



MnROAD Concrete Pavement Research – A 2023 Tour

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NCC Spring Meeting, Savannah, GA

4/11/2023



MnROAD Facility

- Full-scale, cold climate pavement test facility near Albertville, MN
- Owned and operated by the Minnesota Department of Transportation
- 3 mile (4.8 km) “Mainline” section with diverted interstate traffic
- 2.5 mile (4 km) “Low Volume Road” closed loop test track (Loaded by 1 truck)
- Multiple pavement test sections
 - Asphalt
 - Concrete
 - Overlays
- Operation began in 1994

Provides opportunity for bold ideas!

MnROAD- Minnesota Road Research Facility


mindot.gov

Between Albertville and Monticello, MN

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MnROAD History

- **MnROAD Phase 1 (1994-2007)**
 - Funded by MnDOT, Mn LRRB and FHWA
 - Experiments determined by MnDOT and Minnesota LRRB
- **MnROAD Phase 2 (2007-2015)**
 - Funded by MnDOT, Mn LRRB and FHWA, Pooled fund partners (state DOTs)
 - Experiments determined by MnDOT, Mn LRRB, Pooled fund partners (state DOTs)



- **MnROAD Phase 3 (2015-?)**
 - Research and operation funded by National Road Research Alliance (NRRRA)
[Construction funding provided by MnDOT (+NRRRA in future)]
 - Experiments determined by NRRRA: Consists of 15 government agency members, with input from 86 industry and academia associate members

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MnROAD Concrete Test Sections 2023

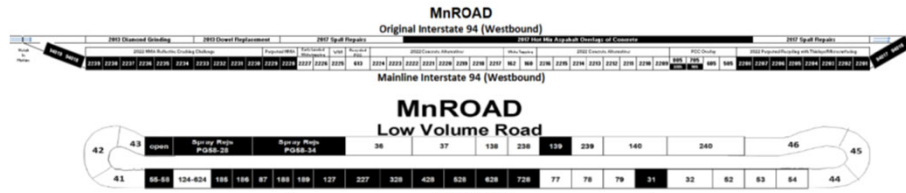
- **Active Concrete Pavement Test Sections**

- 26 - Mainline
- 24 - Low Volume Road
- 47 – Old WB I-94 (Repairs to 1973 JRCP)

- **Mixture of experiments:**

- Jointed plain concrete pavement on gravel base
- Concrete overlay on asphalt
- Concrete overlay on concrete

- **Test sections from all 3 phases (1994-2022)**



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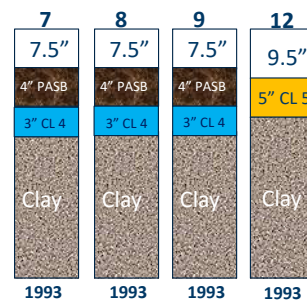
MnROAD Concrete Test Cells 7,8,9 & 12 (1993-2022)

- **Phase 1**

- Cells 7, 8, 9, and 12 – Mainline
- First traffic = 1994

- **Design details:**

- Jointed plain concrete (early 1990's mix specs)
- Panel length/width
 - Cell 7 = 20 ft / 14 ft
 - Cell 8 = 15 ft / 14 ft
 - Cell 9 = 15 ft / 14 ft
 - Cell 12 = 15 ft / 12 ft
- Skewed transverse joints (silicone seals)
- Base layer = Permeable Asphalt Stabilized Base (PASB) or Class 5 gravel
- Dowel bars (epoxy coated steel) = 1"/1.25" dia., 15" long



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MnROAD Concrete Test Cells 7, 8, 9 & 12

- **Loadings**
 - 27+ million CESALS
- **Distress**
 - Very few cracked panels
 - Very little internal joint deterioration for cells on PASB
 - Partial depth repairs needed at 24 yrs.
- **Performance (1994-2022)**
 - Good performance from “thin” design
 - PASB very good at keeping water from saturating joints

Cells removed in 2022





Photo taken @ age = 27 yrs



Breached seal in Cell 12 joint

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MnROAD Concrete Test Cells 36 & 37

- **Phase 1**
 - Cells 36 and 37 - Low Volume Road
 - First traffic = 1994
- **Design details:**
 - Jointed plain concrete (early 1990's mix specs)
 - Panel length/width
 - Cell 36 = 15 ft / 12 ft
 - Cell 37 = 12 ft / 12 ft
 - Skewed transverse joints (silicone seals)
 - Class 5 gravel base layer
 - Sand subgrade
 - Dowel bars (epoxy coated steel)
 - Cell 36 = 1" dia., 15" long
 - Cell 37 = no dowel bars

36	37
6"	6"
5"	12"
Sand	Sand
1993	1993

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MnROAD Concrete Test Cells 36 & 37

- **Loadings**

- 213,000+ passes of 80,000 lb. 5-axle tractor-trailer

- **Distress**

- Cells 36
 - Cracked panels = 2
 - Joint faulting = negligible
- Cell 37
 - Cracked panels = 5
 - Joint faulting = 1 mm (average)

- **Performance**

- Overall very good
- Very little joint faulting, even in undoweled section
- Sand subgrade very beneficial
- Some joint deterioration within joints when seal was breached (slow draining base layer)

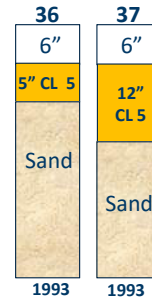


Photo taken @ age = 16 yrs

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MnROAD Concrete Test Cell 32

- **Phase 1**

- Cell 32 - Low Volume Road
- First traffic = 2000

- **Design details:**

- Jointed plain concrete (2000 mix specs)
- 35% GGBFS replacement for cement
- Panel length/width = 10 ft / 12 ft
- Non-skewed, sealed joints
- No dowel bars
- Class 1 gravel bases (former gravel road test section)
- Clay subgrade




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MnROAD Concrete Test Cell 32

- **Loadings**
 - 166,000+ passes of 80,000 lb. 5-axle tractor-trailer
- **Distress**
 - Much pumping early in life
 - Significant number of cracked panels
 - Failed experimental repairs (installed 2013)
 - Short plate dowels
 - Retrofit dowel bars and long plate dowels
- **Several performance reports available**




Age = 22 yrs

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MnROAD Concrete Test Cell 52

- **Phase 1**
 - Cell 52 - Low Volume Road
 - First traffic = 2000
- **Design details:**
 - Jointed plain concrete (2000 mix specs)
 - Panel length/width = 15 ft / 14 ft
 - Non-skewed transverse joints (silicone seals)
 - Dowel bars (/)
 - 1" & 1.25" epoxy coated steel
 - 1.25" & 1.5" fiber-reinforced polymer (FRP)



Dowel bar type	Length, mm (in)	Diameter, mm (in)	Number of joints
Epoxy coated steel	380 (15)	25 (1.00)	9
Epoxy coated steel	380 (15)	32 (1.25)	3
Fiber Reinforced Polymer (FRP)	457 (18)	32 (1.25)	3
Fiber Reinforced Polymer (FRP)	457 (18)	38 (1.50)	3

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MnROAD Concrete Test Cell 52

- **Loadings**
 - 166,000+ passes of 80,000 lb. 5-axle tractor-trailer
- **Distress**
 - No cracked panels
 - Minimal joint faulting
- **Performance**
 - Excellent performance
 - LTE for FRP dowels variable and slightly lower than epoxy coated steel dowel bars

MnDOT Report being published soon




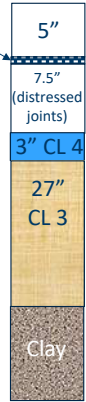
Photo taken @ age = 19 yrs

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MnROAD Concrete Test Cells 505 & 605


- **Phases 2 & 3**
 - Cells 505 and 605 - Mainline
 - First traffic = 2011
- **Design details:**
 - Jointed plain concrete (MnDOT mix)
 - Panel length/width = 6 ft L / 7 ft W
 - Geotextile fabric Interlayer
 - No dowel bars
- **Repairs in 2022:**
 - Full depth panel replacements (w/tie bars)
 - Diamond grind surface

505



2011

605



2011

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MnROAD Concrete Test Cells 505 & 605

- **Loadings**
 - 11+ million CESALs (8+ million trucks)
- **Distress (2011-2022)**
 - Widespread transverse joint spalling
 - Low number of cracked panels
 - Significant joint faulting
- **Performance (2011-2022)**
 - Good performance until faulting developed
 - Faulting not expected (maybe warp & curl?)




Photo taken @ age = 11 yrs

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MnROAD Concrete Test Cells 505 & 605

- **Distress (2023)**
 - All replacement panels in 505 cracked
 - Possible causes
 - Poor support from broken joints below
 - Restraint from tie-bars around perimeter of repairs



Tie bars around perimeter of repairs





Photo taken @ age = 9 months

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MnROAD Concrete Test Cells 160 & 162


- **Phases 2 & 3**
 - Cells 160 and 162 - Mainline
 - First traffic = 2013
- **Design details:**
 - Fiber-reinforced concrete (20% RSR - C1609)
 - Panel length/width = 6 ft L / 6 ft W
- **Repairs in 2022:**
 - Full depth panel replacements (w/tie bars)
 - Diamond grind surface

160



2013

162



2013

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MnROAD Concrete Test Cells 160 & 162

- **Loadings**
 - 9.3+ million CESALs (6.8 million trucks)
- **Distress (2013-2022)**
 - Low number of cracked panels
 - Significant joint faulting
- **Performance (2013-2022)**
 - Good performance until faulting developed
 - Fibers contained tight cracks, but not larger ones
 - The fibers type and dosages did not have a significant impact on the mitigation of joint faulting
 - Several publications available




Photo taken @ age = 9 yrs

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MnROAD Concrete Test Cells 160 & 162

- **Distress (2023)**

- Moderate faulting has returned to many joints



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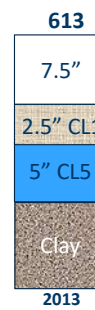
MnROAD Concrete Test Cell 613

- **Phase 2**

- Cell 613 - Mainline
- First traffic = 2013

- **Design details:**

- Jointed plain concrete
- 75% of course aggregate replaced with recycled concrete aggregate
- Panel length/width = 15 ft / 12 ft
- Neoprene sealed joints
- Dowel bars 1.25" epoxy coated steel
- Several joints with drain system under transverse joint only



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MnROAD Concrete Test Cell 613

- **Loadings**
 - 9.3+ million CESALs (6.8 million trucks)
- **Distress (2013-2022)**
 - Low number of cracked panels
 - Some wide transverse joints
- **Performance (2013-2022)**
 - Good performance (little surface distress)
 - MnDOT report underway


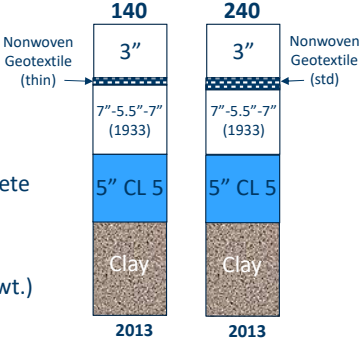


Photo taken @ age = 10 yrs

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MnROAD Concrete Test Cells 140 & 240

- **Phase 2**
 - Cells 140 and 240 – Low Volume Road
 - First traffic = 2013
- **Design details:**
 - Ultra-thin unbonded concrete overlay on concrete
 - Fiber-reinforced concrete (20% RSR - C1609)
 - Panel length/width = 6 ft L / 6 ft W
 - Geotextile fabric Interlayer (thin and standard wt.)



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MnROAD Concrete Test Cells 140 & 240

- **Loadings**
 - 82,300+ passes of 80,000 lb. 5-axle tractor-trailer
- **Distress (2013-2022)**
 - Many cracked panels
 - Very little joint faulting
- **Performance (2013-2022)**
 - Very good performance
 - Fibers appear to be keeping cracks tight
 - Noise issue in cooler condition for panels on standard weight fabric




Photo taken @ age = 10 yrs

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MnROAD Concrete Test Cells 124-624

- **Phase 3**
 - Cells 124-624 - Low Volume Road
 - First traffic = 2017 (Very early loadings)
- **Design details:**
 - Jointed plain concrete (MnDOT standard mix)
 - Panel length/width = 15 ft / 12 ft
 - Unsealed joints
 - Dowel bars = 1" epoxy coated steel, 15" long
 - Staged early loading

124-624

6"
6" CL 6
Sand

2017

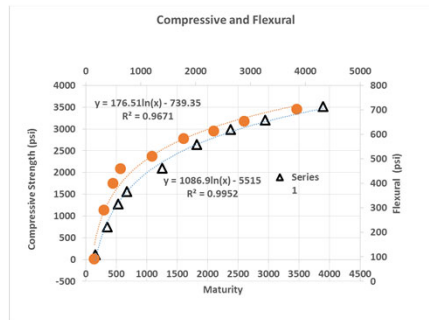


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Early loading of Cells 124-424

Cell x24 Early Loading Sequence		
Maturity (Deg-Hr)	Flexural (psi)	Loads applied to lanes
100	73	1st Load on Cell 124 (forward and back) 3 hrs
200	196	1st Load on Cell 224, 2nd load on Cell 124
300	267	1st Load on Cell 324, 2nd load on Cell 224, 3rd load on Cell 124
400	318	1st Load on Cell 424, 2nd load on Cell 324, 3rd load on Cell 224, 4th load on Cell 124

Starting Day 2, 5 passes per day for first week



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MnROAD Concrete Test Cells 124-624

- **Loadings**
 - 47,300+ passes of 80,000 lb. 5-axle tractor-trailer
- **Distress (2013-2022)**
 - No cracking or surface distress
 - Some wide joints
- **Performance (2013-2022)**
 - Very good performance
 - LTE lower in some joints



Photo taken @ age = 5.5 yrs


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MnROAD Concrete Test Cells 138-238

- **Phase 3**
 - Cells 138-238 - Low Volume Road
 - First traffic = 2017
- **Design details:**
 - Jointed plain concrete
 - Reduced cementitious content mix (470/500 lb/yd³)
 - Panel length/width = 15 ft / 12 ft
 - Unsealed joints
 - Dowel bars = 1" epoxy coated steel, 15" long

138-238



8"
5" CL 5
Clay
2017

No construction issues reported

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MnROAD Concrete Test Cells 138-238

- **Loadings**
 - 47,300+ passes of 80,000 lb. 5-axle tractor-trailer
- **Distress (2013-2022)**
 - No cracking or surface distress
- **Performance (2013-2022)**
 - Very good performance



Photo taken @ age = 5.5 yrs

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MnROAD Concrete Test Cells 139, 239, 339

- **Phase 3**
 - Cells 139-339 – Low Volume Road
 - First traffic = 2017
- **Design details:**
 - Ultra-thin jointed concrete on gravel base
 - Fiber-reinforced concrete (30% RSR - C1609)
 - Panel length/width = 6 ft L / 6 ft W
 - Sealed joints (hot pour asphalt)
 - HMA overlay added to Cell 139 in 2020

139 339 239

3" 3" 4"

6" CL 5 6" CL 5 6" CL 5

4" borrow 4" borrow 4" borrow

Clay Clay Clay

2017 2020 2017

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MnROAD Concrete Test Cell 139


- **Loadings**
 - 9920+ passes of 80,000 lb. 5-axle tractor-trailer
- **Distress**
 - Major cracking of panels
 - Broken/rutted panels
- **Performance**
 - Susceptible to damage from construction traffic loadings
 - Fibers did hold cracks together
 - Needed to replace panels after 1 year
 - After 16000 additional truck passes (Year 3), had to add HMA overlay to keep cell in service

Cell 139 @ age = 1 year

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MnROAD Concrete Test Cell 239

- **Loadings**
 - 47300+ passes of 80,000 lb. 5-axle tractor-trailer
- **Distress**
 - Major cracking of panels
- **Performance (2017-2023)**
 - Fibers holding cracks together
 - 4" thick panels performing substantially better than 3" panels
 - Starting to develop joint faulting



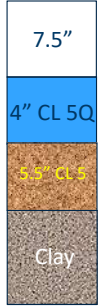
Cell 239 @ age = 5 year

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MnROAD Concrete Test Cells 2209 - 2224

- **Phase 3**
 - Cells 2209-2224 – Mainline
 - First traffic = 2022
- **Design details:**
 - Jointed concrete pavement
 - Alternative cementitious, lower cement content, or carbon sequestration concrete mixes
 - Panel length/width = 15 ft L / 13 ft W
 - Unsealed joints
 - 1.25" dia x 15" L dowel bars
- **Construction issues:**
 - Very few, however some mixes not fully sorted by time of placement
 - Needed to diamond grind most sections due to inadequate texture

2209-2224



2022

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MnROAD Concrete Test Cells 2209 - 2224

Cell	Supplier	Basic Components
2209	ACM – Ultra High Materials	Hydraulic non-Portland cement (100% cement replacement)
2210	Carbon Cure RGC1	Optimized mix w/ASTMC595 Type1L(10) + 30% FlyAsh + Carbon Cure
2211	Carbon Cure RGC2	Control mix w/ASTMC595 Type1L(10) + 30% FlyAsh + Carbon Cure
2212	Carbon Cure RGC3	Optimized mix w/ASTMC595 Type1L(10) + 30% FlyAsh (no Carbon Cure)
2213	Carbon Upcycling – Processed Flyash	ASTM C595 Type1L(10) reduced cementitious + 30% ASCM
2214	Ash Grove	ASTM C595 Type IP(30) with calcined clay pozzolan
2215	Urban Mining – Ground Glass	ASTMC595 Type1L(10) + 30% ground glass pozzolan
2216	TerraCO2 – Manufactured Flyash	ASTMC595 Type1L(10) + 30% ASCM
2217	Carbon Cure Control	ASTMC595 Type1L(10) + 30% FlyAsh
2218	Control Mix (MnDOT mix)	ASTM C595 Type 1L(10) + 30% Flyash
2219	Optimized Mix (CPTech mix)	ASTM C595 Type 1L(10) + 30% Flyash
2220	Burgess Pigments - Natural pozzolan	ASTM C595 Type 1L(10) + 12% Metakaolin + 18% Flyash
2221	3M - Natural pozzolan	ASTM C595 Type 1L(10) + 15% Natural Pozz + 15% Flyash
2222	Hess Pumice - Natural pozzolan	ASTM C595 Type 1L(10) + 30% Natural Pozzolan
2223	Continental Cement – High Limestone	Blended PLC (20% limestone) + 30% Flyash
2224	Carbon Limit – Blended ASCM	Natural Pozzolan + Catalyst (30% cement replacement)

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Summary

- **MnROAD continues to be a useful tool to evaluate innovative pavement design concepts and materials**
- **It continues to strive to remain on the leading edge of the research needs and trends related to concrete pavements**
- **Many lessons have been learned and implemented nationwide in the past 28 years**
- **Guidance from the National Road Research Alliance will keep MnROAD on the correct path toward answering questions relevant to agencies and the concrete pavement industry**

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2023 NRRRA Call for Innovation

Looking for proposals for new research/test cells at MnROAD

➤ **Link:** <http://www.dot.state.mn.us/mnroad/nrra/call-for-innovation.html>

➤ **Deadline for submittal of proposals: May 5, 2023**

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Questions?

Tom Burnham

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