MnROAD Concrete Pavement Research

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MnROAD Open House – August 23, 2010

Topics

MnROAD Concrete Pavement Research

- History
- Phase 1
  - Findings
- Phase 2
  - Current studies
  - Preliminary findings
- New projects

MnROAD Operations

- Improvements

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Concrete Pavement Research

- Phase 1 (1994-2008) – Structural Design Verification
  - 5 and 10 year design PCC test sections
  - Low volume design PCC test sections
- Phase 2 (2009-2014?) – Current Hot Topics
  - Thin full-depth concrete test sections
  - Pervious concrete test sections
  - Thin concrete overlays
  - Long-life design test section
  - Composite test sections
- Other studies
  - 1997, 2004: Thin and ultra-thin whitetopping
  - 2000: Thin full-depth concrete
  - 2000, 2008, 2010: Alternative dowel systems

Concrete Pavement Research

- Field measurements
  - Embedded sensors
    - Thermocouples = Temperature gradients
    - Vibrating wires = Thermal expansion/contraction
    - Dynamic strain sensors = Traffic load response
    - LVDT sensors = Vertical deflection
    - Horizontal clip sensors = Joint opening
    - Moisture sensors = Moisture gradients
  - Seasonal monitoring
    - Distress surveys
    - Load testing = FWD and truck
    - Joint faulting measurements
    - Ride quality
    - Friction
    - Noise
    - Warp and curl
  - Forensic Investigation

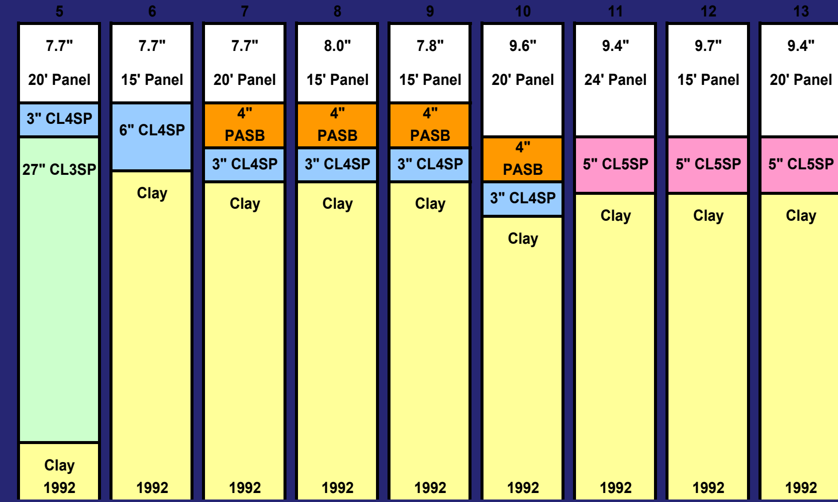
Concrete Pavement Research

- Analysis
  - Empirical observations
  - Design Guides – AASHTO, PCA, MEPDG
  - Finite Element Analysis
  - Comparison to similar test sections in Minnesota

- Implementation
  - Publication of findings
    - Mn/DOT reports
    - Peer reviewed research papers (ISCP, TRB)
    - Tech briefs ("2 to 4 pagers")
  - Presentations
    - Local and international conferences and workshops
  - Information exchange with international peers

MnROAD

Concrete Pavement Research



- Phase 1 (1994-2008)
  - 5 and 10 year design PCC test sections
  - Low volume design PCC test sections
  - Variables: Slab and base thickness, drainage, panel length, dowels

- Lessons learned
  - AASHTO design predictions may be conservative in terms of serviceability for shorter design periods
  - Smoothly constructed sections remain smoother
  - Joint faulting progresses linearly (for undoweled joints)
  - Joint placement is critical to ultrathin whitetopping performance
  - Subsurface drainage has an effect on joint performance
  - Joint sealing has an effect on joint performance

MnROAD Phase 1 Findings

New breakthrough formula!

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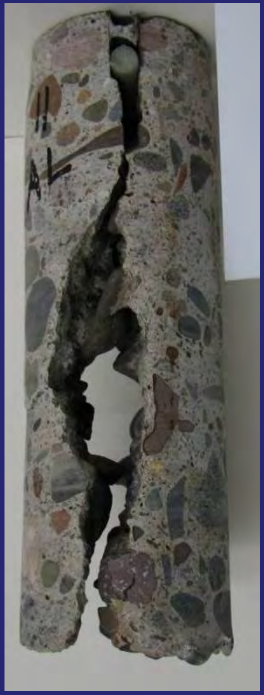


MnROAD Phase 1 Findings

Effect of drainage on joint performance

- High traffic volume:
  - Joints over drainable (PASB) base layers performed well
  - Joints over slow draining bases (CL 5) with no edge drains exhibited significant mid-depth distress

  - If joint well sealed, joints over CL5 base with edge drains showed less distress
  - Distress occurred without resulting in significant joint faulting (at 14 years) [LTE was declining]

- Confirmed by similar pavements throughout Minnesota
  - ➢ Distress not as severe, however correlated with drainability of base

MnROAD Phase 1 Findings

Effect of drainage and joint sealing 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 result in significant joint distress

MnROAD Phase 1 Findings

Effect of drainage on joint performance

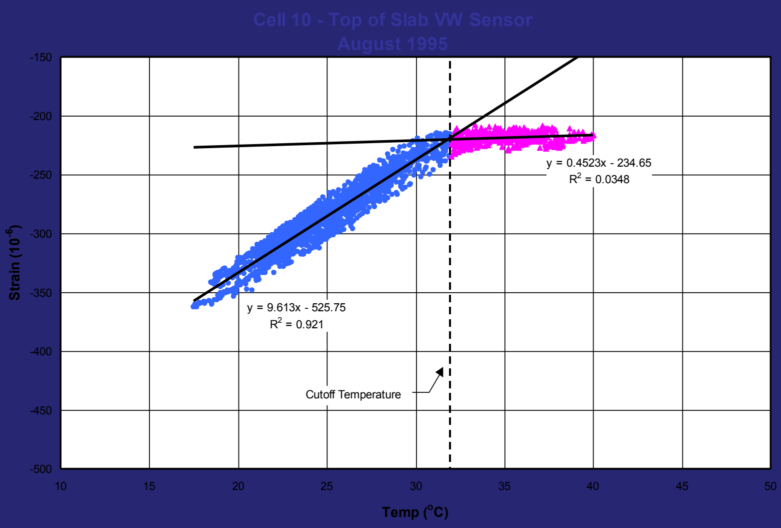
Bottom line:

Design your pavement system to avoid water retention!

Mn/DOT report 2010-18

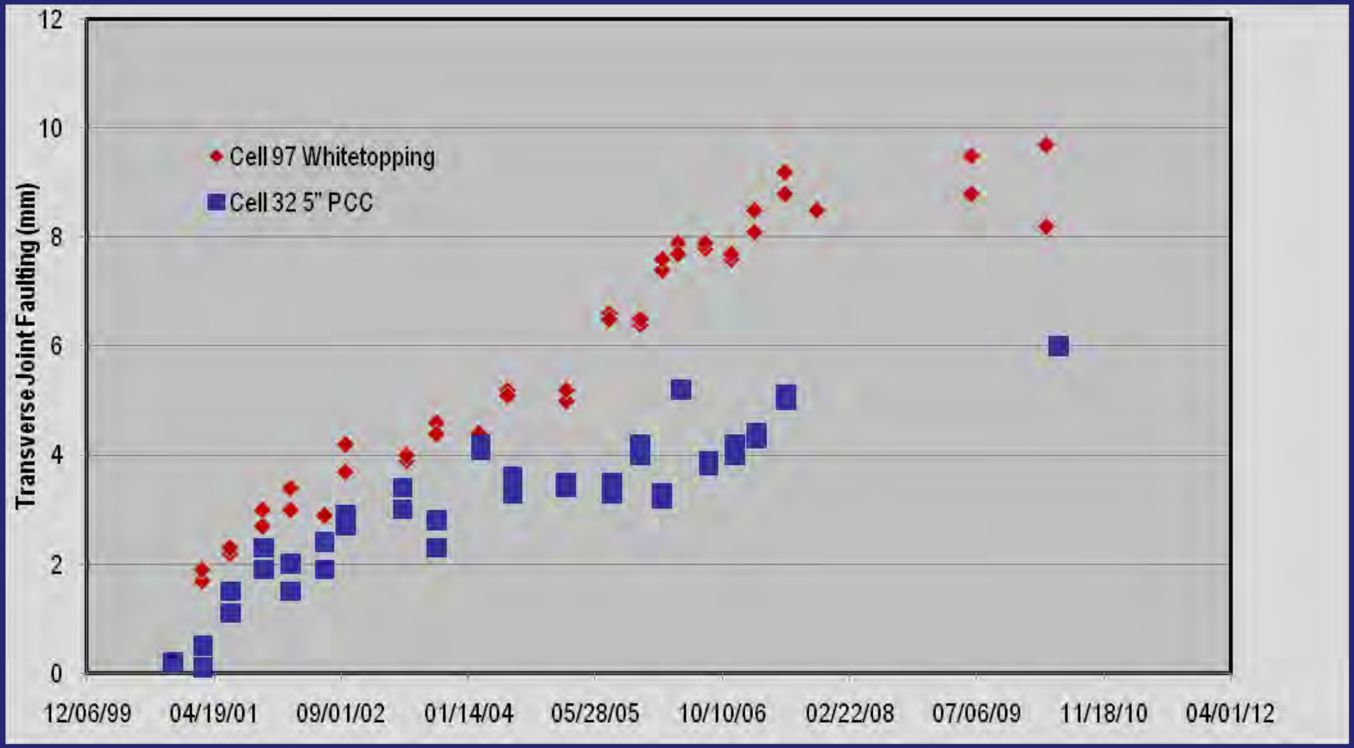
Other notable Phase 1 Findings

- Whitetopping performance
  - Keep panel edges away from wheelpaths
  - <u>Shrinkage</u> fibers not cost effective
  - Thermal reflective cracking is a major distress in Minnesota
- Characterization of thermal expansion of slabs
  - Able to characterize periods when joints fully close
  - Varies with season



Other notable Phase 1 Findings

- Faulting in undoweled joints is approximately linear



MnROAD Phase 2

- New cells paved in fall 2008
  - Thin unbonded overlay of PCC
  - Thin full-depth PCC
  - Thin whitetopping
  - Full-depth pervious concrete
  - Thin pervious concrete overlay of PCC
  - Long life (60 year) design PCC
  - Composite (TICP and SHRP2) pavement
- Multiple surface characteristics

Expect shorter life spans = Quicker results!

MnROAD Phase 2 Update

- Thin unbonded overlay of PCC
  - 4" and 5" thick PCC over 1" PASSRC over 14 year old 7.5" PCC test section
  - 15'Lx14'W overlay panel size (exceeds recommendations for given thickness)
  - ½ joints = 14 year old naturally distressed

    ½ joints = artificially distressed

Companion test section on TH53 near Duluth

Thin unbonded overlay of PCC

- Joint condition prior to thin unbonded overlay

14 year old Cell 5
after breaking

36 years old TH 53
before overlay

Thin unbonded overlay of PCC

After 1 year of I-94 interstate traffic

- Thin unbonded overlay performance
  - “Block cracking” in 4 inch thick overlay sections
  - Does not appear to be directly related to underlying cracking pattern (most likely warp and curl)
  - Possibility caused by poor quality aggregates in mix
  - 5 inch thick overlay performing significantly better, but starting to exhibit transverse cracks near shoulder

MnROAD Phase 2

- Thin Full-Depth PCC – "How Thin Can You Go?"

Cell	Design Thickness (in)	Average As-built thickness (in)
513	5	5.9
113	5	5.63
213	5.5	5.96
313	6	6.22
413	6.5	6.43

  - All cells have 15'L x 12'W panels
  - Wide range in as-built thickness
  - One crack observed in 5" thick (design) section after approx. 1 million ESALs

Thin Full-depth PCC

- Cells 113-413 have 1” diameter round dowels

  = exceed design recommendations
- Cell 513 has flat plate dowels (industrial floor technology)

MnROAD Phase 2

- Thin whitetopping of distressed HMA
  - 6” thick PCC over 14 year old full-depth thermally cracked HMA test section
  - Remaining HMA thickness range: 5” to 8”
  - Panel sizes: 6’ x 6’ and 6’W x 12’L
  - 6’ x 12’ panels have flat dowels in joints

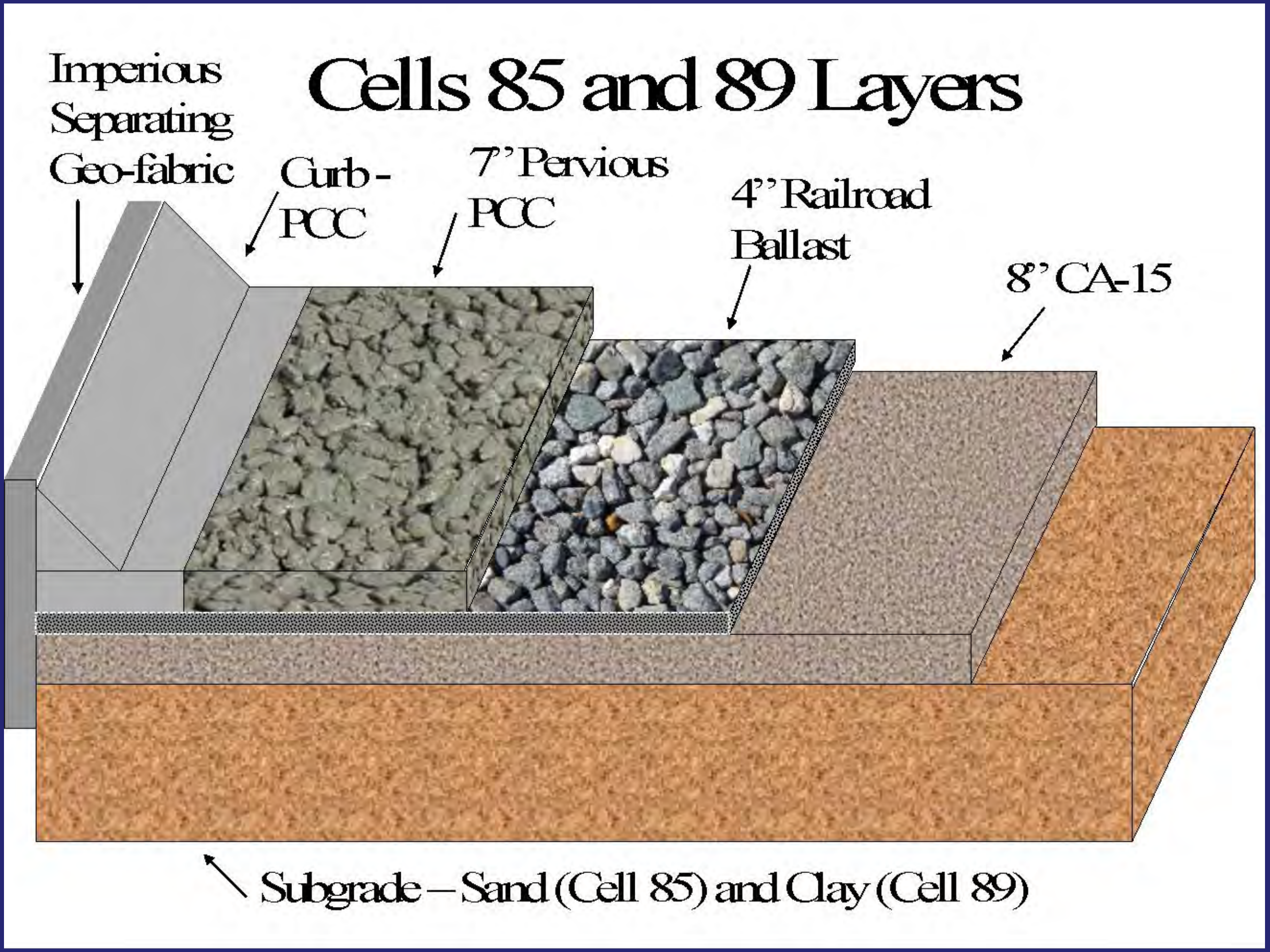
Beginning to show some longitudinal cracking in outer wheelpath of passing lane (5” HMA)

MnROAD Phase 2

- Thermally Insulated Concrete Pavement
  – Cells 106 (doweled jts) and 206 (undoweled jts)
  – 5” PCC with 2” HMA overlay
  – Structural failures in Cell 206 due to variability in layer thicknesses (only 3.5” PCC with 2.5” HMA)
  – Reflection cracking through HMA (both cells) and pumping of base material through PCC joints in cell 206
  – Cell 106 doweled joints performing better

MnROAD Phase 2

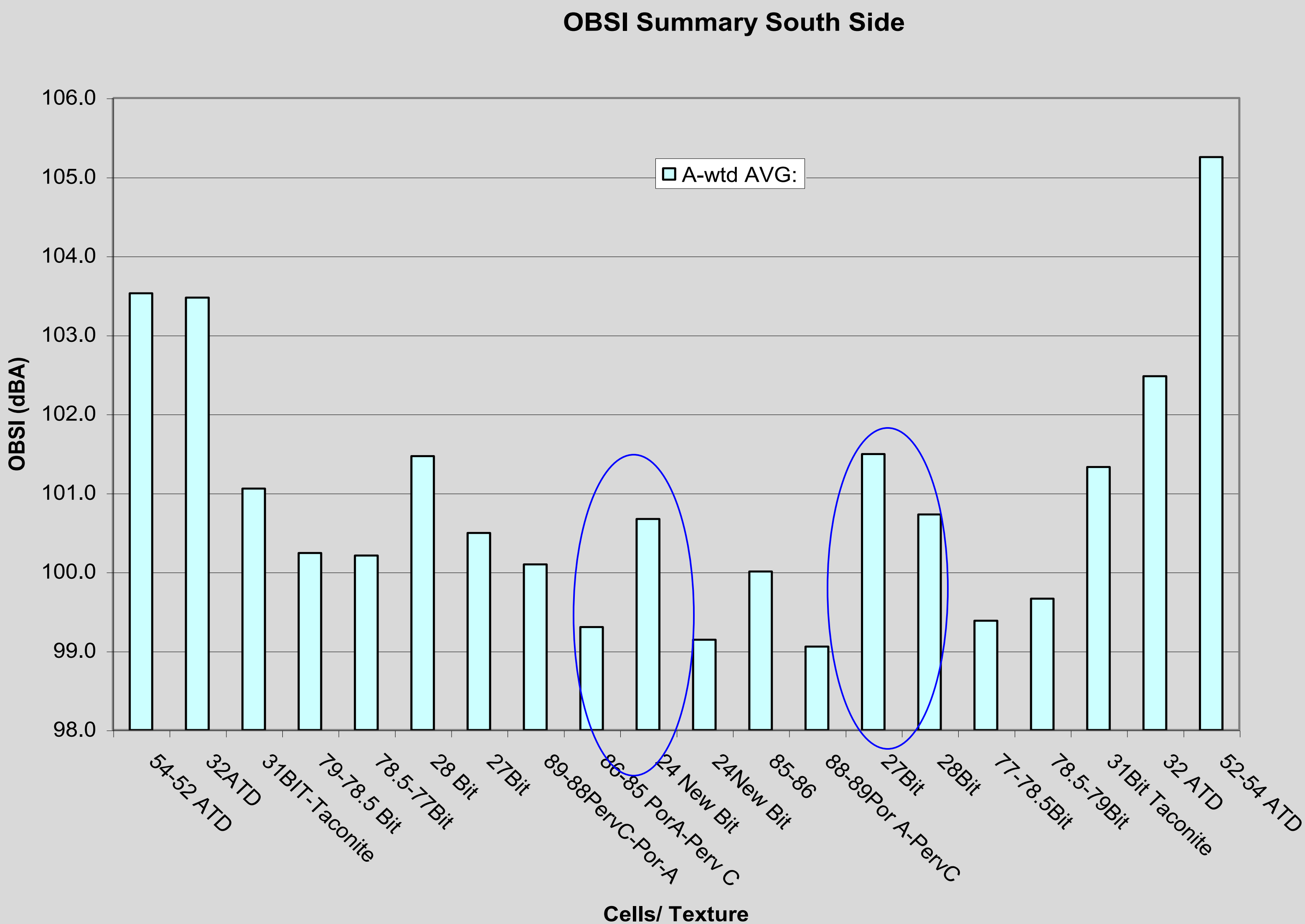
- Full-Depth Pervious Concrete Pavement



MnROAD Phase 2

- Full-Depth Pervious Performance
  - Performing well under heavy MnROAD truck loads
  - Some surface raveling of transverse joints
  - Some longitudinal cracks in section over clay subgrade
  - Permeability improved after vacuuming
  - System shows strong effect on frost penetration (less!)
  - Quiet pavement (excellent sound absorption)

OBSI RESULTS (NOISE)



LVR North Side OBSI with Porous Porous Cells Accentuated

New projects

- SHRP2 – Composite Pavement Sections

  Built in June 2010

Cell #	Lower layer	Upper Layer
70	6 inch Recycled PCC	3 inch hot mix asphalt
71	6 inch Recycled PCC	3 inch concrete w/exposed aggregate surface
72	6 inch Low Cost	3 inch concrete w/exposed aggregate surface

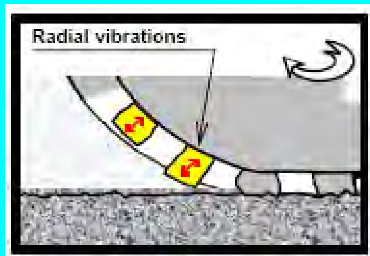
  – Cells 71-72: Wet-on-wet concrete paving
  – Sustainable concepts
    - 50% recycled (MnROAD) concrete as PCC aggregate
    - Up to 60% cement substitution
  – European style exposed aggregate texture

MnROAD Phase 2

- PCC Surface Characteristics
  - Noise
  - Texture
  - Friction
  - Smoothness (IRI)
  - Durability

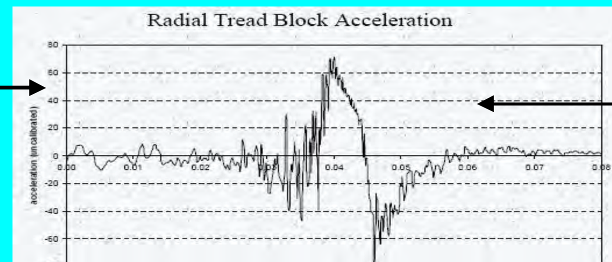
MINNESOTA CONCRETE TEXTURING

TIRE-PAVEMENT NOISE GENERATION MECHANISMS



Hammer Mechanism due to radial vibration

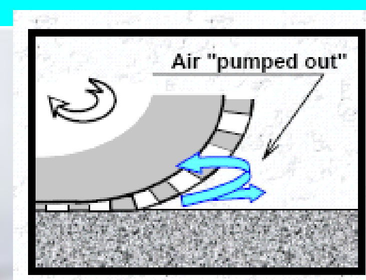
Hammer
Radial block
acceleration



The spike is a tone similar to uniform transverse texturing

Adhesion

Stick Snap



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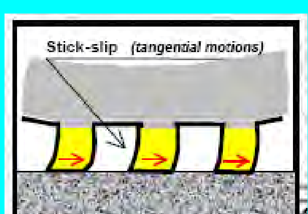
Clapper: As Air Gets Pumped out of the Contact Area



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High Frequency squeals

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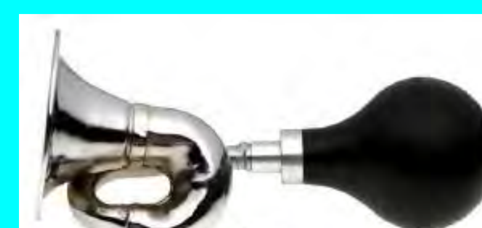

Horn: Tire Road Geometry serves as An Amplifier

Periodic Monitoring

- **AASHTO TP 76-08 On-Board Sound Intensity tests for TPIN**
- **ASTM E965-95 Sand volumetric technique for surface texture**
- **ASTM E-2157-02 Sand Volumetric Technique Circular Track Meter for texture**
- **ASTM E- 303 (1995), Friction measurement Using the British Pendulum**
- **ISO 13472-1 Standard Sound Absorption measurement Using a White noise source an Impedance Tube and 2 Sound Pressure Meters.**

MnROAD Phase 2

– MnROAD has some of the **"QUIETEST CONCRETE PAVEMENT SURFACES MEASURED ON EARTH!"**

  - "Next Generation" diamond grinding
  - Porous PCC overlay (Cell 39)

New projects

- Innovative joint load transfer devices

- Old W.B. I-94 (adjacent to MnROAD): Retrofit dowel bars between existing dowels

RAPID CONCRETE EVALUATION TECHNOLOGY

CHAIN DRAG TECHNIQUE

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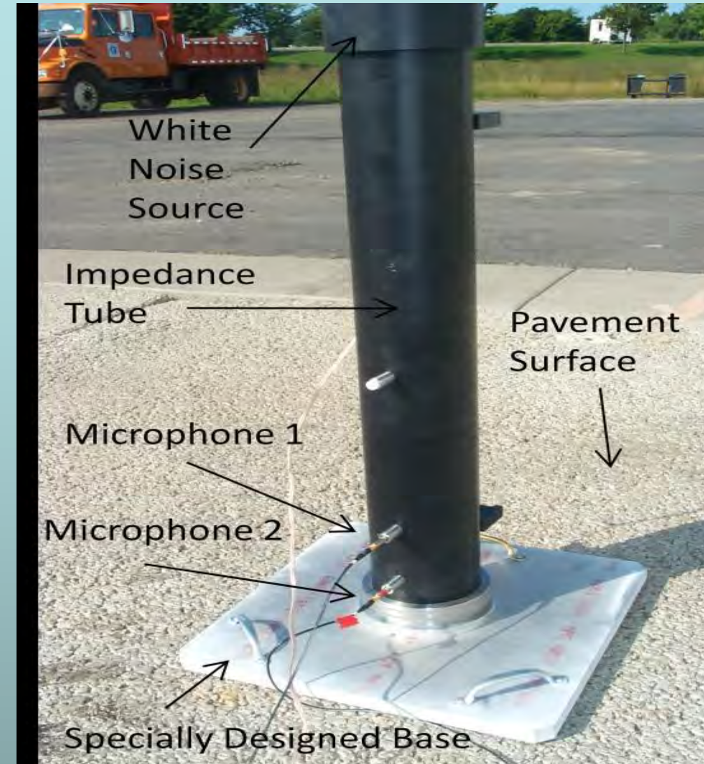
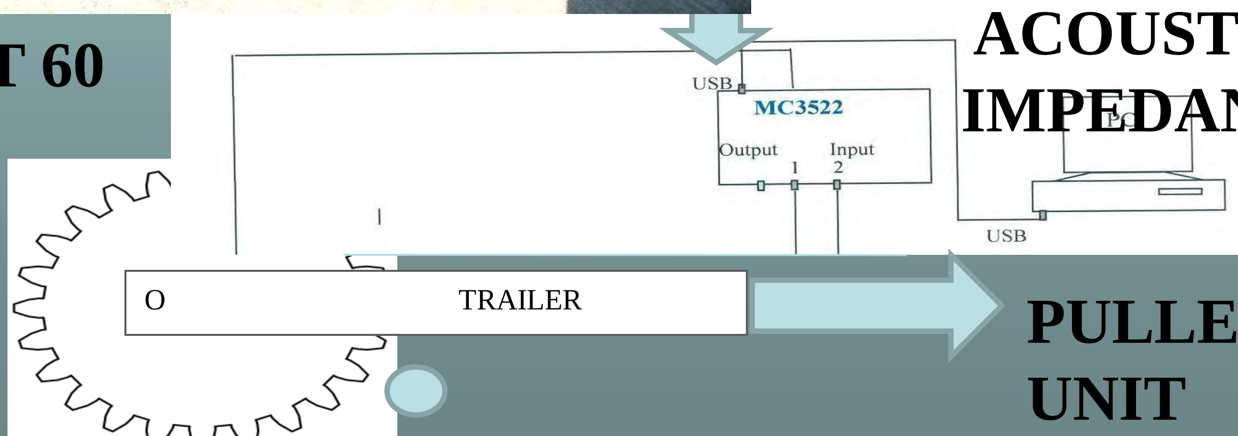


OBSI AT 60 MPH

ACOUSTIC IMPEDANCE



PULLED BY STATE UNIT

O BRIDGE DECK

MnROAD Operations Improvements

- VTS = Vehicle Tracking System (GPS)
  - Centimeter level accuracy at 45mph
- Automated faultmeter
- Wireless triggering
- Live traffic triggering
- ALPS2 = warp and curl
- Sensor installation techniques

Thank you

Questions?