MICHIGAN DOT'S RESEARCH IN ACTION TOWARDS THE GOAL OF BRIDGES FOR LIFE

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ABSTRACT

The subject of this paper is Bridge-Research and Implementation of Research Findings for improving bridge conditions. The Michigan Department of Transportation (MDOT) conducts Bridge Research based on the needs defined through biennial bridge inspection program. MDOT has about 4,418 bridges on its Interstate, US and Michigan routes under its jurisdiction. Most of the research work is awarded to the Centers of Excellence which are part of the Civil & Environmental Engineering Departments at the major universities in the state of Michigan.

Implementation of research results is given high priority to improve bridge conditions and therefore, longevity of the existing bridges.

The main focus areas of this paper are a) Prestressed Precast I beam/box beam bridges with reinforced concrete decks, b) short and medium spans, and c) bridges under MDOT's jurisdiction.

Keywords: Bridges for Life, Bridge Component Evaluation, Bridge Research Implementation

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INTRODUCTION

The goal of "Bridges for Life" can be stated with two objectives. The first objective is to maintain the current inventory of bridges by improving overall conditions of the bridges and reducing the number of structurally deficient and functionally obsolete bridges on the roadway system.

The second objective is to design new bridges using a) the Load and Resistance Factor Design (LRFD) method, and b) high strength and durable materials. The High Performance Concrete and Prestressed Concrete bridge elements are most suitable. Construct these new bridges achieving high quality control and quality assurance, and followed by a preventive maintenance program in place.

This paper places emphasis on the first objective of maintaining and improving the current inventory of bridges with focus on utilizing bridge research findings. MDOT is conducting research towards building new bridges with long term (75 to 100 years) life expectancy. MDOT is also participating in "Innovative Bridge Program" under the Federal Highway Administration's sponsorship to utilize High Performance Concrete, Self-Consolidating Concrete, Composite materials and rapid bridge construction techniques.

CONCEPTS TO DESCRIBE BRIDGE LIFE

In order to assess ability bridges to provide safe and reliable services, several terms such as Structurally Deficient and Functionally Obsolete are used. The Inventory and Operating Ratings of bridges, based on the AASHTO specifications, are also used for this purpose.

In order to improve service life of bridges, let us take a holistic approach. As the bridge population is aging this new holistic approach can help the Transportation Agencies in managing the existing bridge population so that life of bridges is extended to 75 years to 100 years before these bridges may need total replacement.

The holistic approach involves evaluating each bridge component and its impact on structural integrity, safety of a bridge, and its ability support all legal truck loads.

Following components need to be considered for overall evaluation of a bridge.

- Bridge Railing
- Bridge Deck Overlays
- Reinforced Concrete Bridge Decks
- Expansion Joints
- Bridge Deck Drainage System
- Prestressed Concrete I Beams/Box Beams
- Bearings
- Reinforced Concrete Piers
- Abutments
- Foundations

The concept is to evaluate the conditions of these components through biennial bridge inspection, and define needs for research based on observed statewide problems. Implementation of research findings and technology transfer activities provide necessary tools to the engineers in improving overall conditions of bridges.

MAJOR CHALLENGES

- Corrosion: The bridges in the Snow Belt states such as Michigan are subjected "corrosive" effects of deicing salt used on highways and bridges for snow and ice removal during the Winter months. Corrosion of steel reinforcement as well as prestressing strands is a major concern.

- Durability of Concrete: Durability of concrete is also a major concern for older structures. Bridge deck concrete has shown signs of cracking, spalling, and delaminations due to shrinkage, thermal effects, freeze-thaw cycles, salt ingress and alkaline silica reactivity (ASR). Even few new reinforced concrete decks show signs of cracking due to shrinkage and improper concrete curing. Due to corrosion and concrete deterioration, in few cases, concrete from bottom of old (30+ years) deck slab has fallen on lower levels of the freeways. This is a major safety issue for MDOT, particularly in the Detroit Metropolitan area. MDOT has taken actions to address this safety issue.

- Structural Systems: The older structures (built in 60's & 70's) were mostly simple span structures, which resulted in the use of expansion joints on the top of bearings and pier caps. Leaky expansions joints have caused PCI Beam/Box Ends to deteriorate. The reinforced pier caps and columns show signs of delamination, spalling of concrete and corrosion of steel reinforcement.

- Highway Loads: Live load carrying capacity needs to be evaluated from time to time for few old bridges. State of Michigan allows 11 Axle, 77 Ton (154,000 Lbs) gross weight legal trucks on its state trunk line system. In the past MDOT has used "Bridge Load Testing" program where analytical results of the Bridge Rating need to be verified by "Bridge Load Testing".

- Scour: Potential Scouring of bridge foundation is a major concern. Impact floods during the Spring snowmelt and the Summer storms needs to be evaluated, by following FHWA's guidelines. Calibration of these guidelines to Michigan's geology, and hydrology is needed.

BRIDGE RESEARCH PROGRAM

MDOT's bridge research program is designed to address above mentioned major challenges, as well as, how to improve all the bridge components of individual bridges. Since FY 2000 through FY 2006, MDOT has sponsored about thirty (30) bridge research projects. A complete list of research projects titles is given in the Appendix A.

In addition, MDOT has received funding from FHWA under "Innovative Bridge Program". A list of MDOT's projects under this program is presented in the Appendix B.

SOLUTIONS TO MAJOR CHALLENGES

- Corrosion:
  - Use of epoxy coated reinforcement (since 1975)
  - Larger reinforcement cover, 3" cover for top mat in the bridge decks (since 1975), 9" thick reinforced concrete bridge deck
  - Improving concrete mix designs for high performance
  - Stainless steel or stainless steel clad reinforcement in the bridge decks
  - Evaluation of GFR reinforcement in bridge decks
  - Evaluation of MMFX- corrosion resistant reinforcement
  - Use of GFR sheets for PCI Beam/Box repairs and column wrappings
  - Use of latex modified concrete or silica fume modified concrete for bridge deck overlays
  - Improving bridge deck drainage system
  - Use of concrete coating for bridge railing, and substructure units

- Durability of Concrete:
  - Improved mix design, for high performance (strength, permeability, & durability)
  - Use of shrinkage compensating cement for deck concrete

- Structural System:
  - Preferred choice of continuous structure over simple spans
  - Continuous for live load designs, with expansions joint over abutments or in the approach slabs
  - Preference to use of PCI Beam or PC Box beams. Use of bulb T PCI Beams for span up to 120 feet or more

- 6” concrete deck over PC Box beam bridges to provide better structural performance of the deck

- Live Load Capacity
  - Bridge Load Testing program covering short, and medium span bridges was completed by MDOT. Results indicate that the bridge superstructures have significantly more live load carrying capacity than required for the legal truck loads. MDOT analyses and rates bridges using the AASHTO specifications.
  - Load Tests with one 77 ton truck with eleven axles, on the span as well as two 77 ton trucks side by side on the same span, were completed by MDOT.

- Scour of Bridge Foundation
  - This research is just getting underway. The main objective is to accurately predict scour depths at piers and abutments of bridges over waterways taking into account Michigan’s geology, and floods in various river basins in Michigan.

IMPROVING DURABILITY OF BRIDGE COMPONENTS

Bridge research findings have pointed out ways for improving bridge components as follows:

- Bridge Concrete Barrier Railing

In Michigan, most of the bridge concrete barrier railings are poured by using continuous slip casting method. Improper consolidation of concrete can result in surface as well as interior voids. Accumulation of salt water in these areas leads to early signs of deterioration. The research findings recommend to improve consolidation of concrete.

- Bridge Deck Overlays

Latex Modified Concrete and Silica Fume Modified Concrete overlays are used to improve corrosion resistance and ride quality. After proper surface preparation about 1 ½ inch thick overlays are applied. Eight day wet-curing is used. These overlays provide 15 to 20 year service based on observed performance of these overlays. Research is being conducted on ways to maintain these overlays even for a longer period of time.

<u>Concrete Bridge Decks</u>

In order to avoid timber forms during deck casting, MDOT has allowed use of stay-in-place forms. In few cases, stay-in-place concrete deck panels have been used.

For bridges built in 1970’s and 1980’s under side of the bridge deck slabs are showing signs of deterioration. Corrosion of lower layer of steel reinforcement, deterioration of concrete, and vibrations of bridge superstructure due to traffic loads have caused falling of deck concrete from bottom of these slab. MDOT has given high priority to monitor

these older decks. A preventative maintenance program includes removing loose concrete by scaling operation, and in few cases, providing timber false work to catch any loose concrete from under side of the bridge deck. Total replacement of these bridge decks is planned in the near future.

The state-of-the-art bridge decks that are part of ongoing research implementation and technology transfer program have corrosion resistant reinforcement, and high performance concrete.

MDOT design standards call for 9 inch reinforced concrete bridge decks, with 3" cover for top steel reinforcement and 1 ½" for bottom steel reinforcement.

Bridge Deck Drainage

A proper design to handle bridge deck surface run off is important. All the down spouts, if needed, are extended below bottom of the beams.

- Expansion Joints

MDOT is providing new improved expansion joints on bridges. One of the research projects involves investigating use of "link slabs". The link slabs are short length slab composed of strain-hardening cementitious composites cast in the deck at expansion joint location. Currently field tests are going on, and if proven successful, link slabs can provide an alternative to use of expansion joints in forming jointless bridge decks.

- Prestressed Concrete I Beam/Box Beams

    - In the 1990's MDOT developed PC Bulb T. Number of ideas were taken from Nebraska DOT's PC Bulb T shape and design.
    - MDOT is working on rapid bridge construction techniques using precast bridge elements.
    - The older bridges, where PC I Beams and Box Beams were used, need preventive maintenance to repair damage due to corrosion, particularly at the beam ends. Research is ongoing to access conditions and provide suitable repair techniques.
    - MDOT has used GFR sheets to repair and improve strength of PC Beams and Boxes.

- Bearings

Bearings seem to be less of a problem, as compared to, other bridge components. Elastomeric bearing pads are providing a good long term performance. In few cases, for older bridges, MDOT has replaced these bearings with new elastomeric bearing pads.

- Reinforced Concrete Piers

In older bridges, where simple span arrangement was used, leaky expansion joints over top of pier cap have caused deterioration of pier cap and columns. Depending upon the extent of deterioration, pier caps are repaired or replaced. For reinforced concrete columns, MDOT is evaluating use of GFR sheets for column wrappings, to repair and strengthen columns.

- Abutments

Reinforced concrete abutments have provided excellent performance. Minor problems are due to poor foundation drainage, scour and excessive thermal forces causing cracks in the abutment wall specifically on skew bridges. Minor concrete patching, proper slope protection, and proper surface drainage for embankments near abutments have helped to improve overall conditions. Scour protection for abutments of bridge over waterways is also important activity.

- Foundations

MDOT has used spread footings for many older bridges over waterways. Current research is evaluating scour depth calculations and adequate scour protection. In addition to the AASHTO & FHWA guidelines (HEC-18), MDOT's research on scour evaluation will be customized to Michigan's environment.

MDOT is also investigating use of micro piles to retrofit existing pier foundations (spread footings) to improve scour safety.

SUMMARY

This paper has presented MDOT's past seven year bridge research program. The research program has provided tools to the engineers for improving conditions of bridge components of the existing bridge population. The research program is taking lead in evaluating LRFD design method, rapid construction techniques and new high performance materials.

Implementation of research results, as well as, increase funding level for bridge program has helped in making excellent progress towards the goals set by MDOT.

APPENDIX A:

MDOT Sponsored Bridge Research Projects 2000-20007

1. Causes & Cures for Cracking of Concrete Barriers (Joint Project w/ WSU & MTU)
2. Investigate Cause and Develop Methods to Minimize Early-Age Cracking on Michigan Bridge Decks
3. Development of Durable Bridge Deck Overlays for Ready Mix Applications
4. Stainless reinforcement in Bridge Decks
5. Stainless-Clad Reinforcing Bars in Bridge Decks
6. Development Length of Stainless Steel Reinforcing Bars
7. Durable Link Slabs for Jointless Bridge Decks Based on Strain-Hardening Cementitious Composites
8. Combining Link-Slab, Deck Sliding Over Back-Wall, and Revising Bearings
9. Non-Metallic Reinforcement of Concrete Bridge Decks
10. Verification of Girder Distribution Factors for Bridges
11. Investigation of Current Bridge Loading vs Design Loading
12. Forecast & Resolve Deterioration Problems with the Ends of PC Beams-Causes & Cures of PC Bridge Beam End Deterioration
13. LRFD Load Calibration for State of Michigan Trunkline Bridges – Phase III
14. Investigation of Current Bridge Loading vs Design Loading
15. Repair & Strengthening of Reinforced & Prestressed Concrete Beams Using CFRP Glued-On Plates
16. Sensors to Monitor Bond in Concrete Bridges Rehabilitated with FRP
17. Determining the Impact of the AASHTO LRFD Bridge Code & Transition the Department into the use of the AASHTO LRFD Design Code
18. Development of a Guide for the Evaluation of Existing Bridges Phase II
19. Causes and Cures for Bridge Deck Corner Cracking on Skewed Structures
20. High Performance Materials for Rapid Durable Repair of Bridges and Structures
21. Identification and Development of Rapid Bridge Replacement Techniques Using Pre-cast Concrete Elements
22. Ultra-High Performance Concrete for Michigan Bridge Materials Performance Phase I
23. Monitoring and Evaluation of Rapid Bridge Deck Technique at Parkview, Kalamazoo
24. Condition Assessment and Methods of Abatement of Pre-stresses Concrete Box Beam Deterioration
25. Assessment of Concrete Bridge Deck Overlays
26. Transverse Post Tensioning of Side-by-Side Box Girders
27. Design for Strand De-bonding at Ends of Pre-tensioned Beams
28. Skewed Bridges
29. Investigate Causes and Develop Methods for Preventing Falling Concrete from Bridge Decks: Reasons, Detection & Mitigation

APPENDIX B:

MDOT's "Bridge Technology" Projects funded by the Federal Highways (FHWA) under Innovative Bridge Program

Project #- MI-1999-01
Material(s)- FRP Bonded Reinforcement
Element(s)- Pier Columns
Bridge Name(s)- I-96 over US 27 (Lansing Rd) Lansing
Project Description- Rehabilitation- 4-span, simple span bridge; wrap deteriorated, square concrete columns w glass and carbon fiber reinforced polymer (FRP) composite wraps after minimal repair; monitor and evaluate performance.

Project #- MI-1999-02
Material(s)- FRP Prestressing, FRP Rebar
Element(s)- Griders-Concrete Double "TEEs", Deck Slab, Superstructure
Bridge Name(s)- City of Southfield Bridges
Project Description- New Bridge- Twin Double-T prestressed concrete beam bridges (each is 260' long x 28' wide); one bridge will be built w/ fiber

Project #- MI-2000-01
Material(s)- FRP Rebar
Element(s)- Deck Slab
Bridge Name(s)- M-15 over Goodings Creek, 1.2 km south of Vassar, Michigan
Project Description- New Bridge- Single span spread prestressed box beam bridge (49' x 45' wide); deck slab reinforced w/ aramid fiber reinforced polymer (FRP) composite rebars

Project #- MI-2001-02
Material(s)- Clad Stainless Steel Rebars
Element(s)- Deck Slab
Bridge Name(s)- n/a
Project Description- Replacement- Utilizing Clad Stainless Steel reinforcing bars in a bridge deck slab in order to prevent future corrosion damage

Project #- MI-2003-01
Material(s)- Clad Stainless Steel Rebars
Element(s)- Deck Slab
Bridge Name(s)- M-52 over Shiawassee river
Project Description- Bridge Replacement: 3-span bridge (150' long x 47.5' wide); clad stainless steel reinforcement in concrete bridge deck

Project #- MI-2003-02
Material(s)- MMFX Rebars
Element(s)- Deck Slab
Bridge Name(s)- I-94 over Shook Road and C & O RR
Project Description- Brigde Replacement: 4-span bridge (238’ long x 50’ wide); MMFX steel reinforcement in concrete bridge deck

Project #- MI-2004-01
Material(s)- Self Consolidating Concrete
Element(s)- Girders- Concrete Box
Bridge Name(s)- M-50 over Grand River
Project Description- This project will provide for a concrete bridge superstructure replacement, using self consolidating concrete (SCC) for the prestressed beams. The SCC beams are being evaluated as a potentially durable and cost-effective replacement.

Project #- MI-2004-03
Material(s)- Clad Stainless Steel Rebars
Element(s)- Deck Slab
Bridge Name(s)- M-43 over Sebewa Drain
Project Description- Prestressed concrete spread box beam, single span, 35 feet long, 36 feet wide, concrete deck. Innovative material consists of stainless clad steel reinforcement used for concrete bridge deck

Project Name- M-153 (Ford Road) under Greenfield
Material(s)- High Performance Concrete
Element(s)- Deck Slab