Thin Concrete Pavements and Overlays - Ongoing MnROAD Research

NCC Spring 2013 Meeting
Philadelphia, PA
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Office of Materials and Road Research

“How Thin Can You Go?”

- Structural Capacity
  - Flexural strength
  - Joint load transfer
  - Fatigue loading
  - Ultimate loading

- Environmental response
  - Warp and curl
  - Uniform slab support

Performance of Thin Jointed Concrete Pavements Subjected to Accelerated Traffic Loading

aka: "How Thin Can You Go?"

- Authors: Tom Burnham and Bernard Izevbekhai

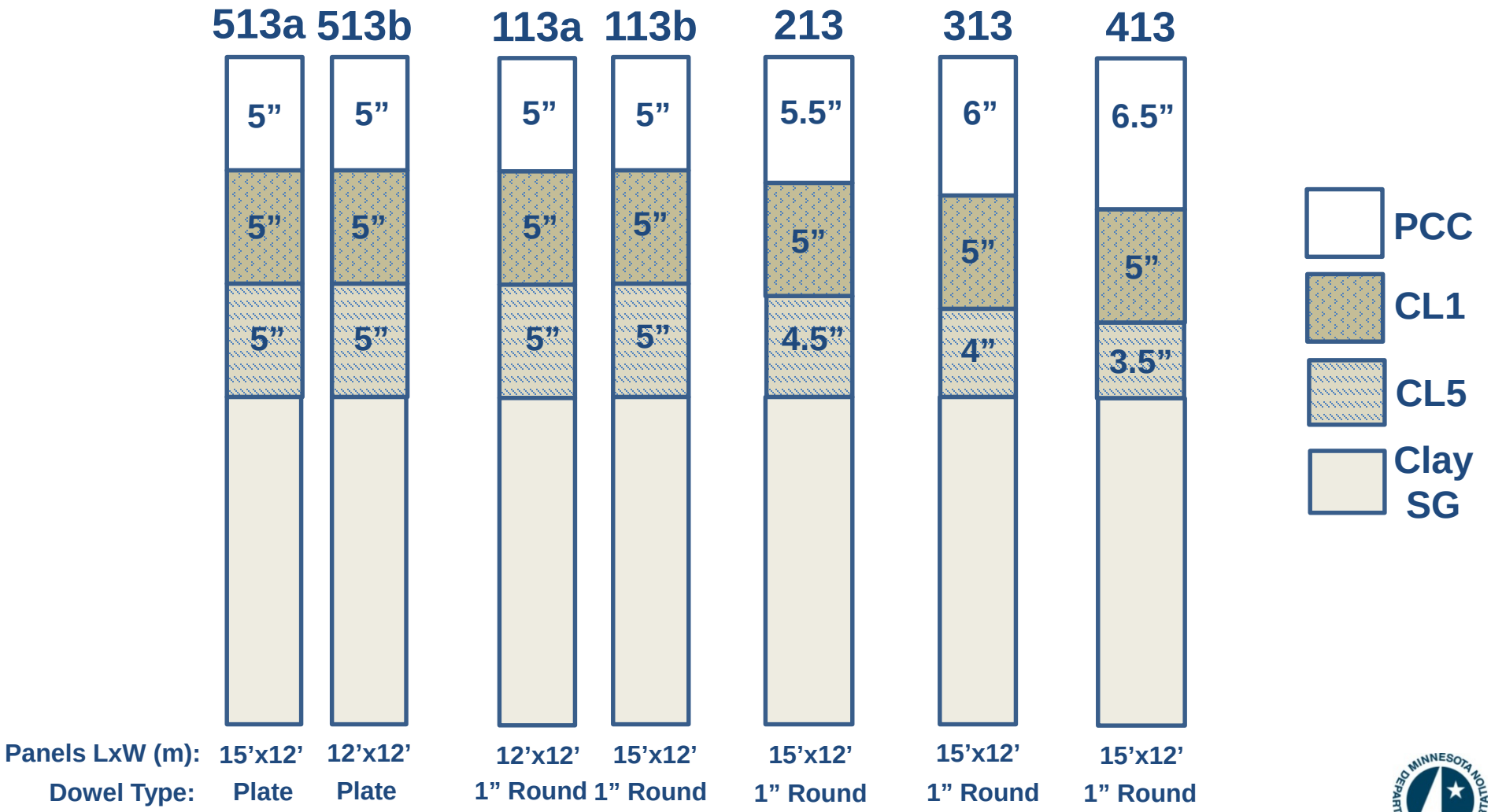
- Paper presented at 4th APT Conference, Sept. 2012

MnROAD "Mainline"

Live interstate traffic = "Accelerated" for thin PCC designs

MnROAD

Cells 113-513, Constructed 2008



MnROAD

Cells 113-513

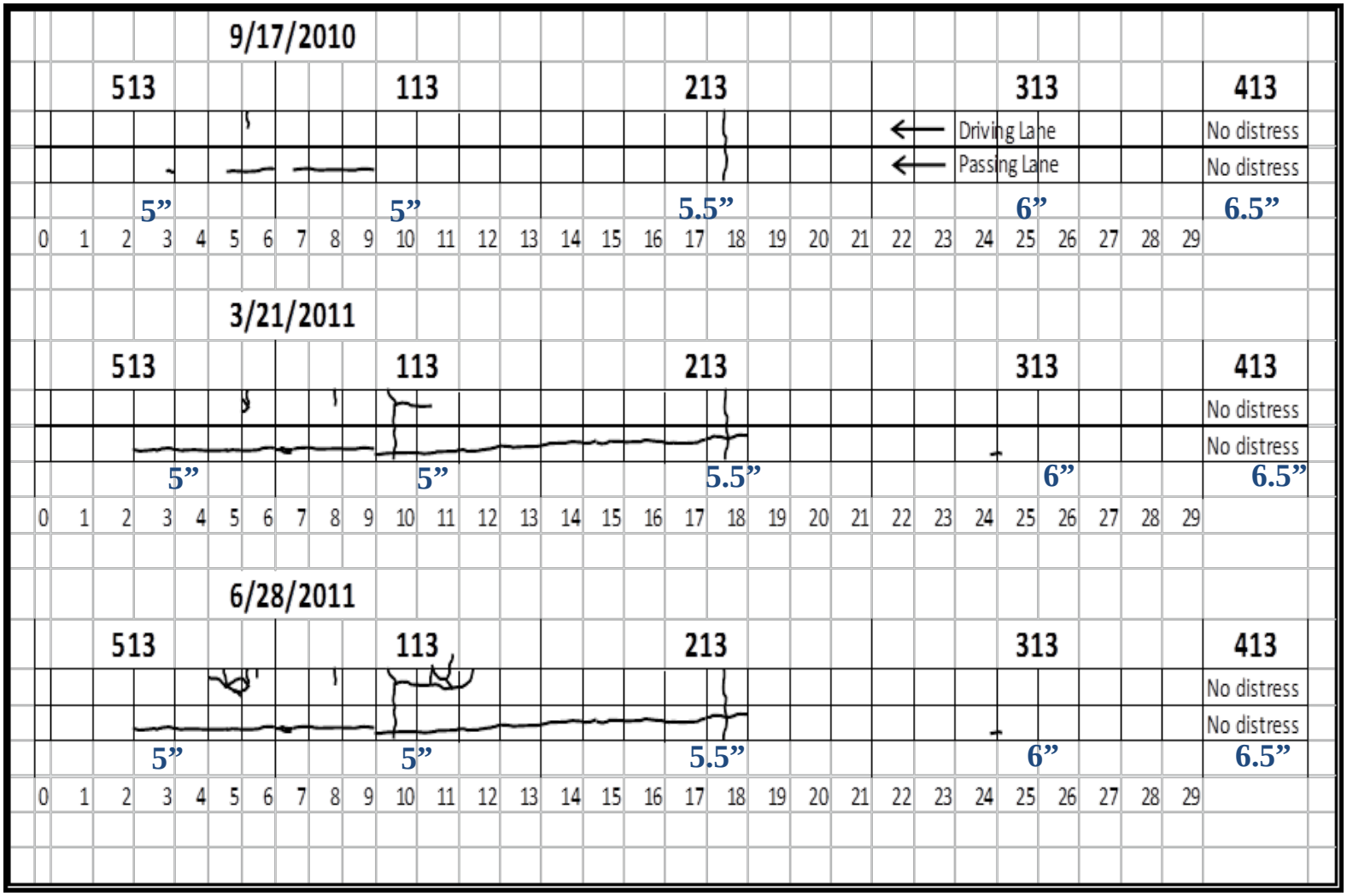
Cell	Design slab thickness, in.	Average slab thickness in driving lane outer wheelpath, in.	Average slab thickness at centerline, in.	Overall average slab thickness, in.	Difference between as-built and design thickness, in.
513	5	6.1	5.7	5.9	+0.86
113	5	5.7	5.2	5.6	+0.63
213	5.5	6.1	5.6	5.9	+0.43
313	6	6.1	6.2	6.2	+0.24
413	6.5	6.5	6.3	6.4	-0.08

MnROAD Cells 113-513

Predicted performance to terminal serviceability (P_t=2.5) using MnDOT (AASHTO based) design

Cell	As-built thickness (in)	CESALs
513	5.7	685000
113	5.2	560000
213	5.6	720000
313	6.1	905000
413	6.4	1050000

Test Cell Performance



> 1 million CESALS to first visible cracks

Routing Sensor Leads

Test Cell Performance

Distress from sensor leads?

Test Cell Performance

Pumping from shoulder joint, July 2011

Repairs

Drainage and smaller slabs work better

Conclusions on Thin PCC Under Accelerated Loading

- Thin concrete sections can withstand substantially more traffic than AASHTO based designs predict (now over 4+ million CESALS on 6”)
  - Would they fail differently with LVR traffic?
- They are much more sensitive to loss of support and curling effects
  - Some panels were longer than recommended for thickness (12’, 15’ for <6” thick slabs)
  - Different cracking types in driving versus passing lanes
  - Wet base and subgrade areas failed first
- Very difficult to repair

Cells 306-406 Performance

- **152 mm (6”) PCC constructed in 2011**
- **Design based on “good” performance of Cell 313**
- **Designed with “drainable, but stable” base**
  - **Cracking within 6 months (loss of support?)**

Rehabilitation of Thin Concrete Pavements

- Cell 32: 5” thick concrete section constructed in 2000
  - LVR traffic = 80k 5-axle truck
  - 10’L x 12’W panels, undoweled joints
  - Undrained base, gravel shoulders

- Significant joint faulting (9mm, 3/8”)

- Multiple slabs with corner and longitudinal cracks

Cell 32, 5” thick, after 12 years

Cell 32, 5” thick, after 12 years

Cell 32 Repairs Scheduled for 2013

- Full panel replacements for cracked panels
  - Plate (CoVex) dowels to provide load transfer
  - Plate dowels on basket for joints between contiguous panels

- Retrofit transverse joints between uncracked panels
  - ¾” dia round dowels
  - 3/8”T x 2”W x 12”L plate dowels
- Diamond grind to remove faulting
- No base support restoration provided

How much more service life can we get?

CoVex plate dowels in full-depth repair
[installed in 6” Cell 38 in Oct . 2010]

Full-depth repair Feb 2013

Pooled Fund Project TPF 5-165:

Development of Design Guide for Thin and Ultrathin Concrete Overlays of Existing Asphalt Pavements

Goal: Mechanistic-Empirical design procedure. Want to better predict long term performance and life cycle costs.

Participating states:

Phase 1 (2008-2012): *Minnesota, Mississippi, Missouri, New York, Pennsylvania, Texas*

Phase 1B (2012-2013): Iowa, Kansas, Minnesota, Missouri, North Carolina, Pennsylvania, South Dakota

Project began in Fall 2008. Completion August 2013.

Pitt Procedure

Proposed design spreadsheet_updated-new6.xlsm - Microsoft Ex...

File | Home | Insert | Page Layout | Formulas | Data | Review | View | Add-Ins | Acrobat

F6 | 1000000

UTW/TWT Design Sheet

Instruction:

Pick from the drop-down list;	Type in the cell.

Overall design parameters		
Estimated Design Lane ESALs:	Estimate ESALs	1,000,000
Maximum allowable percent slabs cracked (%):		20
Desired reliability against slab cracking (%):		85
Climatic consideration		
Latitude (degree):		45
Longitude (deree):		80
Elevation (ft):		700
AMDAT Region ID		2
Sunshine zone		6
Existing structure		
Post-milling asphalt thickness (in):		5
HMA ref. res. modulus (psi):	January	2,000,000
HMA Poission's ratio (default 0.35):		0.35
Modulus of subgrade reaction (pci):		100
Surface preparation method:		Milling
Whether existing HMA layer has transverse cracks?		Yes
Concrete properties		
Average 28-day flexural strength (psi):		750
Estimated elastic modulus (psi):		3,600,000
Type of Coarse Aggregate:		Limestone
Fiber type:		No fibers
Fiber content (% volume):		0
Joint spacing (ft):		6

Calculate Design

Design sheet | Estimate ESALs | Climatic charts

Ready | 100%

TPF 5-165 Status

- Modified Phase 1 Tasks (Spring 2013):
  - Characterize bond degradation over time
  - Develop design inputs for structural fibers
  - Further develop project suitability guidelines

- Phase 1B (Late Spring 2013):
  - Develop improved fatigue models which characterize actual cracking mode (longitudinal)
  - Adjust climate response models affected by new fatigue models
  - Create final design spreadsheet *(June release)*
  - Create training module to aid implementation

All work to be completed by August 2013

Fiber-Reinforced Bonded PCC Overlay Cells MnROAD 2013

- Repeat of existing whitetopping cells 60-63 (constructed 2004)
  - 4” PCC over 7” HMA
  - 5” PCC over 6” HMA
  - 6’x6’ panels
  - Structural fibers
  - ½ sealed, ½ unsealed joints

Note that full panel replacement repairs and diamond grinding were done to Cell 63 in 2011 to keep in service

- *4” PCC over 8” HMA*
- *Unsealed joints*
- *55% cracked panels after 6.5 million ESALs*

Use of Non-Woven Fabric Interlayer for Unbonded Concrete Overlays

Study Using Minne-ALF at University of Minnesota

- Tested 5” unbonded PCC overlay over 5” PCC slab w/ fabric interlayer
- Tested 3” unbonded PCC overlay over 5” PCC slab w/ fabric interlayer
- Conducted drainage study (static & during loading)

- Findings
  - Could not fail 5” thick overlay (> 20 million ESALs)
  - 3” overlay failed by corner crack after 1.1 million ESALs
  - Fabric drains well

Drainage experiment set-up

Ultra-thin Unbonded PCC Overlay MnROAD 2013

- Existing thickened edge (5.5”-7” design) PCC Cell 40
  - 15’x12’ panels, skewed joints
  - Undoweled joints, currently has average joint faulting of 5 mm (1/4”) after 19 years on LVR
  - Some longitudinally cracked panels
  - Long history of pumping

- New ultra-thin 3” thick unbonded PCC overlay
  - 6’x6’ panels, sealed joints
  - Structural fiber concrete
  - Fabric interlayer (2 thicknesses)
  - Gravel shoulders

Pooled Fund Project TPF 5-269:

Development of an Improved Design Procedure for Unbonded Concrete Overlays

Goal: Improved mechanistic-empirical design procedure. Want to better predict long term performance and life cycle costs for unbonded concrete overlays (thin to thick).

Participating states: *Georgia, Iowa, Kansas, Michigan, Minnesota, Missouri, Oklahoma, North Carolina*

Anticipated to be a 3 year project.

Development of an Improved Design Procedure for Unbonded Concrete Overlays

- Patterned after TPF 5-165 Whitetopping Design Procedure project
- Stand alone software design procedure for UCOCP (DARWin ME compatible)
- No overlay thickness limit (3”-12”)
- Characterization of and guidelines for interlayers
- Project selection criteria

TPF 5-269 Status

- RFP selection committee chose team:
  - Lev Khazanovich - U of Mn
  - Julie Vandenbossche - U of Pitt
  - Mark Snyder – Consultant

- Kick-off TAP meeting Dec 2012
  - Work plan and contract development underway

Anticipated completion by Fall 2015

MnROAD Cells 505-605

5” UBOL, 6’x8’ panels, fabric interlayer, RCC shoulders

Questions????