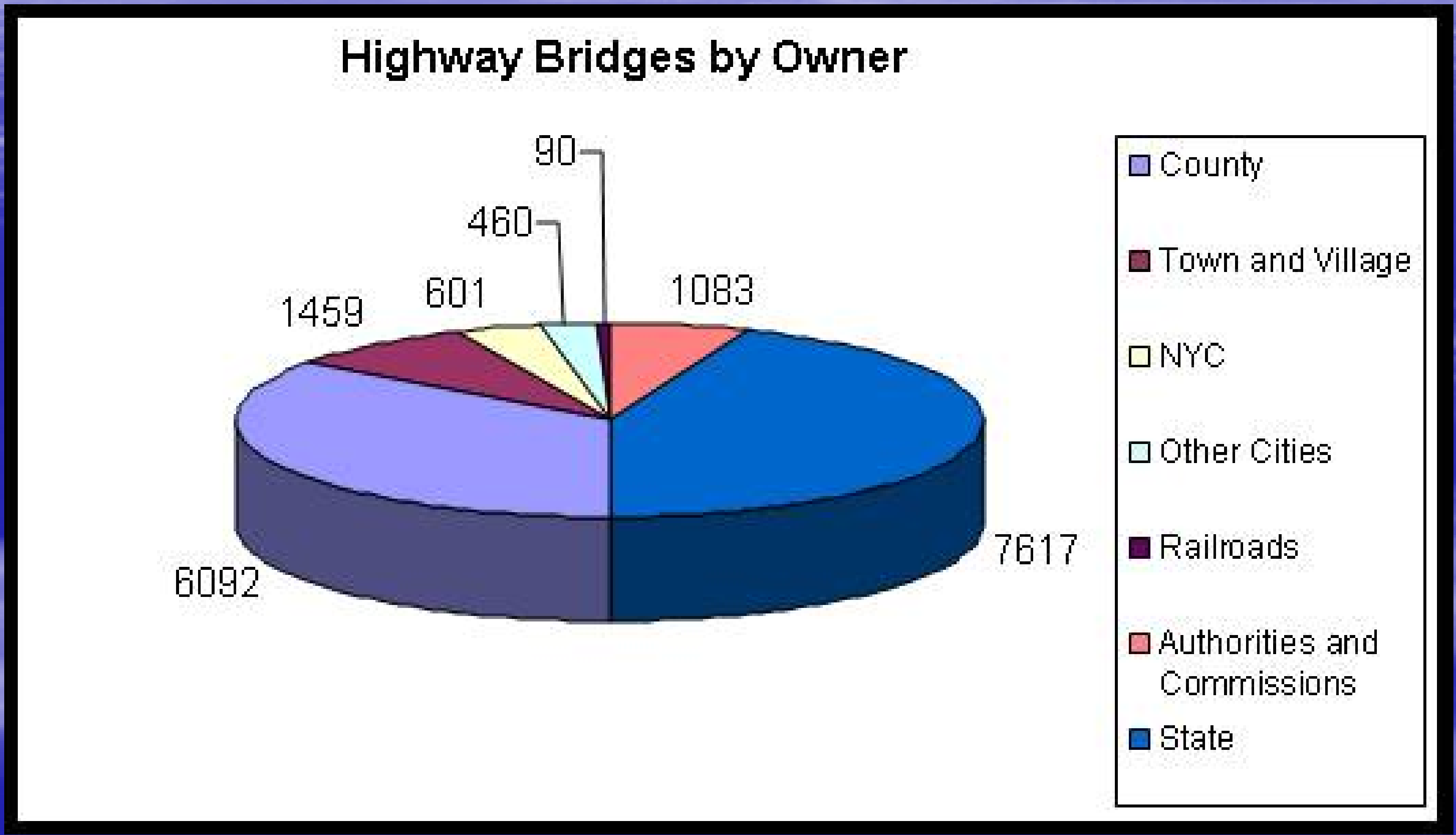
Elevation


6. 12. 2003

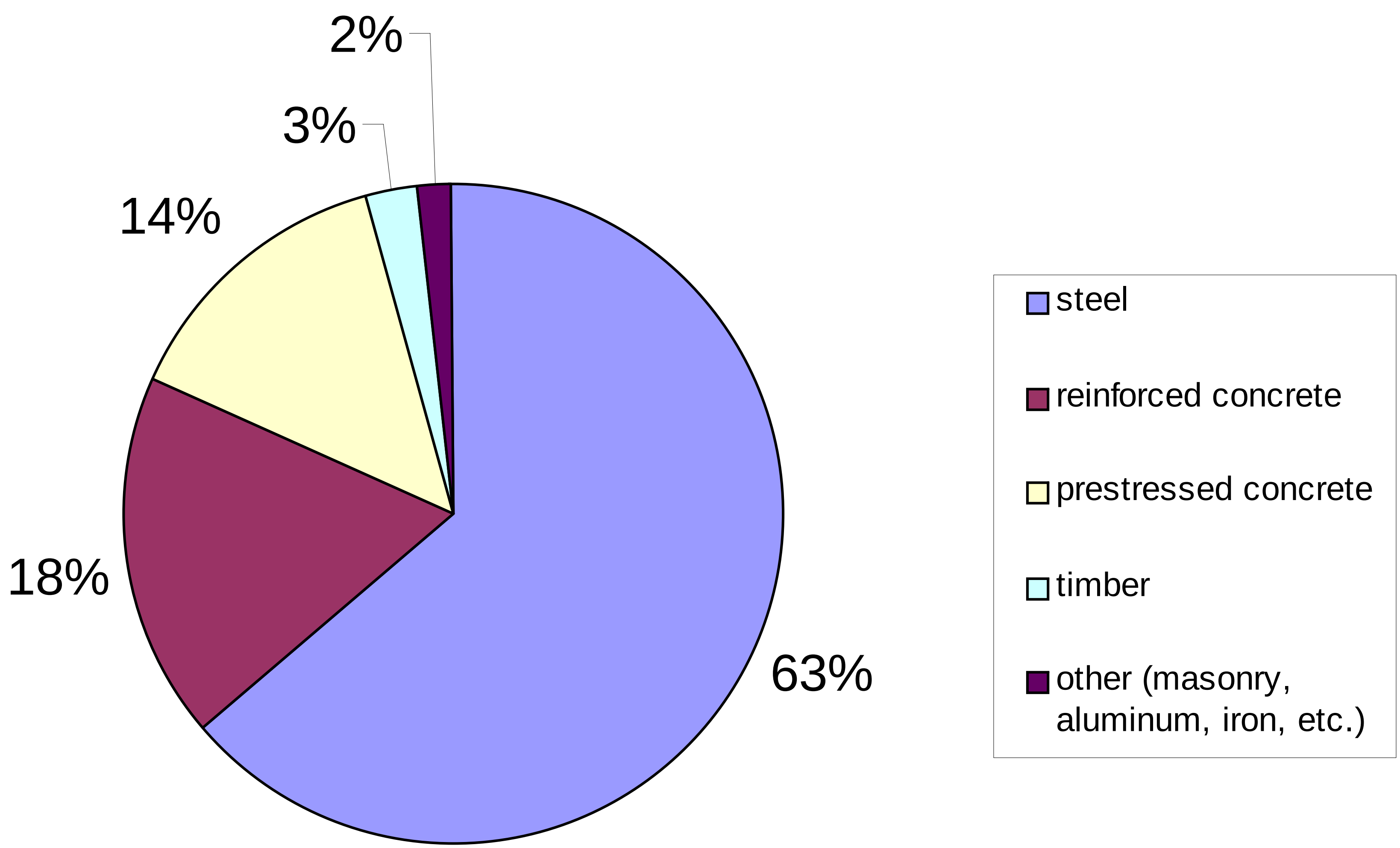

MAR 31 2003


6. 26. 2001

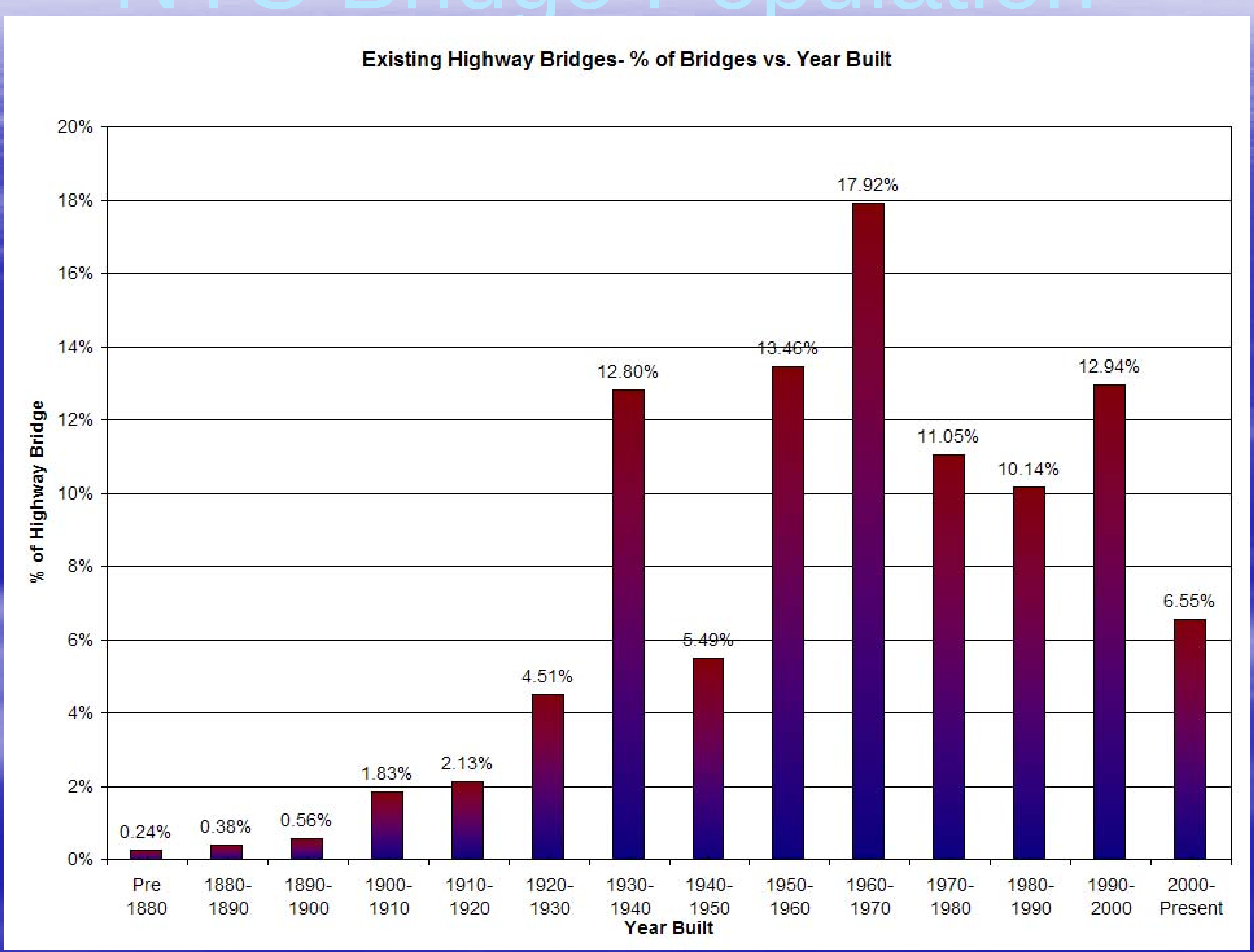
NYS Bridge Ownership



NYS Highway Bridges by Material



NYS Bridge Population



NY Inspection History

- 1930s to 1970s
  - Touring route bridges inspected by the state regional personnel
    - Inspectors did not always have structural background
    - Limited or no training
    - No standardized procedures
    - Value of inspection was not realized or appreciated
  - Local bridge owners were responsible for their bridges
  - Limited bridge inventory and inspection corporate database
    - Used to support planning functions

NY Inspection History

- Early 1970s
  - Assigned to Structures Division
  - Ad hoc Inventory and Inspection units formed
  - Better inventory data collection (BIIS emerged!)
  - Element level inspections with ratings collected in every inspection cycle
  - Computerized inventories started with paper print-outs
  - Reduction in staff, limited to one-man inspections
  - But no dedicated staff or equipment
  - Failed to meet federal standards in many cases

NY Inspection History

- Late 1970s
  - State became responsible for inspection of local bridges thru 1977 state legislation
    - 1978-79: Consultants hired for inspection, inventory, and load rating of local bridges
    - Mostly compliant with federal standards
    - Two-man inspection teams with reasonable work access
- Schoharie Creek Collapse in 1987
  - Five vehicles fell into water with 10 fatalities

NY Inspection History

- 1988 Legislative Action (Graber Bill)
  - Resulted in Uniform Code of Bridge Inspection
  - The current program resulted due to this bill
  - Higher standards than those imposed by FHWA
    - Inspector Qualifications
    - Load Rating
    - Structural Integrity Evaluations
    - Database Establishment
    - Bridge Safety Assurance Program
  - Flagging Procedure

NY Inspection History

- 1993 Automation Efforts Initiated
  - Electronic Bridge Inspection (BIPPI) in 1999
  - By 2003 BIPPI in full use by all regions
- 2003 Automation
  - Moved old database to Oracle Database
  - Easy access to data with ad hoc querying capabilities
  - Data update done on a daily basis
  - Annual Federal Data generated automatically

Inspection Basics

- “Statutory Requirements:
  - Federal Regulations: National Bridge Inspection Standards (NBIS)
  - NYS Regulations: Uniform Code of Bridge Inspection

Bottom line is to ensure the safety of the traveling public

NY Inspection Standards

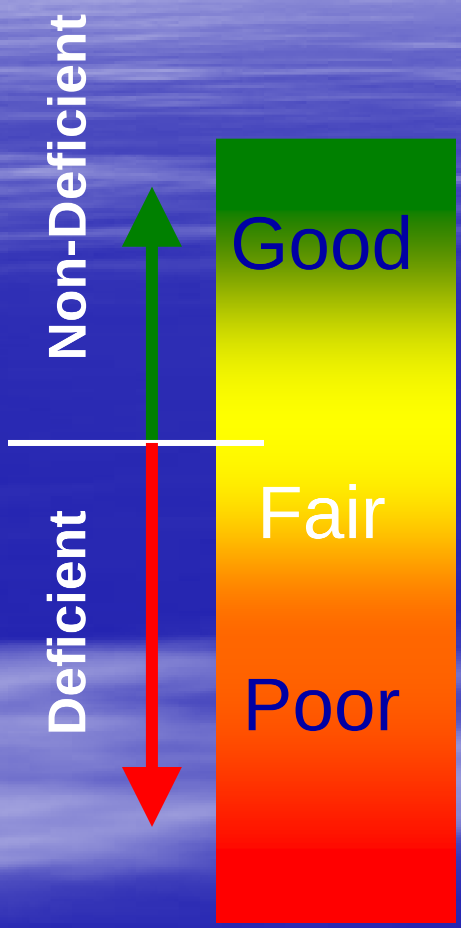
- Reference Manuals
  - NYS Bridge Inspection Manual (BIM - 1997) including addendums and appendices
  - NYS Bridge Inventory Manual (2004)
  - Bridge Diving Inspection Manual
  - Bridge Inspection Safety Manual
  - Federal Manuals


Sight
Sound
Touch
04/24/2007

Inspection

- All inspections completed by a Team Leader (PE) and an Assistant Team Leader
  - Both inspection types examine and evaluate all elements of the bridge
  - Rate 47 elements, on a span basis
  - Measure and sketch deterioration and scour as necessary
  - Update load rating and inventory data
  - Flag serious bridge deficiencies that require fast attention, or to report conditions that are or may be a clear and present danger

NYS Bridge Inspection Rating Scale



7 -- New condition, no deterioration

6 – *shade between 7 and 5*

5 -- Minor deterioration and functioning as designed

4 -- *shade between 5 and 3*

3 --Serious deterioration or not functioning as designed

2 -- *shade between 3 and 1*

1 -- Totally deteriorated or failed condition


SEP 30 2002

Inspection

- Condition Rating
  - It is a rating calculated based on weighted inspection ratings of several components
  - Uses 13 different element ratings
  - When several elements exist, such as piers, the calculation utilizes lowest rating of all piers
  - If less than 5.00, the bridge is considered deficient according to NYSDOT
- General Recommendation
  - A number between 1 to 7, based on inspector's judgment – very close to condition rating

Inspection

- Inspection data gathered using NYSDOT proprietary software BIPPI
- Interfaces with Bridge Data Management System (BDMS)
- BDMS provides current inventory and inspection data
- Continuous update of BDMS with daily extracts for routine use

NYS Inspection Ratings

Abutment Ratings:	Beg Abut	End Abut
Joint with Deck	3	3
Bearings, Bolts, Pads	3	3
Seats and Pedestals	2	3
Backwall	3	2
Stem (Breastwall)	5	4
Erosion or Scour	5	5
Footings	5	5
Piles	8	8
Recommendation	3	3

Wingwall Ratings:	Beg Abut	End Abut
Walls	5	4
Footings	5	5
Erosion or Scour	5	5
Piles	8	8

NYS Inspection Ratings

Deck Element Ratings:	001	002	003
Wearing Surface	4	3	4
Curbs	4	4	4
Sidewalks, Fascias	5	5	5
Railings, Parapets	8	8	8
Scuppers	3	3	3
Gratings	8	8	8
Median	8	8	8
Mono Deck Surface	8	8	8

Superstructure Ratings:	001	002	003
Structural Deck	2	2	2
Primary Members	3	3	3
Secondary Members	8	8	8
Paint	2	2	2
Joints	8	8	8
Recommendation	3	3	3

Inspection

- Inspection Types and Intervals
  - General Inspections (every two years or more)
  - Diving Inspections (every five years or more)
  - Special Inspections (as needed)
- Reporting Critical Findings
  - Red Flag
  - Yellow Flag
  - Safety Flag

RED FLAG

- Most severe
- Requires quick action (max. 42 days)

YELLOW FLAG


2006 8 4


35mm x 15mm
15mm
16mm
14mm
13mm
12mm dia.
SPAN 2
07.28.2006

SAFETY FLAGS

Non-Structural

Inspection Process

Inspection Team
Completes Inspection
and Report

Submit TO QCE For:
1) QC Review and
2) Submission to MO for QA Review

MO QA Review:
1) No Comments, Finalize Report
2) Comments: Return report for Revisions

Inspector is the only person who can prepare the inspection report

NYS vs. NBIS: Rating Scale

- NYS Ratings:
  – 1 “Total deterioration or failed” - 7 “New”
  – Base-lined to the original design capacity or original functioning of the component
  – Component or element based
  – Span based - “local” focus
- Federal Ratings:
  – 0 “Failed” – 9 “Excellent”
  – Component condition is rated in comparison to its original as-built condition
  – Bridge based – “global” focus

NYS vs. NBIS: Inspection Types

- Fracture Critical Member (FCM) Inspections
  - *A Member in Tension, or with a tension element, whose failure would probably cause a portion of the structure to collapse*
  - – NBIS: Steel Member in Tension
  - – NYS: Non- Redundant and FCM
    - 3 Girder System
    - Certain concrete deck haunches
    - Details vulnerable to Out-of-Plane distortion
- In-Depth Inspections

NYS vs. NBIS: Qualifications

- Qualification of Inspection Personnel: Team Leader to have 3 years of bridge related experience and a NYS PE

- Qualification of Inspection Personnel: Minimum requirements for QCE and ATL

NYS vs. NBIS: Inspection Findings

- Critical Inspection Findings:
  - Robust Inspection Flagging Procedure
- Inspection Findings:
  - Federal Coding requirements emphasize 5 major bridge components and their condition
  - NYS documents 8 groups of components encompassing 47 elements

Uses of Inspection Data

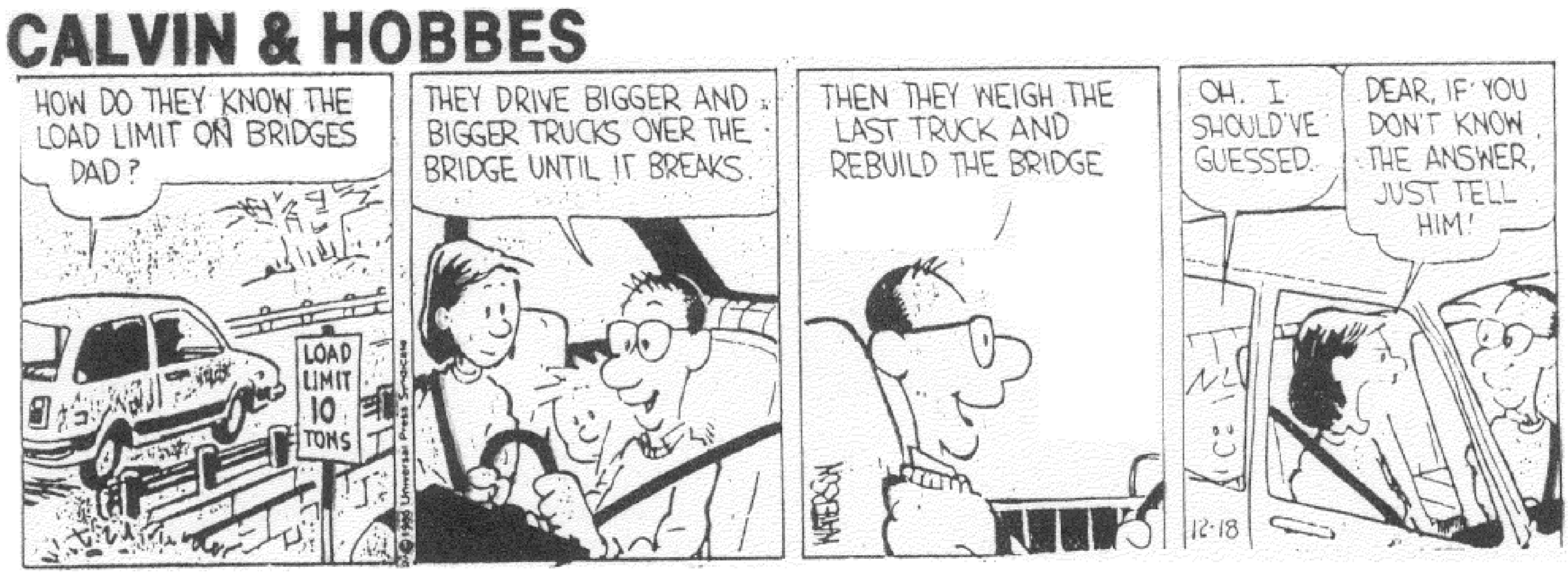
- Maintaining Current Bridge Data
  - Element condition based queries
  - Inventory based queries
  - Element / Feature Combinations
- Assuring Safety of Traveling Public and Structure
  - Critical Findings (Structural and Safety related)
  - Emergency Repairs
  - Closures (Post-Event)
  - Flood Watch
  - Postings and Closings

Load Rating

- Load rating is the determination of the safe live load capacity of a bridge
- Used for determining what loads can go on a bridge
- Updated after every inspection and as needed
- LL Capacity = (Capacity – DL Effect)/SF

Load Rating

- Done using bridge structural element database and software such as AASHTOWare® VIRTIS
  - Deterioration data collected from inspections
- Load testing is another option
  - Diagnostic tests
  - Proof load tests


CALVIN & HOBBES
HOW DO THEY KNOW THE LOAD LIMIT ON BRIDGES DAD?
LOAD LIMIT 10 TONS
THEY DRIVE BIGGER AND BIGGER TRUCKS OVER THE BRIDGE UNTIL IT BREAKS.
THEN THEY WEIGH THE LAST TRUCK AND REBUILD THE BRIDGE
WATERSON
OH. I SHOULD'VE GUESSED.
DEAR, IF YOU DON'T KNOW THE ANSWER, JUST TELL HIM!
12-18

Why Inspect Bridges?

- Bridge Management
  - Preventive maintenance
  - Corrective maintenance
  - Replacement and rehabilitation assistance
  - Funding eligibility determination
  - Permitting operations
  - Post-event assessment

Uses of Inspection Data

- Scheduling Maintenance Activities
  - Emergency Repairs
  - Flag Repairs
  - Corrective Maintenance
  - Preventative Maintenance
- Satisfying Federal and State Reporting Requirements
  - Annual “Federal Tape”
  - Annual NYS “Report of Bridge Management and Inspection Programs” – Graber Report

Uses of Inspection Data

- Providing Data for Capital Program Planning
  - Used for developing capital program by using data with BMS software
  - Used to compute “Sufficiency Rating” (measure of the bridge’s ability to remain in service) to determine federal funding eligibility
- Supporting Design Functions
  - Inspection report used as a basis for structural integrity evaluations, load rating, and other functions
  - Inspection report documentation as a reference

Uses of Inspection Data

- Permits
- Post-event assessment
  – Needed to make decision on opening or closing a bridge
  – Prioritization of funding
  – Appropriate repair actions
- Vulnerability Assessment


OVER SIZE LOAD


31 12:41PM

Uses of Inspection Data

- Permits
- Post-event assessment
  - Needed to make decision on opening or closing a bridge
  - Prioritization of funding
  - Appropriate repair actions
- Vulnerability Assessment

IMPACT HAZARD

IMPACT HAZARD

Uses of Inspection Data

- Permits
- Post-event assessment
  - Needed to make decision on opening or closing a bridge
  - Prioritization of funding
  - Appropriate repair actions
- Vulnerability Assessment

CORROSION

SCOUR HAZARD

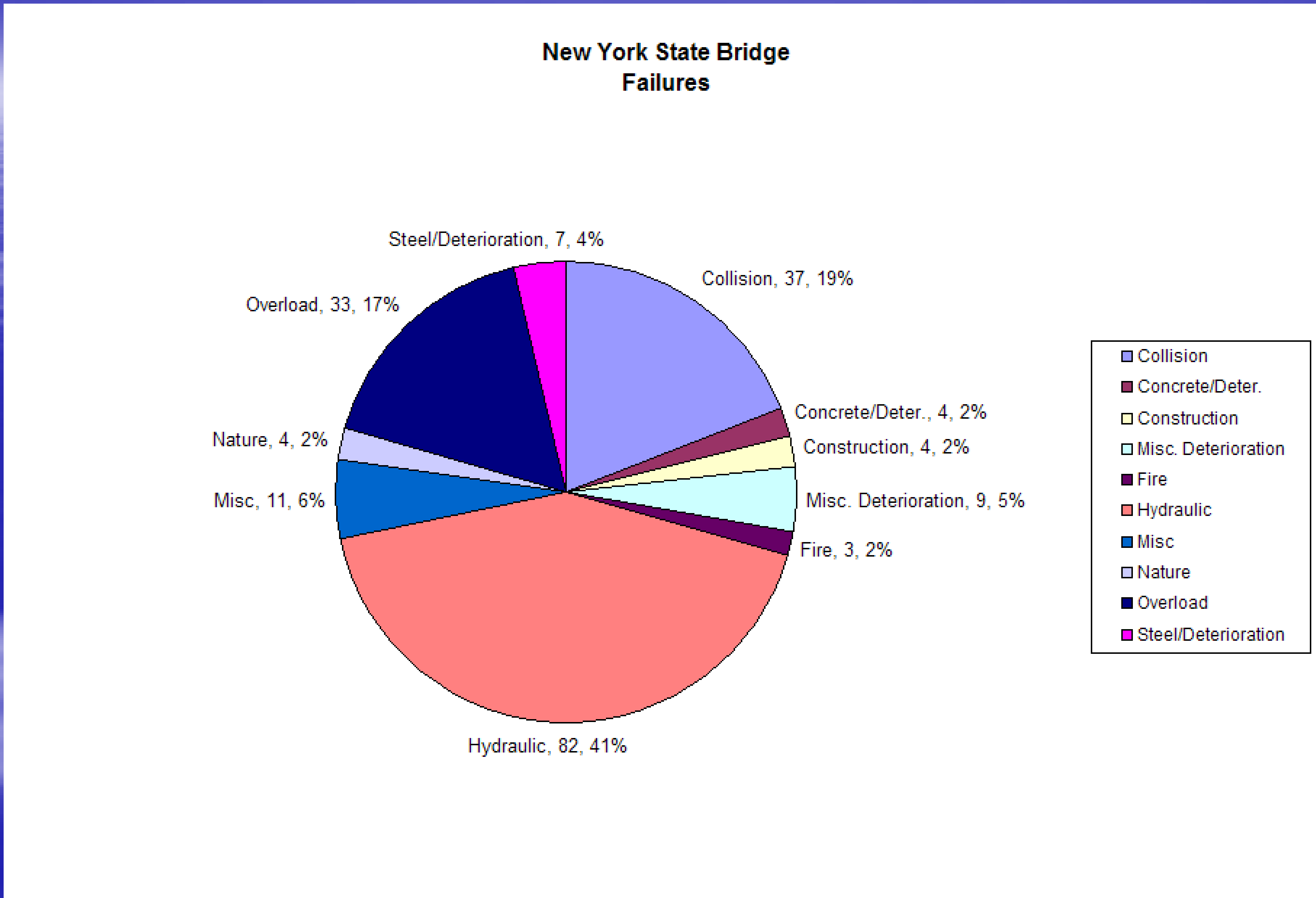
SCOUR HAZARD

OVERLOADS

OVERLOADS

SEISMIC HAZARD

STEEL DETAIL


New York State Bridge
Failures
Steel/Deterioration, 7, 4%
Collision, 37, 19%
Overload, 33, 17%
Concrete/Deter., 4, 2%
Construction, 4, 2%
Nature, 4, 2%
Misc, 11, 6%
Misc. Deterioration, 9, 5%
Fire, 3, 2%
Hydraulic, 82, 41%
Collision
Concrete/Deter.
Construction
Misc. Deterioration
Fire
Hydraulic
Misc
Nature
Overload
Steel/Deterioration

Bridge Vulnerability Program

- Pro-active program
- Based on an expert task force's recommendations
- Systematic evaluations of bridges based on failure modes
- Evaluate statewide bridge population:
  Screen → Assess → Classify
- Classifications consider risk
  - Failure likelihood
  - Consequence

Bridge Vulnerability Program

- Bridge Vulnerabilities
  – Scour
  – Earthquakes
  – Collision
  – Overloads
  – Steel details
  – Concrete details
  – Security

Issues

- FHWA Intended Use
  - Assuring safety
  - Inventory and statistics
  - Planning at national level
  - Works well for intended purposes
- Several Stakeholders
  - Several players to satisfy
  - Change in formulae and definition can have significant impact on federal funding to states

Issues

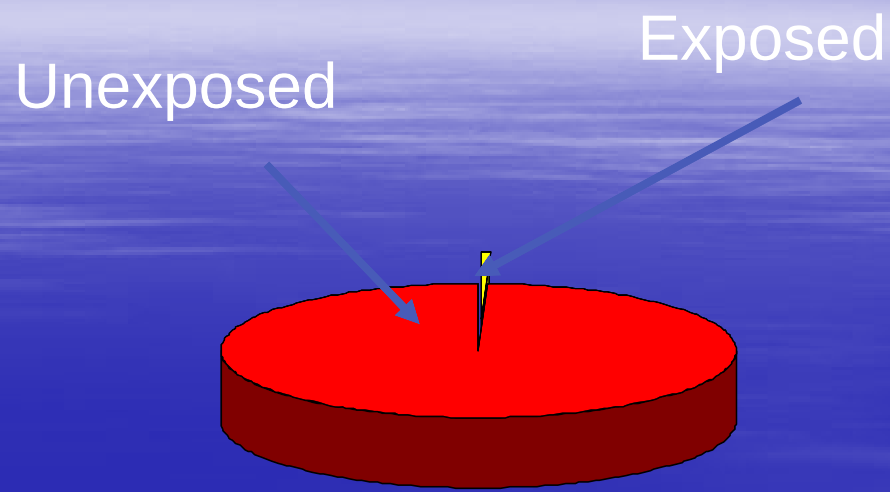
- Designed for routine bridges and does not cover adequately
  - Special bridges
  - New materials
  - New designs
  - Complex bridges
- Completely visual and hence, hard to evaluate concealed elements
- No rational basis for inspection interval
- Appraisal ratings' definitions do not reflect current state-of-practice

Elevation

Issues

- Designed for routine bridges and does not cover adequately
  - Special bridges
  - New materials
  - New designs
  - Complex bridges
- Completely visual and hence, hard to evaluate concealed elements
- No rational basis for inspection interval
- Appraisal ratings definitions do not reflect current state-of-practice

How Much of the Cable is Inspected?



Inspecting a 20-foot length of cable with wedging at 8 points exposes less than 0.1% of the wire for a typical suspension bridge (4,000 foot main cable with 15,000 wires).

(Robert Nickerson (1998), “Safety Appraisal of Suspension Bride Main Cables”, National Cooperative Highway Research Program, Transportation Research Board, Contractor’s Report for a Workshop in Newark, NJ)

Courtesy of Mike Higgins

FRP Bridge Deck

Issues

- Limited data: Not effective for bridge management practices
  - Global ratings: do not extend to element level
  - Qualitative and does not lend to deterioration rate estimations for significant elements
  - Need extent of damage for financial estimations
  - No link to bridge maintenance practices and inspection data
- Not hazard specific (reactive not pro-active)

Looking into Future

- Identifying and recording data needed to evaluate and improve performance
  - Environmental data
  - Operational data: deicing salts, etc.
  - Load data
  - Material data
  - Maintenance, R&R data
- Evaluate how data is used and how it can be used more effectively
  - Identify elements needing improvement
  - Focus on maximum benefit with associated cost

Looking into Future

- Account for structure type and complexity
  - Inspection interval
  - Inspector qualifications
  - Inspection extent
  - Data collected
  - Supplement with NDT methods as needed
  - Resources
  - Addressing critical findings

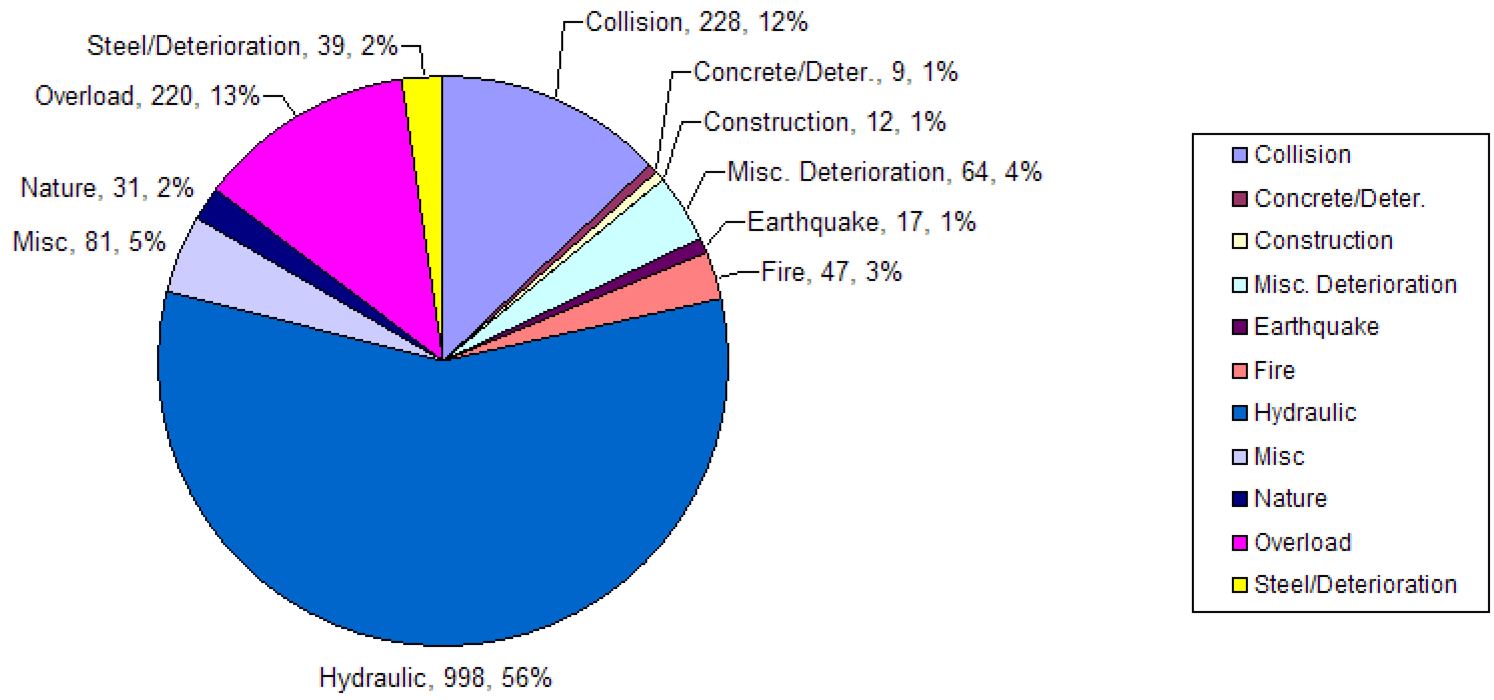
Brooklyn Bridge


MAR 31 2003

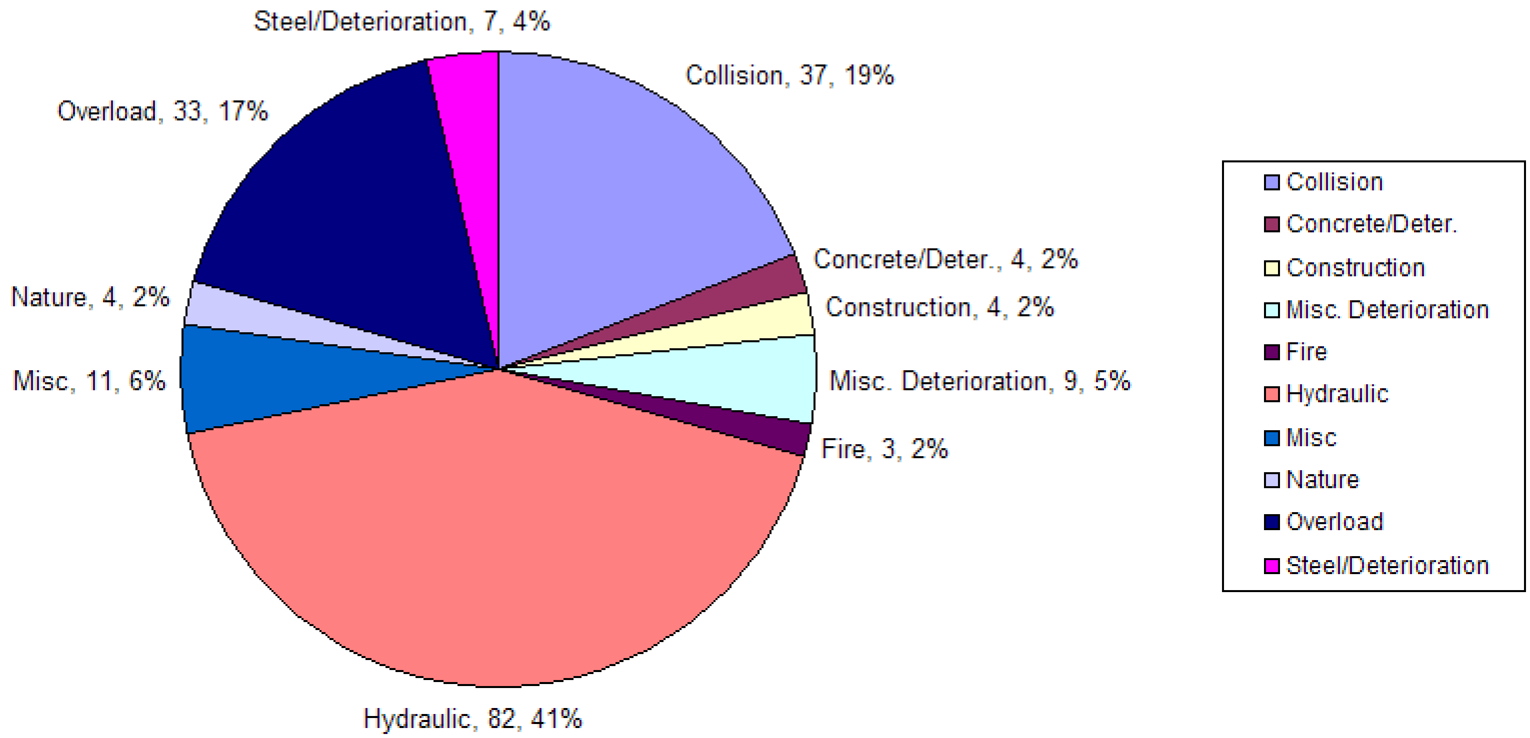
Looking into Future

- More uniformity and consistency in ratings
  - Reference bridges
  - Uniform QC/QA procedures
  - Uniform qualifications, training, and continuing education
  - Better manuals
  - Quantitative data
  - Deterioration extent
  - Recording maintenance data
  - Certification and calibration of inspectors

US Bridge Failures

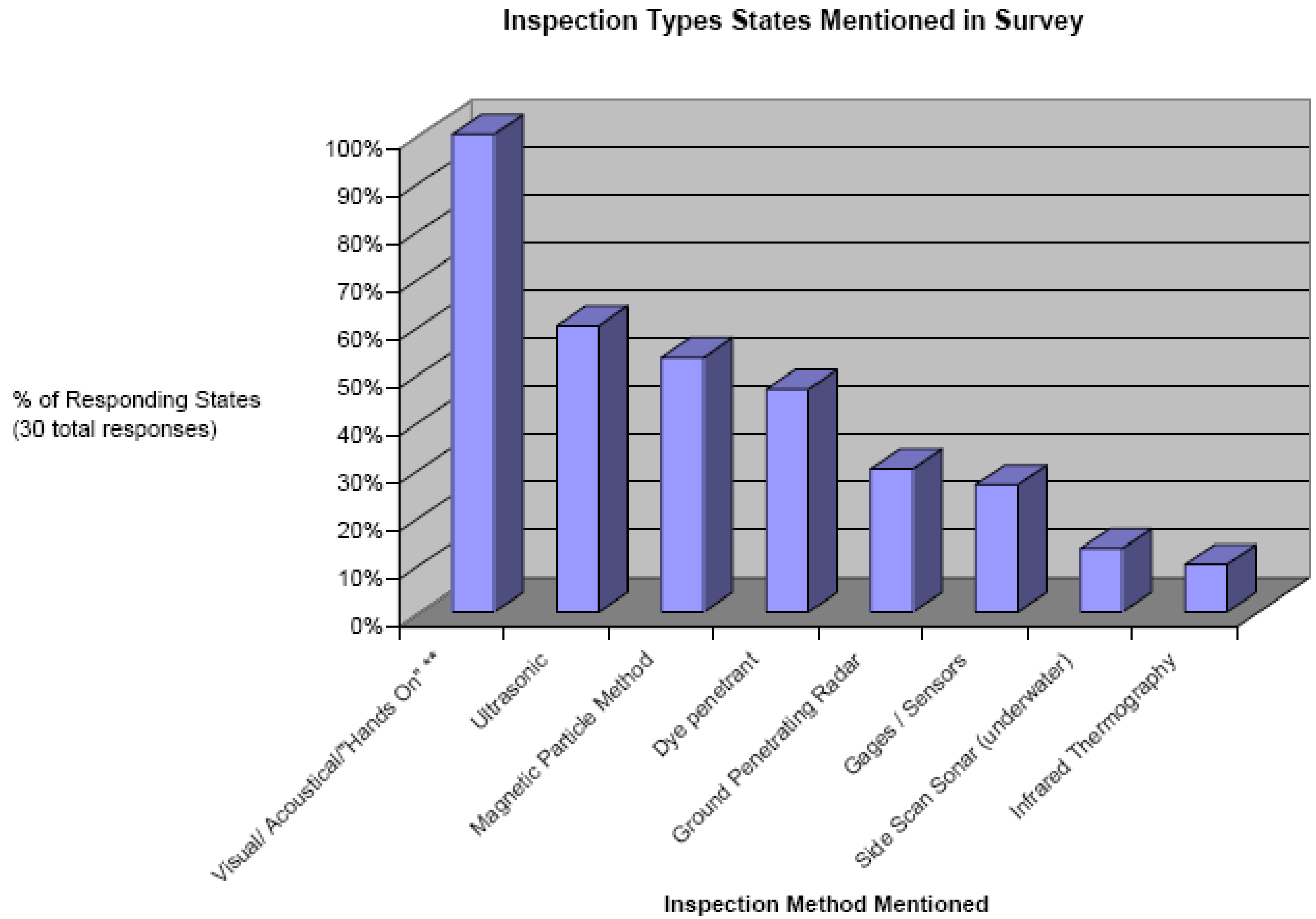


New York State Bridge Failures



Looking into Future

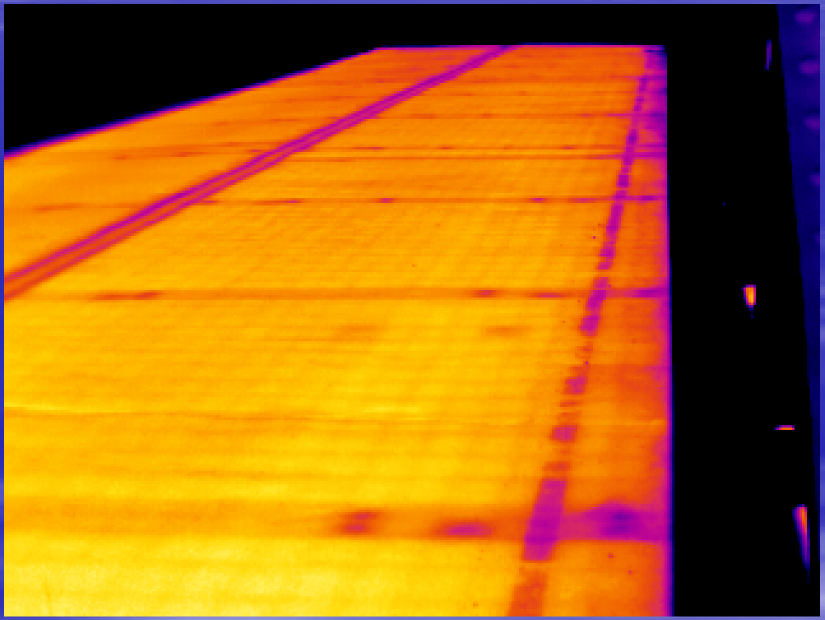
- Pro-active inspection and assessment
  - Design and construct for inspection ease
  - Multi-hazard approach
  - Leveraging current sensor and computing technologies
    - Passive sensors
    - New test methods
    - Smart structures



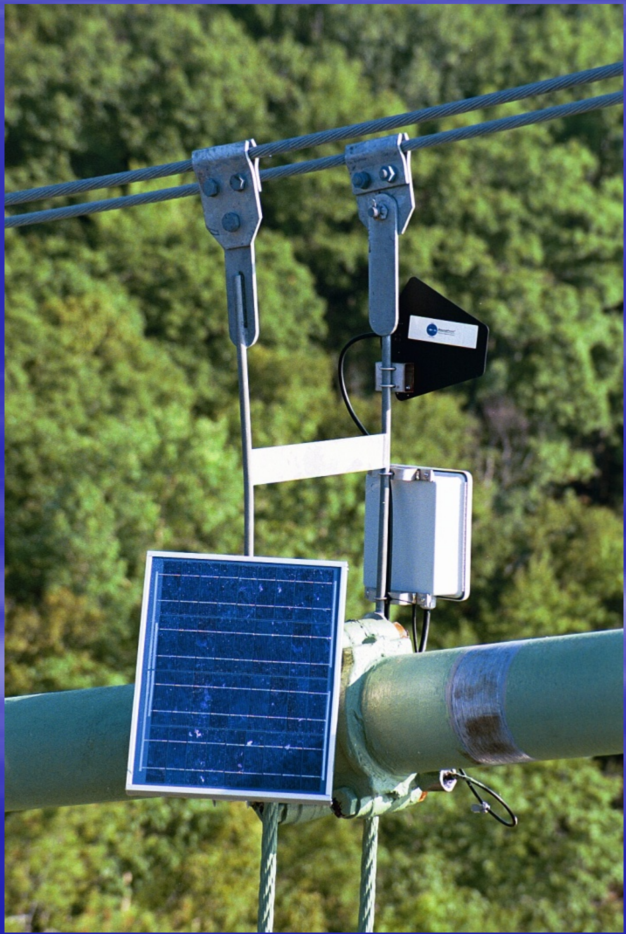
** -acoustical includes chain drag and hammer sounding
-"hands on" includes the use of snooper trucks, measurement calipers, digital cameras, etc.

Courtesy: K. Rehm, AASHTO

Thermographic Inspection



Sensor Technologies



Courtesy of Mike Higgins

Minnesota Bridge Collapse

- Bridge Details
  - – Carries I-35W, 8 lanes with 140,000 AADT
  - – Deck truss bridge
  - – Under construction (deck repair)
  - – Rated “structurally deficient” by federal standard
- Failure
  - – August 1st, 2007
  - – 13 people killed during rush hour traffic

NTSB Findings

- Reasons for the collapse
  - Inadequate load capacity of connection due to a design error of the gusset plates
  - Failure under a combination of:
    - Substantial increases in the weight of the bridge, which resulted from previous bridge modifications
    - Traffic and concentrated construction loads on the bridge the day of the collapse
  - Recommended that owners assess the truss bridges in their inventories to identify locations where visual inspections may not detect gusset plate corrosion and use of NDE to assess gusset plate condition
- FHWA plans to issue a technical advisory recommending NDE methodology to meet the above recommendation

State and Local Summary

Region	Truss Population	Requiring Analysis	Analysis Completed	% Requiring Analysis
1	108	22	22	20.4%
2	50	11	10	22.0%
3	41	7	7	17.1%
4	87	32	32	36.8%
5	44	9	9	20.5%
6	27	2	2	7.4%
7	70	25	25	35.7%
8	75	11	11	14.7%
9	94	11	11	11.7%
10	6	1	1	16.7%
11	2	1	1	50.0%
Sub Total	604	132	131	
Percentages		22%	99%	22%

Summary Of Repairs

Region	BIN	Condition
1	1017670	Six gusset plates replaced due to deterioration
1	1007050	One plate retrofitted, bridge to be replaced
1	4001020	Numerous gusset plates strengthened
1	5521189	Several gusset plates strengthened due to deterioration
2	4030970	Posted 25 Tons until gusset plate repairs completed
5	1041590	Numerous gusset plates strengthened due to deterioration
8	1007140	Several gusset plates deteriorated, Bridge replaced
8	3346530	Numerous plates had severe deterioration, bridge closed
10	2000200	Several gusset plates strengthened due to deterioration
Total	9	

No design deficiency was found

ASCE-AASHTO Ad hoc Group

- ASCE and AASHTO formed an ad hoc group to identify critical inspection needs and improvements
  - White paper released in September 2008
  - Describes gaps, needs and issues with current practice
- Report available on ASCE web site
- Also available in Jan/Feb 2009 issue of the ASCE Journal of Bridge Engineering

Enhancing Bridge Performance Workshop

- Co-sponsored by ASCE and FHWA
- Focused on bridge deterioration, safety, and long-term survivability
- Report is available from ASCE

Other Research

- NCHRP Project to study rational based inspection criteria
- Review of QC/QA programs was conducted and report available from NCHRP/FHWA
- Long-Term Bridge Performance Program
- Evaluating Consistency/Reliability of NYS Bridge Inspection Program
- Risk based fracture critical inspections – FHWA Study

Looking into Future

- Points to Remember
  - SAFETY FIRST
  - Decision-making process should drive the programs
    - Do not collect data which you are not going to use
    - Do not use technologies just because they exist
    - Cost-benefit analysis
    - Risk analysis
    - Reliability evaluation of technologies

Questions

1. If a bridge is "Structurally Deficient (FHWA)/Deficient (NY)," is it not safe for use by public?
2. What does a red flag mean? How many days does the owner have to address the flag condition?
3. What is the predominant cause of bridge failures in US and in NYS?

Questions

4. How often do bridges get inspected?

5. Why do we inspect bridges?

6. When was the last revision made to National Bridge Inspection Standards (NBIS)?

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