MnROAD Phase 3 Concrete Pavement Construction Update

Tom Burnham, P.E. | Senior Road Research Engineer, Minnesota Department of Transportation

NCC Fall Meeting, Minneapolis, MN

9/20/2017

DEPARTMENT OF TRANSPORTATION

NRRA National Road Research Alliance

MnROAD Facility

MnROAD

- Full-scale, cold climate pavement test facility near Albertville, MN
- 3.5 mile (5.6 km) “Mainline” section with diverted interstate I-94 traffic
- 2.5 mile (4 km) “Low Volume Road” closed loop test track
- Multiple pavement test sections
  - Asphalt
  - Concrete
  - Overlays
- Operation began in 1994
  - Beginning Phase 3 experiments

Provides opportunities for bold ideas

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 (NRRA)**
    [6 states, MnLRRB]. Construction $ = MnDOT
  - **Experiments determined by NRRA members (includes input from 30 industry and academia members)**

MnROAD Staff

Responsible for site operations

- Install and maintain supporting infrastructure
- Install sensors
- Conduct load tests
- FWD testing
- Distress surveys
- Provide loading on Low Volume Road
- Assist with non-pavement related studies

MnROAD Phase 3 - Round 1
Primary PCC Studies

- **Fiber-reinforced Concrete Pavement**
  - Thin overlays
  - Thin slabs on grade
- **Long-Term Impacts of Early Opening of Concrete Pavements to Traffic**
  - New pavements
  - Repairs
- **Reduced Cementitious Content Concrete Mixtures**
  - Current limits
  - How low can you go?

- **(Long Term Effects of Diamond Grinding on PCC and Impact of Sealers)**

  FUTURE?
- **(Compacted Concrete Pavement)**

  FUTURE?

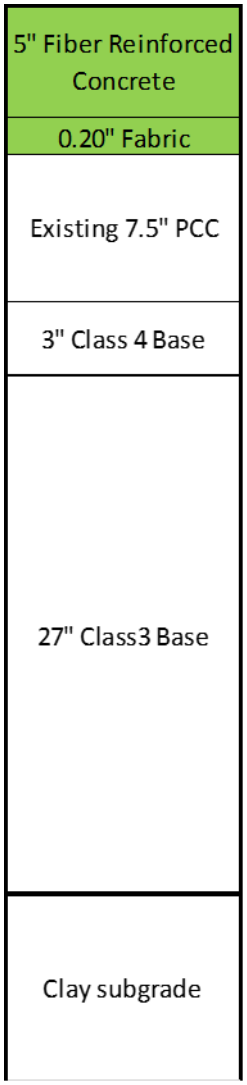
Fiber Reinforced Concrete Study

Objectives

- Determining contribution of fibers in reducing panel fatigue cracking
- Determining contribution of fibers in mitigating joint faulting
- Determining optimal panel size

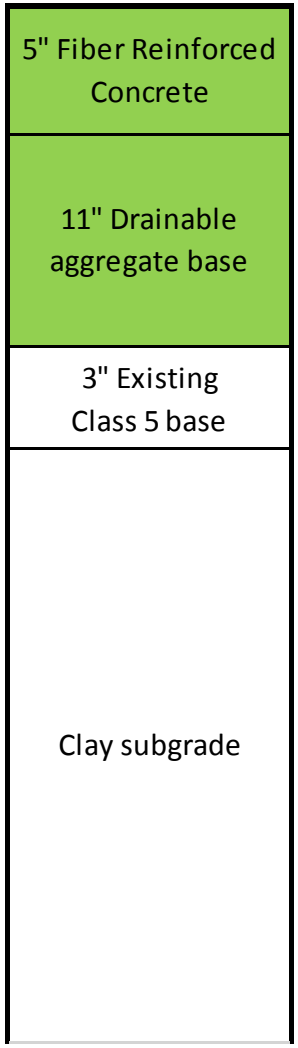
Fiber Reinforced Unbonded Concrete Overlay

- **MnROAD Cells 705, 805 (Mainline interstate traffic)**
  - Fiber content: 20% RSR (ASTM C1609)
  - Non-woven geotextile fabric interlayer
  - Cell 705: 14’W x 12’L, 12’x12’ panels
  - Cell 805: 6’Wx12’L & 8’Wx12’L panels
  - 3’ wide passing lane PCC shoulder



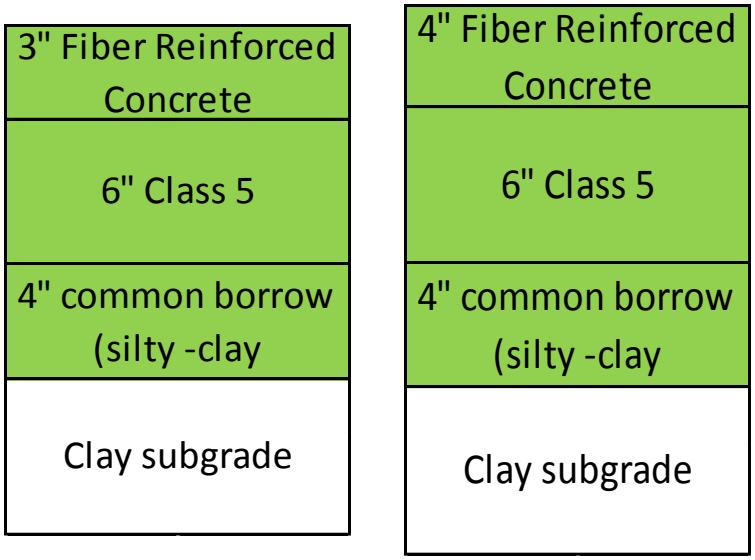
Fiber Reinforced Concrete On Grade

- **MnROAD Cells 506, 606, 706, 806**
  (Mainline interstate traffic)
  - **All cells: 6’ x 6’ panels**
  - **Fiber content:**
    - Cell 506: No fibers (control)
    - Cell 606: 20% RSR (ASTM C1609)
    - Cell 706: 30% RSR (ASTM C1609)
    - Cell 806: 0.75% by volume



Ultra-thin Fiber Reinforced Concrete On Grade

- **MnROAD Cells 139, 239**
  (Low Volume Road traffic)
  - **All cells: 6’ x6’ panels**
  - **Fiber content:** 30% RSR (ASTM C1609)



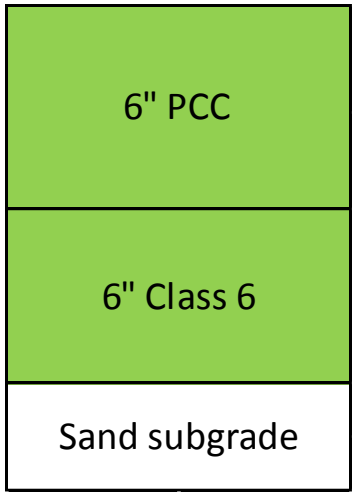
Early Opening to Traffic Study

Objectives

- Evaluate visible and non-visible immediate damage caused by early age loading
- Quantify the effect of early loading damage on long-term performance
- Determine minimum strength at opening or other measurable variables associated with this parameter
- Recommend strategies for minimizing or avoiding early loading damage detrimental to long-term performance

Early Opening to Traffic

- **MnROAD Cell 124**
  (Low Volume Road Traffic)
  - **Standard panel size 12'W x 15'L**
  - **Standard concrete mix**
  - **Doweled joints**
  - **Early sequential traffic loadings**
    - **Based on maturity**
  - **Vehicle driven across concrete before full set to cause visible damage**

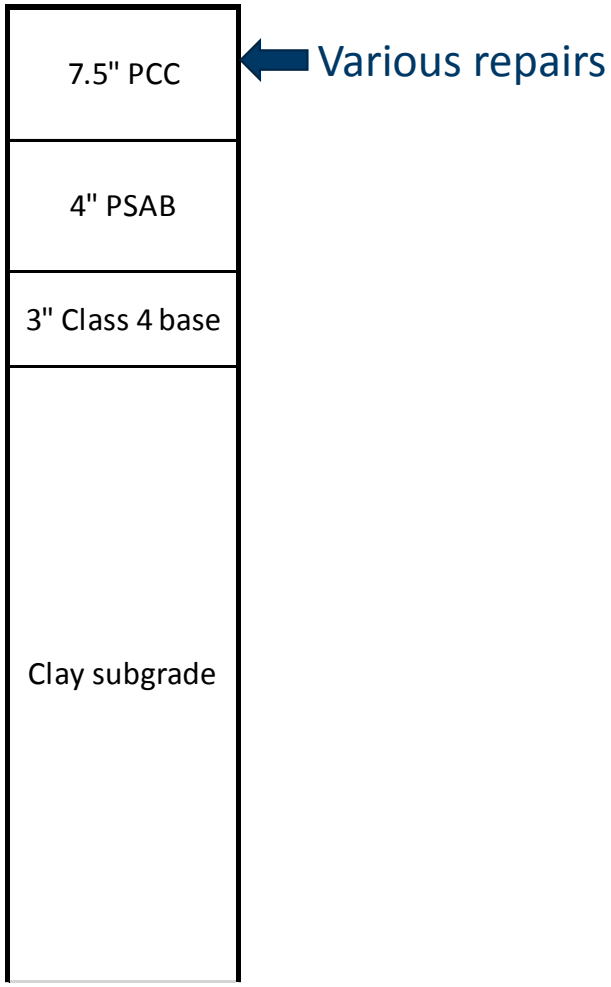


Early Opening of Repairs

- **MnROAD Cells 7 & 8**
  (Mainline interstate traffic)

  - **Full panel replacements, full-depth joint repairs, and partial-depth repairs**

  - **Various repair materials**
    - MnDOT spec. 3U18M
    - MnDOT spec. 3U58
    - Contractor design high early mix
    - Internal cure mix
    - Roller Compacted Concrete
      - 1 and 2 lifts
  - **Early sequential traffic loadings**



Reduced Cementitious Content Concrete Study

Objectives

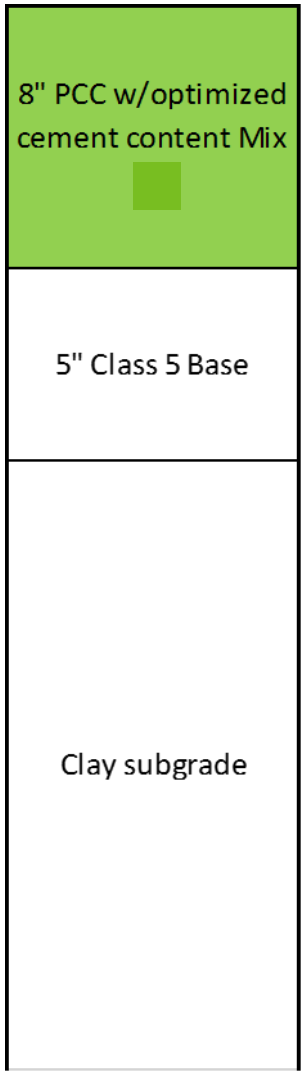
- Investigate the early-age characteristics of concrete paving mixes containing low and lower cementitious content
- Assess causes of, or potential for, durability issues with very low cementitious content
- Identify effect of reduced cementitious content on long term serviceability and economics of concrete pavements
- Develop recommended specifications, mixing and placement practices for the use of low cementitious content concrete mixes

Reduced Cementitious Content Mixes

- **MnROAD Cells 138, 238**
  (Low Volume Road traffic)

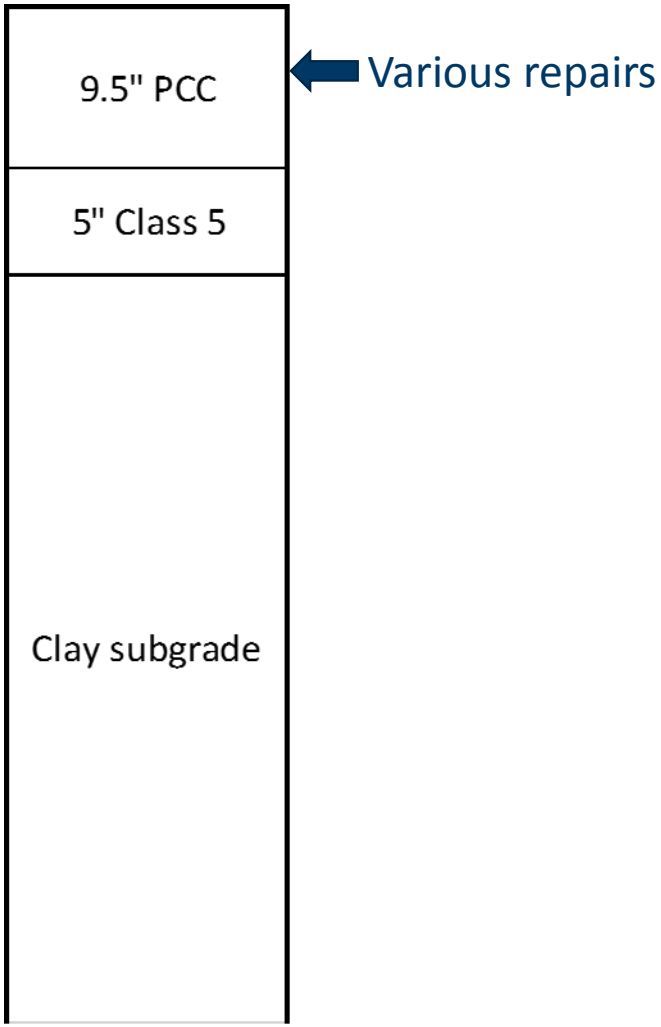
  - **All cells: 12'W' x 15'L panels**

  - **Cell 138: Cementitious content = 500 lb/cy**
  - **Cell 238: Cementitious content = 470 lb/cy**



Concrete Repair Product Evaluations

- **I-94 MnROAD Bypass (1900 ft)**
  (intermittent interstate traffic)
  - **44 year JRCP (27' long panels)**
  - **Partial-depth joint and mid-panel repairs**
  - **Various repair materials**
    - 15 early-set materials
    - Installed by MnDOT maintenance workers
    - Guided by manufacturer/supplier reps



Concrete Mix Designs

Minnesota Department of Transportation (5/9/16)

Contractor Mix Design - Specialty Concrete (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/ Class	SP.G / Dosage
Cement	Holcim Ste. Gen.	STGBLMO	I/II	3.15
Fly Ash	Headwaters Coal Creek	COCUNND	F	2.50
Slag				
Other CM				
Admx#1	Sika Air 260	SIAIR260	AEA	0.01-3
Admx#2	Sika Viscocrete 1000	ASIV1000	A	1-3
Admx#3	Sikatard 440	BSITA440	B	1-4
Admx#4	Sika Stabilizer 4R	SSISA4R	S	1-5
Color				

Use for:

Job Specific Concrete using a JMF

Paving Projects 3,500 CY or greater

High Performance Bridge

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	C. Sand		2.63	0.009
FA#2					
CA#1	27005	1-1/2"	C	2.73	0.009
CA#2	71041	67	C	2.69	0.013
CA#3	71041	3/8"	C	2.67	0.015

SP Number	SP 8680-180
Requested By	Tyler Otteson
Company	Aggregate Industries
Phone	612-246-0816
Email	tyler.otteson@aggregate-us.com
AgencyContact	
Agency Phone	
Agency Email	
Plant Name	841 Rogers
Contractor	C.S. McCrossan
JMF Number	

Estimated Batch Weights - Pounds (Dry)

Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Th. Unit Wt.	Slump Range
													% Aggregate Proportion by Volume							
													39		18	33	10			
MR-3A21	7.0	228	400	170			30				570	0.40	1173		562	1015	305	27.0	142.7	1/2-3"
MR-3A21A	7.0	197	353	117			25				470	0.42	1242		595	1075	323	27.0	144.5	1/2-3"
MR-3A21B	7.0	210	375	125			25				500	0.42	1218		584	1054	317	27.0	143.8	1/2-3"

Low Cementitious Cells (138-238)

Table courtesy of American Engineering Testing

Concrete Mix Designs

Minnesota Department of Transportation (5/9/16)

Contractor Mix Design - Specialty Concrete (JMF)

	Name/Mill/Plant	MnDOT Abbreviation	Type/ Class	SP.G / Dosage
Cement	Holcim Ste. Gen.	STGBLMO	I/II	3.15
Fly Ash	Headwaters Coal Creek	COCUNND	F	2.50
Slag				
Other CM				
Admx#1	Sika Air 260	SIAIR260	AEA	0.01-3
Admx#2	Sika Viscocrete 1000	ASIV1000	A	1-3
Admx#3	Sikatard 440	BSITA440	B	1-4
Admx#4	Sika Stabilizer 4R	SSISA4R	S	1-5
Color				

Use for:
Job Specific Concrete using a JMF
Paving Projects 3,500 CY or greater
High Performance Bridge

	Pit #	Size	Class	SP.G.	ABS.
FA#1	71041	C. Sand		2.63	0.009
FA#2					
CA#1	71041	67	C	2.69	0.013
CA#2					
CA#3					

SP Number	SP 8680-180
Requested By	Tyler Otteson
Company	Aggregate Industries
Phone	612-246-0816
Email	tyler.otteson@aggregate-us.com
AgencyContact	
Agency Phone	
Agency Email	
Plant Name	841 Rogers
Contractor	C.S. McCrossan
JMF Number	

Estimated Batch Weights - Pounds (Dry)

Mix #	% Air	Water	Cement	Fly Ash	Slag	Other CM	% Fly Ash	% Slag	% Other CM	% Ternary	Total CM	W/C Ratio	FA#1	FA#2	CA#1	CA#2	CA#3	Volume	Th. Unit Wt.	Slump Range
													% Aggregate Proportion by Volume							
													41		59					
MR-3A21FC	7.0	239	400	170			30				570	0.42	1222		1798			27.0	141.8	1/2-3"
MR-3A21F1	7.0	248	413	177			30				590	0.42	1204		1773			27.0	141.3	1/2-3"
MR-3A21F2	7.0	252	420	180			30				600	0.42	1196		1761			27.0	141.1	1/2-3"
MR-3A21F3	7.0	258	430	185			30				615	0.42	1184		1743			27.0	140.8	1/2-3"

Fiber Reinforced Concrete Cells

Fiber type: FORTA-FERRO

20% RSR = 5 pcy; 30% = 8 pcy; 0.75% vol = 11.66 pcy

Table courtesy of American Engineering Testing

Residual Strength

Table 1 – Summary Test Results – ASTM C1609 – 28 days

Set ID		5 pcy	8 pcy	11.7 pcy
Specimen Dimension	Width (in.)	6.15	6.10	6.20
	Depth (in.)	6.05	6.05	6.00
Initial Deflections	δ_1 - Deflection at First Crack (in.)	0.0017	0.0019	0.0019
	δ_P - Deflection at Peak Load (in.)	0.0019	0.0020	0.0021
Loads	P_1 - First Crack Load (lbf.)	7,928	9,011	8,257
	P_P - Peak Load (lbf.)	8,109	9,433	8,866
	P_{600}^{150} - Load at L/600 (lbf.)	1,492	2,522	3,782
	P_{150}^{150} - Load at L/150 (lbf.)	1,322	2,437	3,528
Stress	f_1 - First Crack Stress (psi)	635	730	660
	f_P - Peak Stress (psi)	650	765	710
	f_{600}^{150} - Stress at L/600 (psi)	120	205	305
	f_{150}^{150} - Stress at L/150 (psi)	105	195	285
Toughness	T_{150}^{150} - Toughness (in-lbs)	187	327	460
	$f_{T,150}^{150}$ or Fe_{3mm} (psi)	126	221	307
	$R_{T,150}^{150}$ or Re_{3mm} (%)	20.1	30.3	46.6

Table courtesy of American Engineering Testing/Testing, Engineering & Consulting Services, Inc.

Box Test

After 30 minutes

Low cementitious mix

20% RSR Fiber mix

Photos courtesy of American Engineering Testing

Removal of Previous Test Cell

Cell 405

Removal of Previous Test Cell

Cell 406

Instrumentation

Instrumentation

Paving

Paving

Paving

Cell 139, 3” FRC

Sampling

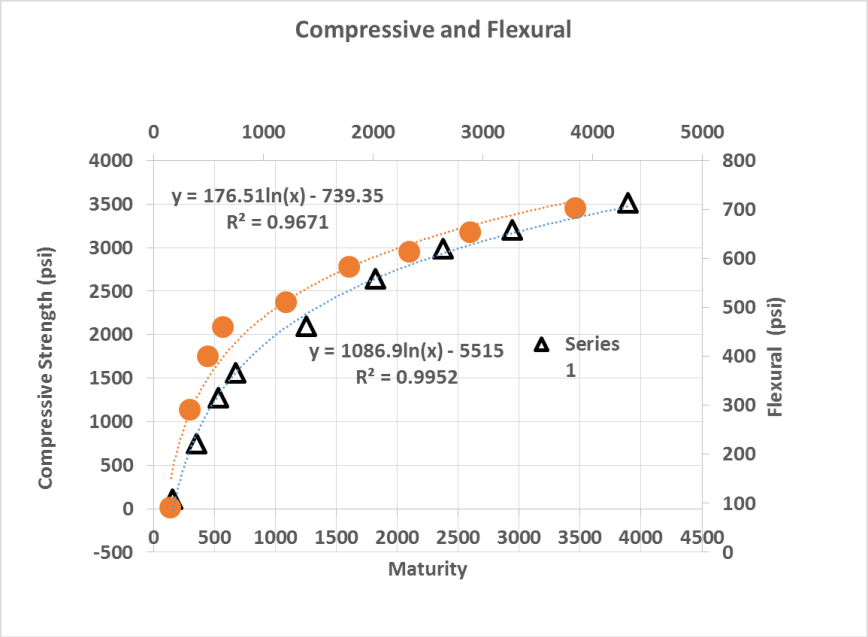
Construction Issues

- **FRC Cell 606 paved 1” too thick**
- **Passing lane sawed 1 foot narrower than planned on Cells 705/805**
- **Spongy/non-uniform base under LVR cells**
- **Damage to Cell 139 from construction traffic**

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)
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



Early Loading of Cell 624

Early Loading of Cell 624

Early loading of Cells 124-424

4,000 lb axle vs 14,000 lb axle loads (1st Cell @ 3hrs)

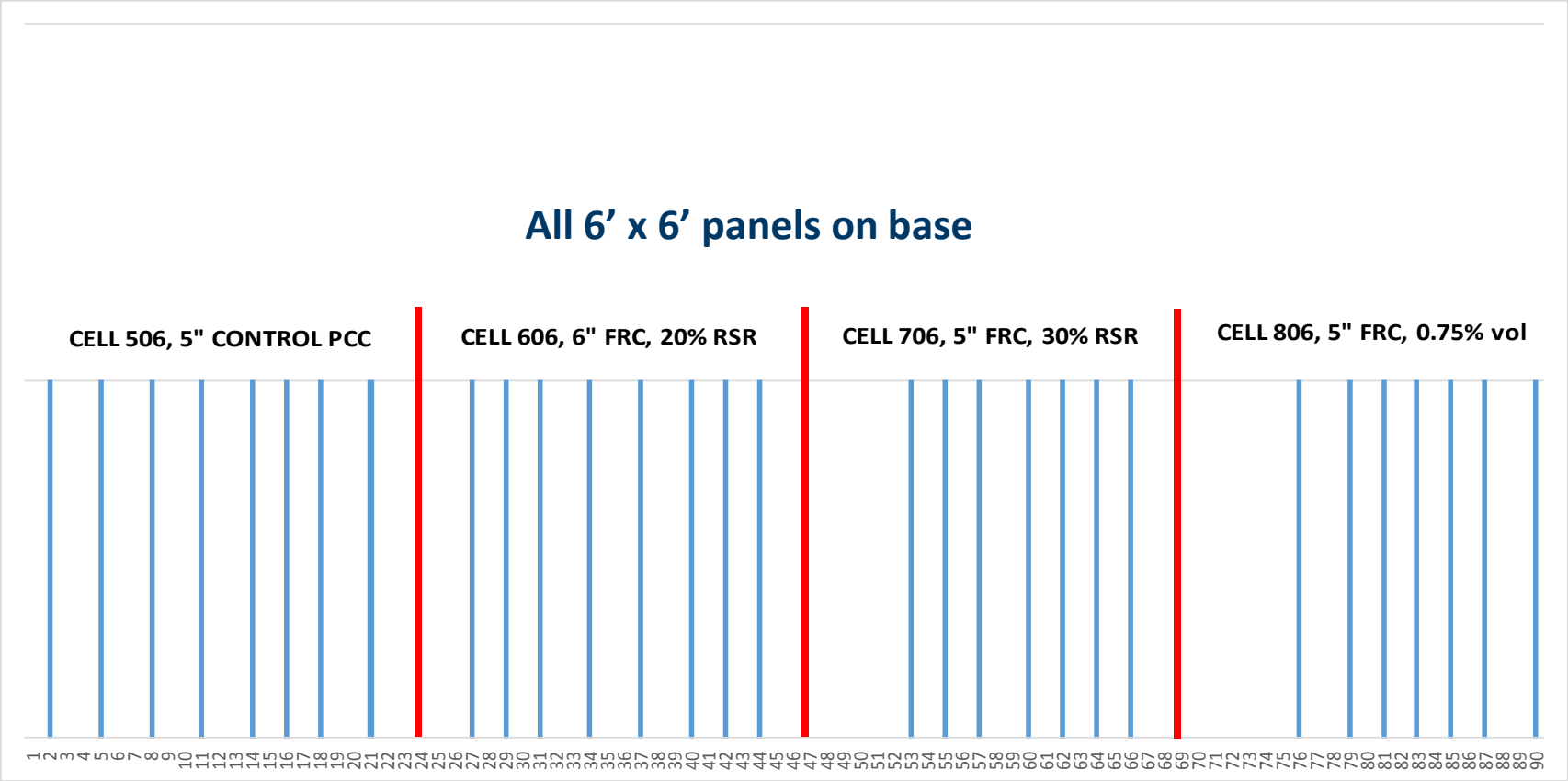
Post Paving Activities

- **Profile (Lightweight profiler)**
- **Mix uniformity mapping (MIRA)**
- **Slab thickness (MITScan T2)**
- **Transverse joint deployment**
  - **Edge observations before shoulder placement**
- **Warp and curl (ALPS2 laser profiler)**
- **Install joint opening sensors and pins**
- **FWD Tests (after shoulder placement)**
- **Initial load testing with MnROAD truck**
- **Compile PCC strength and durability specimen results**

Warp and Curl Profiling

ALPS2

Early Transverse Joint Deployment



Observation on 7-5-17, Age range: 5 to 9 days

Early Loading Damage

Cell 139, 3” FRC, Loaded with construction traffic @ 2 weeks old

Early Loading Damage

Cell 139, 3” FRC

Early Loading Damage

Cell 139, 3” FRC

Early Loading Damage

Cell 139, 3” FRC

Remaining Activities

- **Partial-depth concrete repairs on parallel WB- I-94**
  - **15 fast set mixes**
  - **Same repair pattern**
- **General repairs of older MnROAD mainline PCC cells**
- **Repairs (with early loading) in Cells 7 and 8 (25 years old)**
  - **Partial depth repairs with MnDOT 3U18M and 3U58**
  - **Full-depth joint replacements with high early strength mix**
  - **Full panel replacements**
    - **Internal cure mix**
    - **RCC (compacted with small maintenance roller)**
      - **Driving lane 2 lifts**
      - **Passing lane 1 lift**

Questions?

Tom Burnham

tom.burnham@state.mn.us