MnROAD Lessons Learned and Future Initiatives

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MnROAD Research Conference
October 4, 2011
Presentation Outline

- Introduction to MnROAD
- Phase – I
  - HMA Lessons Learned
  - PCC Lessons Learned
  - Other Lessons Learned
- Phase - II
- Recent & Future Initiatives
Introduction to MnROAD
A long-term accelerated pavement testing facility that gives researchers a unique, real-life laboratory to study and evaluate the performance of materials used in roadway construction.
MnROAD Original Construction

History of Test Sections
- Original Funding ($25M)
- Original Construction (‘92-'93)
- Open to Traffic (‘94)

Layout and Designs
- Mainline / Low Volume Road
- Asphalt, Concrete, Aggregate Cells
- 3,5,10 Year Designs

Phase I
- 1994-2006

Phase II
- 2007-present
MnROAD Operations

- Traffic Loading
  - LVR 80K Truck, ML Traffic Switches

- Performance Monitoring
  - Coordination, Collect & Share Data

- Instrumentation & Data Management
  - 9000+ Sensors
  - Oracle Database

- Research Support

- Facility / Buildings
Instrumentation

Soil Pressure
HMA and PCC Strains
Deflection
Weigh in Motion
Temperature
Moisture
Frost
Water Quality
MnROAD Traffic Loadings

Low Volume Road Traffic
MnROAD 5-axle Semi
Inside Lane = 80k truck 5 days/week
Outside Lane = 102k truck (pre-2007); no traffic since then

Mainline Traffic
I-94 WB Public Traffic
28,500 AADT
12.7% Trucks
Pavement Performance Monitoring

- FWD testing
  - Regular and special testing
- Dynamic load testing
- Distress surveys
- PCC joint faulting
- Surface characteristics
- HMA rutting
- Coring
- Forensics
Data Collection Improvements

- Sensor Installation Techniques
- Roadway Profile Measurements
  - Rutting and Curl/Warp
- GPS Vehicle Tracking System
- Dynamic Data Collection
  - Radar and wireless triggering
- Ride Quality Measurements
  - High speed, lightweight, and benchmark profilers
MnROAD Database

- 17 years of data (some data every 15 minutes)
- Over 1 Billion rows
- SQL-Relational Database

Contents
- Test section parameters
- Sensor data
- Monitoring data
- Lab testing results

Current activities
- Table reorganization
- Data validation procedures

MnROAD Data Release
Data Validation Tools

FWD File Name
- 001DWP021710.mdb: scan failed
- 001A0FDP021710.mdb: scan failed
- 001MDLD02171C.mdb: scan passed
- 001MDLF02171C.mdb: scan failed

FWD Scan

“PAT”

TC Flags
Dynamic Load Testing Analysis

Peak
Pick
Program
HMA Lessons Learned
Original Asphalt Cell Variables

- Thickness
- Binder
  - AC-20 (PG 64-22)
  - AC 120/150 (PG 58-28)
- Mix Design Methods
  - 35, 50, 75 Blow Marshall
  - Gyratory
- Single Aggregate Blend
- Base and Subgrade Materials
Typical HMA Distress Types

- Top Down Cracking
- Transverse Cracking
- Rutting
- Less Rutting in Passing Lane
Environment Drives Pavement Performance

- Thermal Cracking
Transverse Crack Forensics

Observations

- Ridges of fine material (2.5”)
- Cracks as wide as 1” at bottom of slab
- Crack affects deflections about 2-3 feet on either side of the crack.
- Pumping similar to that of rigid pavements
MnDOT Network Thermal Cracking

- MnDOT Pavement Management Data
- MnROAD Cells
  - Cell 34 (1999)
  - Many Phase II Cells (2007+)

Graph showing median number of transverse cracks per 305 m (per 1000 ft) over BAB age years. Key data points include:

- PG XX-34 Avg.
- 1971 to 1980
- 1981 to 1990
- 1991 to 1994
- 1995 to 1999

2 cracks/1000’ at age 7!
Shoulder Cracking

- Cell 31 – cracks from shoulders propagate through lanes
- PG 52-34 + RAP is common shoulder mix
Keep Track of Your Shoulders!

- **Marshall**
- **Gyratory**

Graph showing data points for Shoulder Transverse Cracking and Mainline Transverse Cracking, with different markers for Marshall and Gyratory methods.
10+ Year Effort

- Fracture testing on lab & field mixtures
- Developing LTC mix specification
Aging

- Embrittlement of asphalt
  - Leads to cracking
- Function of depth, time, binder properties, etc.
- Surface treatments to reduce aging
- U of MN, Texas A&M, Asphalt Institute studies
Current Designs are Too Conservative

- Original 3, 5, 10 year cells performed long beyond their design lives
  - Cell 1 still in service
  - Little fatigue cracking, rutting, or other traditional structural failures
- Old design methods extrapolated way beyond original scope
- Not economical – need to accurately predict how long pavements will perform
Predicted Design Lives

- MnPAVE Design
- R-Value Design

Expected Life (years)

Cell

Year
- 24
- 25
- 26
- 27
- 28
- 29
- 30
- 31
Cell 28 Forensic Findings

Ground penetrating radar (GPR) investigation
Pavement thickness varied from 2.4”- 3.6”

Representative Trench Area (3.1”)

Fatigue Cracking

Failed Trench Area (2.5”)

Pavement Surface Thickness
Air Voids – 2009 Study

More traffic = lower air voids!
Rutting Observations

- Rutting has occurred only in the upper lifts
- Base type is not a factor for the Mainline
Mainline Maintenance Treatments

- Successful in reducing rutting
- Cracking returns after 1 winter
- Single and double slurry treatments with transverse crack repair (Mastics and MiniMac applications) are performing best
- Crack Seal ride quality
1999 LVR Superpave Experiment

3 LVR Test Cells
Cell 33 (PG 58-28)
Cell 34 (PG 58-34)
Cell 35 (PG 58-40)

Show different rutting and LTC performance
PCC Lessons Learned
MnROAD is Unique!
Concrete Pavement Research

- Phase 1 (1994-2007) – Structural Design Verification
  - 5 and 10 year design PCC test sections
  - Low volume design PCC test sections

- Other “Phase 1” studies
  - 1997, 2004: Thin and ultra-thin whitetopping
  - 2000: Thin full-depth concrete
  - 2000: FRP dowels

- Each test cell approximately 150 m (500 ft) long
Phase 1 Concrete Test Cells

- 14 of 40 original test cells
  - Interstate designs (live traffic)
    - 5-year design life test cells (#5-9)
    - 10-year design life test cells (#10-13)
    - Mn/DOT Design Method (mod. 1981 AASHTO)
  - Low Volume Road designs
    - Test cells #36-40
- Each test cell approximately 150 m (500 ft) long
MnROAD Concrete Cell Design Variables

- Thickness: 7.5”, 9.5”, 6.0”, 7-5.5-7” (190,240,150,178-140-178mm)
- Joint spacing: 15’, 20’, 24’ (4.6, 6.1, 7.3 m)
- Pavement width: 12’/12’, 13’/14’ (3.6/3.6, 4.0/4.3 m)
- Dowel bar diameter: 1.0”, 1.25”, 1.5” (25, 32, 38 mm), undoweled
- Skewed transverse joints
- Tied concrete shoulder (Test cells 8 & 9)
- Base materials: Granular, PASB (Permeable Asphalt Stabilized Base)
  - Subgrade materials: Silty-Clay, Sand (2 LVR Cells)
- Drained and undrained base
Phase 1 PCC Performance

Mainline cells

- After 13 years only Cell 5 developed cracks
  - Longitudinal/diagonal cracks
  - Settlement of deep (27”) base?
Phase 1 PCC Performance

Low Volume PCC Cells

- Small number of transverse cracks (caused by utility trenches)
- Moderate joint faulting in Cell 40
  - undoweled, clay subgrade
- Significant pumping along shoulder in Cells 38-40 (80k lane)
  - material pumping from shoulder
Joint Load Transfer Efficiency

LTE declined more rapidly in thinner 5 year design cells

Driving Lane, Approach, 9k FWD Load

LTE (%)

'Cell 8, 7.5", 15' panels, 1" dowels

'Cell 10, 9.8", 20' panels, 1.25" dowels
Joint Faulting

Faulting trends in undoweled joints are approximately linear.
### CURRENT DESIGN METHODS

Conservative!

<table>
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<th>Test Cell</th>
<th>Mn/DOT Method</th>
<th>AASHTO '93 (50% Reliab.)</th>
<th>1984 PCA Method</th>
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</table>

T. Burnham (Mn/DOT)
SLAB WARP & CURL

It is difficult to measure!

• Several studies conducted
  • University of Minnesota
  • Michigan Tech
• Still trying to determine best way to characterize and quantify
  • Surface profiling?
  • FWD back-calculation?
EDGE JOINT SEALING STUDY

• Evaluated the effect of routing and sealing the longitudinal lane/HMA-shoulder edge joint

• MnROAD Cell 8 sealed, Cell 7 control

*Mn/DOT (2003): Ruth Roberson, Roger Olson, Chad Millner*
Edge drains primarily drain the edge joint.

The presence of edge drains does not necessarily provide positive drainage for the entire pavement system.

Sealing the edge joint significantly reduces surface infiltration.

**Sealing longitudinal edge joints should be considered as a preventive maintenance technique.**

*Mn/DOT (2003) : Ruth Roberson, Roger Olson, Chad Millner*
MnROAD Phase 1 Finding
New breakthrough formula!
MnROAD Phase 1 Findings

Effect of drainage on joint performance

- High traffic volume:
  - Joints over drainable (PASB) base layers perform best
  - Joints over slow draining bases (CL 5) with no edge drains exhibited significant mid-depth distress
  - Well sealed joints over CL5 base with edge drains perform better
  - Distress occurred without resulting in significant joint faulting

- Confirmed by similar pavements throughout Minnesota
MnROAD Phase 1 Findings
Effect of drainage on joint performance

- Low volume traffic volume:
  - Not as sensitive to drainability of base layer if joint adequately sealed
  - If poorly sealed, slowly draining (CL 5) bases can result in significant joint distress
MnROAD Phase 1 Findings
Effect of drainage on joint performance

**Bottom line:**
Design your pavement system to avoid water retention!
Characterize Rate of Thermal Expansion

\[ y = 0.4523x - 234.65 \quad R^2 = 0.0348 \]

\[ y = 9.613x - 525.75 \quad R^2 = 0.921 \]

T. Burnham (Mn/DOT), A. Koubaa (U of M) [2001]
Phase 1 Findings
Whitetopping performance

- Keep panel edges away from wheelpaths
- Interlayer bonding is critical for ultrathin whitetopping (<5 in. thick)
- Shrinkage fibers not cost effective
- Reflective thermal cracking is a major distress in Minnesota
- Joint sealing is critical to long term performance
- Best performance from Cell 96
  - 6 inches thick PCC over 7 inch HMA, 5’L x 6’ W panels
  - Matches national trend toward 6” x 6’ x 6’ designs

- Data used extensively in development of national mechanistic-empirical design guide for whitetopping (TPF 5-165) [2012]
Other MnROAD Lessons Learned
1992 MnROAD Research 14 Objectives

1. Evaluate empirical design methods
2. Evaluate mechanistic design methods
3. Develop mechanistic models
4. Verify/improve frost prediction methods
5. Investigate axle loads and pavement performance under spring loading
6. Develop vehicle load damage factors
7. Investigate vehicle gearing/tire systems and pavement performance
1992 MnROAD Research 14 Objectives

8. Investigate asphalt mixes and related pavement distresses/performance
9. Investigate base/subbase properties and flexible pavement performance
10. Investigate base/subbase properties and rigid pavement performance
11. Investigate subgrade type and pavement performance
12. Improve roadway instrumentation
13. Examine “special design variables” in rigid pavements
14. Investigate level of reliability and associated variation in pavement
Phase-I Lessons Learned

- 2007 University of Minnesota Study
- Three more areas were added to the 14
  - Characterizing the MnROAD project (test track expertise)
  - Pavement rehabilitation and maintenance
  - Non-pavement research
Lessons Learned Findings

Organized the “Lessons Learned” into 10 areas
- Climatic Studies
- Drainage
- Educational Benefits
- IRI and Lane Ride Quality
- Low Temperature Cracking
- Low Volume Roads
- Mechanistic-Empirical Design
- New products
- Non-pavement Research
- Whitetopping

Reports on MnROAD Web Site
Lessons Learned – Climatic Studies

- CRREL Materials Tests and Frost Depth Modeling
- Seasonal Variations in Pavements
- Integrated Climate Model
- Low-Temperature Cracking
- Seasonal Load Limits
Lessons Learned – Educational Benefits

- **UM Graduate-Level Students (1994-2004)**
  - Bao, Wenjin
  - Birgisson, Bjorn
  - Bruinsma, James
  - Tanquist, Bruce
  - Clyne, Tim
  - De Sombre, Rachel
  - Fagerness, Aaron
  - Forst, Jesse
  - Glasgow, Drexel
  - Hovan, Jean-Michel
  - Koubaa, Amir
  - Moreno, Angel Mateos
  - Oman, Matthew
  - Ovik, Jill
  - Prakash, Kuppalli S.
  - Schmidt, Sarah
  - Sheehan, Matthew
  - Shongtao, Dai
  - Stroup-Gardiner, Mary
  - Timm, David
  - Van Deusen, David
  - Vandenbossche, Julie
  - Zhang, Wei
  - Non – Pavement
    - Elfering, Jodi
    - Gale, Samuel
    - Lau, Wing
    - Shankwitz, Craig
    - Wang, Dong

- **Educating Pavement Engineers**
  - University of Minnesota – Miles Kersten Chair
  - Center for Transportation Studies
  - TERRA
  - Many Conferences and Tours Given
Lessons Learned – Low Volume Roads

- Low-Volume Road Design
  - ROADENT/MnPAVE Development
- Aggregate Roads
- Oil Gravel - Finnish Design
- Miscellaneous Projects
  - SuperPave
  - Forensics
  - Joint Faulting
  - LVR Conferences – Tech Transfer
Lessons Learned – New Products

- Dynamic Cone Penetrometer
- Ground Penetrating Radar
- Continuous Compaction Control and Lightweight Deflectometer
- New Materials
Lessons Learned – Non-Pavement

- Intelligent Transportation Systems (ITS)
- Pavement Marking (Striping)
- 60 inch Culverts
- Roadside Vegetation Studies
- Homeland Security Drills
- State Patrol Accident Reconstruction
- Profile and Noise Rodeo Support
- Snowplowing
- WIM Calibration, Truck Instrumentation
- Many R&D Partnerships
Phase II Research Themes

- Innovative Construction
- Green Roads
- Preservation and Rapid Renewal
- Surface Characteristics
- Non-Pavement Research
TERRA Partners

- **Academia**
  - Iowa State University
  - Michigan Technological University
  - University of Minnesota

- **Industry**
  - Aggregate and Ready Mix Association of Minnesota
  - American Concrete Pavement Association
  - American Traffic Safety Services Association - Northland Chapter
  - Associated General Contractors of Minnesota
  - Caterpillar Global Paving
  - Concrete Paving Association of Minnesota
  - Mathy Construction Company
  - Minnesota Asphalt Pavement Association
  - RMC Research and Education Foundation
  - Road Science

- **Government**
  - Iowa DOT
  - Michigan DOT
  - Minnesota DOT
  - Minnesota Local Road Research Board
  - New York State DOT
  - North Dakota DOT
  - Norwegian Public Roads Administration
  - United States Federal Highway Administration
  - Wisconsin DOT
Phase II Lessons Learned
(2007-2008 Construction)

Will be discussed throughout the day
Recent Initiatives
Unbonded Overlay, Fabric Interlayer

- **2008 Construction**
  - 4” and 5” Panels
  - 15’L x 14’ W panels = cracks

- **2011 Construction**
  - 5” Panels
  - 6’L x 6.5’ and 7.0’W panels
  - Geotextile Interlayer
    - Same Specification as I-35
    - Germany/Missouri Experience
    - Industry Initiative
New Concrete Research

- 2011 Longitudinal Tining (FHWA Initiative)
- Open Graded Aggregate Base
  - Drainable and Stable
- Multiple Aggregate Gradations
  - Reduce Paste Content
  - Improve Workability
  - Enhance Smoothness
Roller Compacted Concrete

- 2011 Mainline Shoulders
  - 2 Test Cells
  - Selling Points - Quick Strength and Construction

- Experience from Georgia, Iowa, others
Whitetopping Repairs

- Many Reports
- 2011 Concrete Panel Repair Project
  - 1997, 2004
  - 7-14 years performance
  - Replace panels on Cell 63
  - Diamond grind Cells 63 & 96
  - Faulting after 14 years
Stabilized Full Depth Reclamation

- Fatigue Cracking in Original Cell
  - 4” HMA / 6” class 5 / clay subgrade
- 2011 FDR Construction
  - Reclaim 6 inches
  - Engineered emulsion
  - Chip seal surface
- Promote 100% Recycling
- Application of LVR and residential streets
2011 Partial Depth Concrete Repairs

- Safety and ride quality concerns
- Transverse and Longitudinal Joint Spalling
- 7 Original Test Cells
- ~15 different patching mixtures
- ~150 repairs
- Contractor Involvement
- Labor intensive
HMA Performance Testing

Phase I – Synthesis of Existing Tests and State DOT Specifications
- Many states require stripping and/or rutting test
- Cracking test requirements are less common
- DCT, IDT Strength, TX Overlay Tester are most promising candidates

Phase II – Laboratory Testing to Propose a HMA Cracking Performance Specification
Step Frequency GPR

- Measures at multiple frequencies with a large array of transmitters/receivers
- Accurate measurements shallow and deep
- Tested MnROAD cells and multiple state projects
- Layer thickness, locate dowel/tie bars, material properties, detect voids, surface profile
Rolling Resistance

- Tested all ML & LVR cells: HMA & PCC
  - Jerzy Ejsmont (U of Gdansk), Ulf Sandberg (VTI)
- Funding from FHWA, MnDOT via pooled fund projects
- Research Goals:
  - Understand how pavement surfaces affect rolling resistance
  - Correlate rolling resistance to other surface characteristics
  - Reduce energy consumption, GHG emissions
Future Trends

- Rehabilitation
- Construction Uniformity
- Sustainability
- Surface Characteristics
- Continued Partnerships
Proposed Pooled Fund Studies

- Development of an Improved Design Guide for Unbonded Concrete Overlays
  - Solicitation 1309 – Posted Fall 2011
- Identify suitable interlayer materials
- Develop M-E design guidelines
- National Design

WWW.Pooledfund.org
Proposed Pooled Fund Studies

- Development and Implementation of Non-Destructive Testing
  - Solicitation 1310 – Posted Fall 2011
  - Research NDT ready for implementation
  - Enhance data analysis and visualization tools

WWW.Pooledfund.org
Proposed Pooled Fund Studies

- MnROAD other possibilities?
- MnROAD 3rd Phase?
Proposed Pooled Fund Studies

- MnROAD other possibilities?
- MnROAD 3\textsuperscript{rd} Phase?

MnROAD Successful Research
1. Construction Funding
2. Sensor Deployment
3. Research Plan
4. Implementation Plan

WWW.Pooledfund.org
Questions?

- Ben/Tim/Tom
- Ben (9:30) and Tim (12:30)
- MnROAD tours
- Display/Posters
- Presentations Today

www.mndot.gov/mnroad