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Using remote sensing for bridge condition evaluation

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### Conference Moderator

**R. Andrew Swarts, Ph.D.**  
**Assistant Professor**  
**Michigan Technological University**

Mr. Swartz's research interests are driven by the practice of embedded and autonomous interrogation of data collected remotely for the management and protection of both civil infrastructure assets and their occupants. Sustainable management of civil infrastructure systems require not only the collection of relevant data, but also a means of conditioning and interpreting the data such that it can be of use for making decisions regarding both performance and structural health. Novel sensor designs with embedded data processing power offer the advantage of autonomous operation.

His research interests lie in the application of computationally efficient and robust embedded algorithms for monitoring and protection of civil infrastructure assets such as buildings, bridges, pipelines, wind turbines, roadways, and railroads. His work draws upon a diverse range of fields including structural dynamics, performance monitoring, structural health monitoring, structural control, load estimation, system identification, embedded algorithms, signal processing, embedded system design, computer science, and wireless sensor technologies.
Agenda

8:00  Check-in

8:25  Opening Remarks
    Moderator, Andrew Swartz, Ph.D., Michigan Technological University

8:30  Federal Highway Administration Update
    Mark Lewis, Structures/Area Engineer, FHWA—Michigan Division

9:00  Michigan Department of Transportation Update
    Dave Juntunen, P.E., Engineer of Bridge Operations, MDOT

9:30  Local Bridge Program Update
    Keith Cooper, P.E., Bridge Program Manager, MDOT

10:00  Question & Answer Period—FHWA & MDOT

10:15  Break

10:30  Emergency Bridge Replacement of Nine Mile Bridge over I-75
      A Design-Build Success Story
    Jeremy Hedden, P.E., Project Manager, Bergmann Associates
    Mario Quaglia, P.E., Bridge Engineer, Bergmann Associates

11:15  Asset Management Guide for Bridges
    Roger Safford, P.E., Region Engineer, MDOT & TAMC Bridge Committee Chair

12:00  Lunch

1:00  Safely and Accurately Surveying Bridges using 3D Laser Scanning
    Jeffery Wood, P.S., Principle and Director of Surveying, Spicer Group
    Eric Barden, P.S., Senior Associate and Transportation Survey Team Leader, Spicer Group

1:45  Using Remote Sensing for Bridge Condition Evaluation
    Colin Brooks, Ph.D., Associate Professor, Michigan Technological University

2:15  Break

2:30  Historic Concrete Arch Bridge - Rehabilitation
    Amanda Porath, P.E., Northwest Design Group, Inc.

3:15  Stressed Out!
      Common challenges of inspecting adjacent prestressed concrete box beams
    Amy L. Trahey, P.E., President, Great Lakes Engineering Group, LLC

4:00  I-35W Collapse: A Forensic Investigation
    Mark Bagnard, Chief, Investigations Division, National Transportation Safety Board,
    Office of Highway Safety

5:00  Adjourn
Federal Highway Administration Update

Mark Lewis  
Structures/Area Engineer  
Federal Highway Administration-Michigan Division  
mark.lewis@dot.gov  
(517) 702-1846

Mr. Lewis has been with the FHWA for the past three years. He is the Michigan division bridge engineer, and area engineer for the Superior Region. In the past he has worked for MDOT, consulting firms in Michigan and South Carolina, and the Grand Traverse County Road Commission. He received his Bachelors of Science degree from Michigan State University in 1977.

Presentation Summary

Update on the Federal highway program including:

• National Bridge Inspection Program (NBIP) summary and introduction to the 23 “Metrics”
• FHWA Every Day Counts Initiatives related to:
  • Accelerated Bridge Construction (ABC)
  • Geosynthetic Reinforced Soil Integrated Bridge System (GRS-IBS) in bridge designs

Additional Information

• Michigan Division Website:  
  www.fhwa.dot.gov/midiv/index.htm
• National Website:  
  http://www.fhwa.dot.gov

Notes
Michigan Department of Transportation Update

Dave Juntunen, P.E.
Engineer of Bridge Operations
Michigan Department of Transportation

Mr. Juntunen has worked for MDOT for 24 years as a bridge designer, structural research engineer, and bridge operations engineer.

Presentation Summary
Update from Michigan Department of Transportation

Notes
Local Bridge Program Update

Keith Cooper, P.E.  
Bridge Program Manager  
Michigan Department of Transportation

cooperk@michigan.gov  
(517) 335-2844

Mr. Cooper has worked for MDOT for 21 years. The last 8 years he has worked in the Local Bridge Program. Prior to working in Local Agency Programs, he worked in MDOT’s bridge design unit. He earned his Bachelor of Science degree in Construction Engineering from Lawrence Technological University.

Presentation Summary

Update on changes to the Local Bridge Program including:

• Current rating system used to select bridge projects
• Electronic applications (see Appendix A)
• Current maintenance projects
• Financial summary of the Bridge Program

Notes
Emergency Bridge Replacement of Nine Mile Bridge over I-75: A Design Success Story

Jeremy Hedden, P.E.  
Project Manager  
Bergmann Associates  

Mr. Hedden is a Project Manager with Bergmann Associates and is licensed in Michigan and Ohio as a professional engineer. He sits on AREMA’s Committee 8 and helps to maintain and write design code for concrete rail structures.

Mario Quagliata, P.E.  
Bridge Engineer  
Bergmann Associates  

Mr. Quagliata is a project engineer with Bergmann Associates and is licensed in Michigan as a professional engineer. He has co-authored articles on the Nine Mile Bridge in both Roads and Bridges magazine and an issue of Modern Steel Construction.

Presentation Summary

A look at the events which took place during the Summer of 2009 which led to the closure of I-75 and the destruction of the Nine Mile Road overpass. The ensuing response by MDOT, the contracting community, and local residents will be documented as a timeline spanning from June 2009 to the structures reopening in December of the same year.

The presentation will also explain the numerous design and construction challenges required to accommodate specific site constraints, including expedited construction schedules and planned future I-75 freeway conditions. The project used many special techniques, from accelerated structural steel delivery, to Styrofoam backfill and placing concrete during cold weather. The design-build delivery method worked to near perfection and was the pride of MDOT in 2009.

Additional Information

- Modern Steel Construction Article:  

- Roads and Bridges Article:  
  http://www.roadsbridges.com/articles/60_9%20Mile%20Bridge%200710RB.pdf  

Notes
Asset Management Guide for Bridges

Roger Safford, P.E.
Region Engineer
Michigan Department of Transportation (MDOT)
Member, TAMD
Chairman, TAMD Bridge Committee

Mr. Safford is the Region Engineer for the Michigan Department of Transportation’s (MDOT) Grand Region. The Grand Region is comprised of eight counties in Western Michigan, including Oceana, Newaygo, Mecosta, Muskegon, Kent, Montcalm, Ottawa and Ionia. The Metro Region includes Detroit and the surrounding areas. Mr. Safford started with MDOT as a construction technician in 1973, while he attended the University of Michigan, where he received a B.A. in History in 1980. He accepted a full-time position in MDOT’s Testing Laboratory in 1977. He received a B.S. in Civil Engineering from Michigan State University in 1983. Mr. Safford is licensed as a professional engineer in Michigan.

Al Kaltenthaler, P.E.
S.E., Senior Associate & Vice President
TranSystems
Voting Member, TAMD Bridge Committee

Mr. Kaltenthaler is Vice President and Senior Associate for TranSystems Corporation in East Lansing and a Member of TAMD Bridge Committee with 28 years of experience. He received a BSCE from the University of Akron. He has been manager for dozens of MDOT bridge design, rehabilitation, inspection, and load rating projects. Notable projects include a new 3900 foot long bridge on M-231 over Grand River in Grand Haven, the M-6/US-131 interchange, the I-75 corridor projects in Detroit, the I-94/US-24 interchange and corridor reconstruction in Taylor, and bridge and sound wall design.

Keith Cooper, P.E.
Local Agency Bridge Program Manager
Michigan Department of Transportation
Contributing Member, TAMD Bridge Committee

Mr. Cooper has worked for MDOT for 21 years. The last 8 years have been in the Local Bridge Program. Prior to working in Local Agency Programs, he worked in MDOT’s bridge design unit. He earned his Bachelor of Science degree in Construction Engineering from Lawrence Technological University.

Dave Juntunen, P.E.
Engineer of Bridge Operations
Michigan Department of Transportation (MDOT)
Contributing Member, TAMD Bridge Committee

Mr. Juntunen has worked for MDOT for 24 years as a bridge designer, structural research engineer, and bridge operations engineer.
Presentation Summary

Accelerated construction/replacement employs the use of prefabricated and/or pre-engineered bridge systems that are instrumental in reducing road closures and/or construction schedules. This presentation highlights several projects using precast concrete and structural steel elements that allowed state departments of transportation to replace existing bridge and culvert structures in record time.

Additional Information

- TAMC Website:
  www.michigan.gov/TAMC

Notes
Safely and Accurately Surveying Bridges using 3D Laser Scanning

Jeffery Wood, P.S.  
Principle and Director of Surveying  
Spicer Group  
jeffw@spicergroup.com  
(989) 921-5524

Mr. Wood is a 1991 graduate of Ferris State University’s Surveying Engineering Program. He is a Licensed Professional Surveyor in Michigan and Arizona and is the Director of Surveying Services for Spicer Group. He joined Spicer in 1993.

Eric S. Barden, P.S.  
Senior Associate and Transportation Survey Team Leader  
Spicer Group  
ericb@spicergroup.com  
(989) 921-5557

Mr. Barden is a 2002 graduate of Ferris State University’s Surveying Engineering Program. He is a Licensed Professional Surveyor in Michigan and currently leads Spicer’s Transportation Survey Team. The team performs transportation design surveys for federal, state, and municipal clients throughout Michigan. He joined Spicer in 1999.

Presentation Summary

A look at how Spicer Group’s survey team has successfully used 3D laser scanning to survey bridges throughout the state of Michigan. 3D laser scanning provides means to collect highly accurate and detailed survey information on bridges through non-contact methods. This method of survey has eliminated the need for costly lane closures and return visits to collect missed information. The scans also provide a 3D archive of the existing bridge conditions at the time of the survey for viewing at any time in the future.

Notes
Using Remote Sensing for Bridge Condition Evaluation

Colin Brooks
Research Scientist
Manager of Environmental Science Laboratory
Michigan Tech Research Institute (MTRI)

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(734) 913-6858

Colin Brooks has 18 years of experience in applying remote sensing and GIS to a wide variety of pressing issues in transportation, watersheds, agricultural systems, contaminated areas, and ecosystems undergoing land cover and climate change. He is manager of the Michigan Tech Research Institute’s (MTRI) Environmental Science Lab in Ann Arbor, MI, where he is a Research Scientist.

He has applied high-resolution remote sensing to solving transportation-related issues for three USDOT Research and Innovative Technology Administration (RITA) projects, including assessing bridge condition using remote sensing, mapping forested wetlands and high soil moisture areas near transportation corridors for a study with Mississippi State University, and applying remote sensing and data visualization tools for studying freight flow times in congested border crossings with The Ohio State University.

He also been the lead GIS analyst on the Transportation Applications of Restricted Use Technology (TARUT) Study (www.tarut.org) conducted with MDOT, and has led the development of remote sensing-based methods to inventory roadway assets and tools to map potential wetland mitigation sites more efficiently for transportation corridor projects.

In 2008, he and Dr. Robert Shuchman were awarded a three-year grant from the University of Alaska – Fairbanks to analyze the economic and carbon impacts of expanding rail freight transit in Alaska. He is working on a project to assess the crash risk relationship between weather data and road conditions with the Federal Highway Administration.

He has led the development of decision support tools that can be used by Great Lakes stakeholders to analyze impacts of contaminated sediments on human health in the Great Lakes as part of the GLEAMS Center project. Previously, he ran a GIS lab for the University of California - Berkeley from 1996 to 2005 as part of the Integrated Hardwood Range Management Program (IHRMP). From 1993 to 1996, he was a GIS Specialist with the USDA Forest Service – Savannah River (South Carolina). He has a Master’s Degree in Environmental Management from Duke University (1993) and a Bachelor of Science Degree from Lenoir-Rhyne College (1992).

Presentation Summary

Deteriorating infrastructure has burdened transportation agencies for many years. Bridges continue to age, and funds for the repair and replacement of this infrastructure are insufficient at current funding levels. Remote sensing technologies, which enable non-contact data collection at great distances, offer the ability to enhance inspection and monitoring of bridges. Research is being sponsored by the USDOT/RITA Commercial Remote Sensing & Spatial Information Technologies program, in partnership with MDOT, to create remotely sensed bridge health indicators that can be used in combination with physical inspections for condition assessment. Research is also being conducted on
how to combine these measures into a single, integrated bridge signature that can be used as an overall appraisal of bridge condition. This integrated bridge signature is expected to provide inspectors and transportation officials with both a baseline measure of condition and a measure of changes in bridge behavior over time.

Additional Information

- Bridge Condition Assessment using Remote Sensing: www.mtti.mtu.edu/bridgecondition

Notes
Historic Concrete Arch Bridge - Rehabilitation

Amanda Porath, P.E.
Structural/Geotechnical Section Manager
Northwest Design Group, Inc.

Ms. Porath graduated from Michigan Tech in 1998 with BS in Civil Engineering and obtained her professional engineers license in 2002. She began her career with Northwest Design Group as an intern in 1997 then progressed to a CAD operator and worked her way up to the position of Structural Section Manager.

Presentation Summary

A summary of a project for the Mackinac County Road Commission to rehabilitate a historic concrete arch bridge structure. Topics include a historic review, analysis of the existing arch, environmental items and the use of inventive design solutions.

Additional Information

- Northwest Design Group homepage: www.ndgconsulting.com

Notes
Stressed Out! Common Challenges of Inspecting Adjacent Prestressed Concrete Box Beams

Amy Trahey, P.E.  
President  
Great Lakes Engineering Group, LLC  
amy@glengineering.com  
(517) 363-4400

Ms. Trahey is a proud Michigan Tech Graduate and a licensed professional engineer in Michigan and Wisconsin. She worked for the Michigan Department of Transportation for seven years prior to starting the Great Lakes Engineering Group in 2000. She is a qualified team leader and underwater bridge inspector and has performed bridge inspections on over 3,000 structures in the state of Michigan over the past 17 years. She is passionate about bridge safety, preservation, and rehabilitation.

Presentation Summary

Bridge safety inspectors often encounter side by side prestressed concrete box beams during routine bridge inspections. This type of superstructure is often difficult to inspect until the level of deterioration becomes so bad that immediate action needs to be taken in the form of reducing the load posting of the structure, or even bridge closure. The intent of the presentation is to overview typical forms of distress and deterioration of this type of superstructure and describe some possible causes and repair options.

Additional Information

• Board Member of ACEC/M
• Board Member of the Michigan Technological University Civil and Environmental Engineering Advisory board
• Member of the Technical Advisory Council for the USDOT Research and Innovative Technology Administration

Notes
I-35W Collapse: A Forensic Investigation

Mark Bagnard
Chief, Investigations Division
NTSB
Office of Highway Safety

Mr. Bagnard has been an investigator with the National Transportation Safety Board since 1997. During his tenure at the NTSB, Mr. Bagnard has worked for the Office of Highway Safety where he is currently assigned as the Chief of the Investigations Division. Prior to that assignment, Mr. Bagnard worked in a variety of investigative disciplines, but primarily served as a highway investigator and technical reconstructionist. He was the Investigator-in-Charge on the I-90 Tunnel collapse in Boston, MA and the I-35W Bridge collapse in Minneapolis, MN. Mr. Bagnard's background is in Criminal Justice. Before joining the NTSB he had gained 15 years of accident investigation experience through his service as a law enforcement officer. During that time, he spent 11 years as an accident investigator and taught accident investigation and reconstruction courses at area police academies.

Presentation Summary

Discusses the investigation process and briefly examines the major safety issues identified in the investigation including: insufficient bridge design firm quality control procedures; insufficient federal and state procedures for reviewing and approving bridge design plans and calculations; lack of guidance for bridge owners with regard to the placement of construction loads on bridges during repair or maintenance activities; exclusion of gusset plates in bridge load rating guidance; lack of inspection guidance for conditions of gusset plate distortion; and inadequate use of technologies for accurately assessing the condition of gusset plates on deck truss bridges. (see Appendix B for additional information)

Notes
Appendix A: Local Bridge Program Funding Application

Local Agency Bridge “Call For Applications”

Location: [http://www.michigan.gov/mdot](http://www.michigan.gov/mdot)
- doing business
- Local Agency Program
- Bridge Program
- Call for Applications (or)
- Call for Electronic Application Submittal

Web Address to “Call for Applications”:

“Local Agency Bridge Data (Updated Annually)” – Federal Sufficiency Ratings for Local Bridges and Scope Estimate Worksheet

Location: [http://www.michigan.gov/mdot](http://www.michigan.gov/mdot)
- doing business
- Local Agency Program
- Bridge Program
- Requirements
- Bridge Selection Process
  - Local Agency Bridge Data (Updated Annually)

Web Address to “Local Agency Bridge Data (Updated Annually)”: [http://www.michigan.gov/mdot/0,1607,7-151-9625_25885_40558_40560-113381--,00.html](http://www.michigan.gov/mdot/0,1607,7-151-9625_25885_40558_40560-113381--,00.html)
LOCAL BRIDGE PROGRAM
CALL FOR APPLICATIONS FUNDING YEAR 2014

NOTE TO USERS: Please be sure that all structure information is correct on your SI&A form in TMS before submitting your application. Applications received after May 1, 2011 will not be accepted. For assistance, please call (517) 373-2346 or 373-0041.

Instructions: (This form requires Adobe Acrobat Standard or Professional and is not enabled for use in the free Adobe Reader. If you only have access to Adobe Reader, please submit paper documents.)

1. Complete the required application information below.
2. Click on ATTACHMENTS to add your signed resolution, cost estimate, map showing structure location and detour route, narrative description of project, letters of support and photos using the structure.
3. When you have finished, click on SAVE AS to keep a copy for each structure you are submitting an application for. * Multiple structure applications need to be applied for as individual structures and choose “Multiple PM” for “Type of Work”.
4. Click on SUBMIT to email your application to MDOT-DesignLAP@michigan.gov.

APPLICATION INFORMATION (REQUIRED)

Agency Name: ____________________________________________

Structure Number: __________________

Facility Carried: __________________

Feature Intersected: __________________

Cost Estimate: __________________

Type of Work: __________________

Has this structure been previously submitted for funding? ☐ Yes ☐ No

This form requires Adobe Acrobat Standard or Professional and is not enabled for use in the free Adobe Reader. If you only have access to Adobe Reader, please submit paper documents.)
### BAY REGION LOCAL BRIDGE PROGRAM
#### RATING SUMMARY SHEET

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<th>AGENCY NAME</th>
<th>STRUCTURE NUMBER</th>
<th>MDOT BRIDGE ID</th>
<th>FACILITY CARRIED</th>
<th>FEATURE INTERSECTED</th>
<th>LOCATION</th>
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<td>DEFICIENCY STATUS</td>
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<td></td>
<td></td>
<td></td>
<td>PROJECT COST</td>
<td>$660,000</td>
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</tbody>
</table>

#### LOAD CAPACITY AND CONDITION

| Federal Operating Rating (Metric Tons) | 45.6 |
| Points For Load Capacity | 2.56 |
| Bridge Condition Ratings | Deck 5, Super 4, Sub 4, Culv N, Wat'way 8 |
| Points for Condition | 7.00 |

#### SAFETY FACTORS

| Deck Geometry | 4 |
| Lanes On | 2 |
| Bridge Width (m) | 9.1 |

#### TRAFFIC FACTORS

| ADT | 3,093 |
| Func Class | 07 |

#### FINANCIAL FACTORS

| MTF Received | $19,719,087.00 |
| Population | 230,183 |
| Roadway Miles | 159.45 |
| Deck Area (sq m) | 30,526 |

#### PRELIMINARY TOTAL

| Load Capacity And Condition Points | 4.78 |
| Safety Points | 7.39 |
| Traffic Points | 9.00 |
| Financial Points | 11.21 |
| TOTAL POINTS | 32.38 |

#### COUNCIL VOTED POINTS

| Structural Adequacy | 8 Pt Max |
| Bridge and Approach Features | 4 Pt Max |
| Detour Evaluation | 4 Pt Max |
| Functional Adequacy | 8 Pt Max |
| Economic Importance | 8 Pt Max |
| Discretionary Project Value | 4 Pt Max |
| COUNCIL VOTED SUBTOTAL | 36 Pt Max |

#### TOTAL POINTS

| 100 Points Max |
Items which the Regional Bridge Council members will vote on are listed below. A brief explanation of the items is provided with guidance.

**Physical Condition**

1. Structural Adequacy (by council)

   The council should consider the overall structural condition of the bridge. Is the bridge structurally adequate for the traffic using it? From a structural viewpoint, should the bridge be replaced or rehabilitated? Even if the structure is closed, is it critical to replace? Just because a bridge is posted does not mean this category should get a higher rating. Some latitude in reasoning is expected.

   A couple of examples:
   a. A narrow camel back bridge posted at 40 tons with a low average daily traffic and negligible commercial traffic may be rated a zero.
   b. Conversely, a functionally adequate structure posted at 60 tons in a heavily industrial area with significant commercial traffic may be rated with maximum points.

   **Vote 0, 1, or 2 points for each of 4 members (8 points maximum)**

2. Bridge and Approach Features (by council)

   Consideration to physical aspects including the roadway width, vertical and horizontal alignment, and overall acceptability of the bridge to the traffic corridor it serves. Are these features a safety concern? A bridge could be substandard but still be acceptable if it meets minimal design criteria and needs of the traffic that uses it.

   **Vote 0 or 1 point for each of 4 members (4 points maximum)**

**Importance of Structure**

1. Detour Evaluation (2 Points Maximum by Calculation, 2 Points Maximum by RBC Vote)

   The detour length is defined as the distance around the bridge from reference line A to reference line B, over a comparable route. Dead end roads are considered as infinite. The distance, traffic volume and impact, driver delay, should be considered. The sum of a, b, & c below are divided by 2.

   a. Distance of Detour recommendation:
      1. 3 miles or less...........................................0.0 points
      2. Greater than 3 to less than 10 miles........ 0.5 points
      3. 10 miles or more....................................1.0 points

   b. Average Daily Traffic recommendation
      1. less than 100 vehicles per day...............0.0 points
      2. 100 to less than 1,000 vehicles per day....1.0 points
      3. 1,000 or more vehicles per day...............1.5 points
c. Driver Delay Guidelines
   Driver Delay = (miles of detour / posted speed) X (average daily traffic) in hours
   
   1. 0 to 50 hours of delay..........................0.0 points
   2. Greater than 50 to 100 hour delay...........0.5 points
   3. Greater than 100 to 250 hour delay.........1.0 points
   4. Greater than 250 hours delay................1.5 points

   \[(\text{Sum of part a + part b + part c}) / 2 = \text{calculated score (2 points maximum)}\]

d. RBC Voting Points: The RBC will determine if, in their opinion, the detour has a significant impact to the area served.

   \text{Vote 0 or } \frac{1}{2} \text{ point for each of 4 members (2 points maximum)}

2. Functional Adequacy (by council)

   An overall evaluation of the importance of the traffic corridor and the effect the bridge condition may be having on the vehicles and the area served. Some structurally sound bridges should be replaced if they are functionally obsolete.

   \text{Vote 0, 1, or 2 points for each of 4 members (8 points maximum)}

3. Economic Importance (by council)

   Consider the economic importance of the structure to the area served. Does it provide primary access to a major employer? Is it critical to serve essential services such as a public works yard, a fire station, or a hospital? Is it a regionally significant transportation link?

   \text{Vote 0, 1, or 2 point for each of 4 members (8 points maximum)}

4. Discretionary Project Value (by council)

   This category of discretionary rating points is for the council to account for other factors not included directly in the other categories. Examples of these factors are:
   a. If an agency is willing to match their project with more than the standard five percent (5%), the council may wish to score this item higher.
   b. The council may feel that a bridge application represents a very good return on investment that will keep the bridge operating adequately for many years to come.
   c. Any other criteria the council feels is relevant.

   \text{Each council member will vote 0 to 4 points and the council will have the opportunity to discuss their voting decision. After discussions have been completed, the total score will then be averaged. The maximum score for this rating item is 4 points.}

\text{Preventative Maintenance (PM) Projects (by council)}

The council members should review PM applications and create a priority list of the PM projects prior to the rating review meeting. The members, as a group, will discuss their individual rankings, their reasoning, and may consider the computer generated points to determine their final list of priorities.
Appendix B : NTSB Notebook

Investigation Issues

- Inadequate load capacity due to a design error
- Why the collapse occurred
- Why the design error went undetected for 40 years
- Gusset plate issues related to distortion and corrosion

Summary of Collapse Events

2 closed outside northbound traffic lanes
2 closed inside southbound traffic lanes

Piles of aggregate
Construction equipment and vehicles
U10 west node
Summary of Collapse Events

Initial Investigation Activities

- Pre-collapse condition of bridge
  - Cracks
  - Corrosion
- History of bridge
  - Construction
  - Inspection
  - Fatigue evaluations
  - Prior maintenance projects

Initial Investigation Findings

- Most of the structure was in good condition
- Generally well maintained
- Significant attention given to fatigue issues
- Inspected more frequently than required

Initial Investigation Findings

- Two previous construction projects had significantly increased the dead load
- Construction activities on day of collapse had concentrated weight over node U10 west
- Physical evidence indicated that failure at U10 was initiating event
Initiating Event

- Analysis of surveillance camera collapse video
- Inspection of bridge components
  - Superstructure
  - Bearings
  - Piers
- Additional analyses corroborated inspection findings

Fracture and Deformation

- Initial compression failure
- Initial tension fracture
**Gusset Plate Thickness**

- 1.5/8” thick gusset plate (100 ksi) — 2 of 29 gusset plates
- 1” thick gusset plate (50 ksi) — 13 of 29 gusset plates
- 5/8” thick gusset plate (50 ksi) — 4 of 29 gusset plates
- 1/2” thick gusset plate (50 ksi) — 10 of 29 gusset plates

**Gusset Plate Shear Analysis**

**Finite Element Modeling**

- Orange and red shading: exceeds yield stress

**Factors That Did Not Contribute**

- Corrosion damage
- Fracture of a floor truss
- Pre-existing cracking
- Bearings and piers
Increases in Dead Load

• 1977 Modification
  – Deck thickness increased
  – Added over 3 million pounds
• 1998 Modification
  – Barriers / deicing system
  – Added 1.2 million pounds
• August 1, 2007
  – Construction materials concentrated above U10

Concentrated Construction Loads

[Diagram showing construction loads with labels for construction materials and equipment weights]

Increasing Loads on U10W Gusset Plate

[Bar chart showing total load at collapse with categories for construction materials and vehicles, traffic, 1977 added deck (less milled-off lanes), 1998 modified barriers]

Expected capacity of gusset plates for proper AASHTO design:

- Construction Materials and Vehicles
- Traffic
- 1977 Added Deck (Less Milled-off Lanes)
- Dead Load of Original Bridge Design

[Bar chart showing total load at collapse with labels for construction materials and vehicles, traffic, 1998 modified barriers]

Missing reserve capacity for proper design:

- Construction Materials and Vehicles
- Traffic
- 1998 Modified Barriers
- 1977 Added Deck (Less Milled-off Lanes)
- Dead Load of Original Bridge Design
Accident Loads on ½-inch-Thick Gusset Plates

- Stress
- Yield stress
- Allowable

Detection of Design Error

- Error not discovered during original checks and reviews by:
  - Design firm
  - State and federal transportation officials
- Other opportunities for detection
  - Load ratings
  - Annual inspections

Load Ratings

- Required when significant change occurs that affects load-carrying capacity
- First load rating performed in 1979
  - Pavement overlay project to increase thickness of bridge deck
- Additional load ratings performed in 1995 and 1997
  - Modifications to barrier system
**Load Ratings**

- Load rating programs do not include or consider gusset plate strength
- If gusset plates had been included in load ratings
  - Should have revealed improperly designed gusset plates
  - May have determined that improperly designed gusset plates were controlling members

**Bridge Inspections**

- Bridge was inspected at a frequency greater than required by NBIS
- Condition ratings
  - Deck
  - Superstructure
  - Substructure
- Evaluate condition, not design adequacy

**Gusset Plate Distortion**

- Bowed gusset plates not addressed through inspections
- At least one inspector had observed bowing but did not report it
- Lack of specific training references to bowing could cause bridge inspectors to give inadequate attention to this condition
Gusset Plate Corrosion

- Corrosion not a factor in I-35W bridge collapse
- Visual inspections alone are inadequate to detect or quantify gusset plate corrosion
- NDE can greatly enhance accuracy of inspections
- Use NDE when appropriate to evaluate gusset plates
**Issues**

- The design error was not initially detected during
  - Reviews by the design consultant
  - Reviews by Federal or State transportation agencies
- The design error remained undetected
  - Through subsequent load ratings
  - Through annual bridge inspections

REPORTS AVAILABLE AT:
www.ntsb.gov/publictn/h_acc.htm