Mn/DOT Concrete Update

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OUTLINE

- Current Concrete research Initiatives at MnROAD
- Diamond Grinding Initiative
  - Conventional usage Of Diamond Grinding
  - Initiatives For Quiet Pavements: The Innovative Grind
  - Innovative Grinding Techniques
  - OBSI Test Results On Innovative Grinding
  - Conclusion

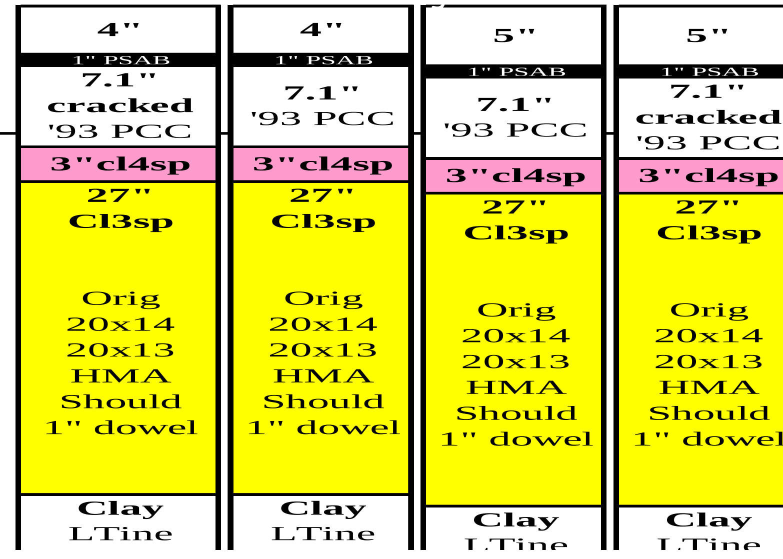
Current Initiatives in MnROAD Phase 2

- Thin-Unbonded Overlay
- Optimized thickness design
- Pervious Concrete in LVR
- White topping
  - Multi-State Pooled Fund project
  - Whitetopping Initiative on Deteriorated Bituminous Substrate
- 60–Year Concrete Pavement
- Composite Pavement (Pooled fund)
- Composite pavement NCHRP
- Tie bar Study

Thin Unbonded Overlay (TUBOL) Subjected to Interstate Traffic

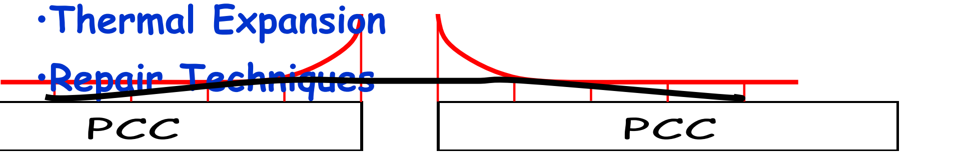
Innovative Features:
- Thinner Overlay
  - 4, 5"
- Strip/Wick drains orientated transverse to pavement
  - Daylight to shoulder
  - No edge drains

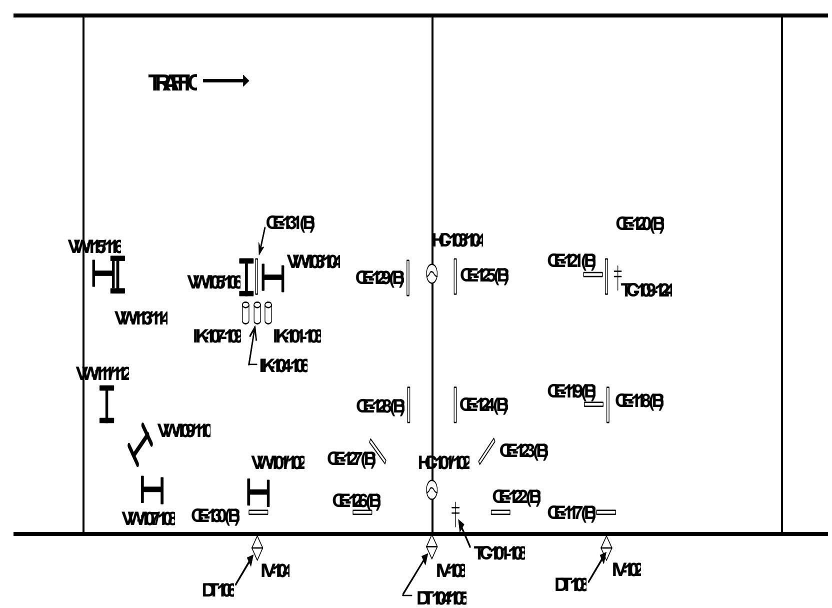
Design Features
- Standard Mn/DOT PCC
- Permeable Asphalt Stabilized Stress Relief Course (PASSRC)
- Joint Spacing of 15' (underlying pavement spacing of 20')
- Joints Sawed to t/3
- No Dowels
- No Longitudinal Ties
- HMA Shoulder (3', 8')



Minnesota Pavement Research -6(016)

- Develop better distress and life prediction models
- Improve Understanding of Behavior
  - Maturity
  - Slab Warp/Curl
  - Thermal Expansion
  - Repair Techniques





Infinite stresses could result from joints
PASSRC Curbs those infinite stresses

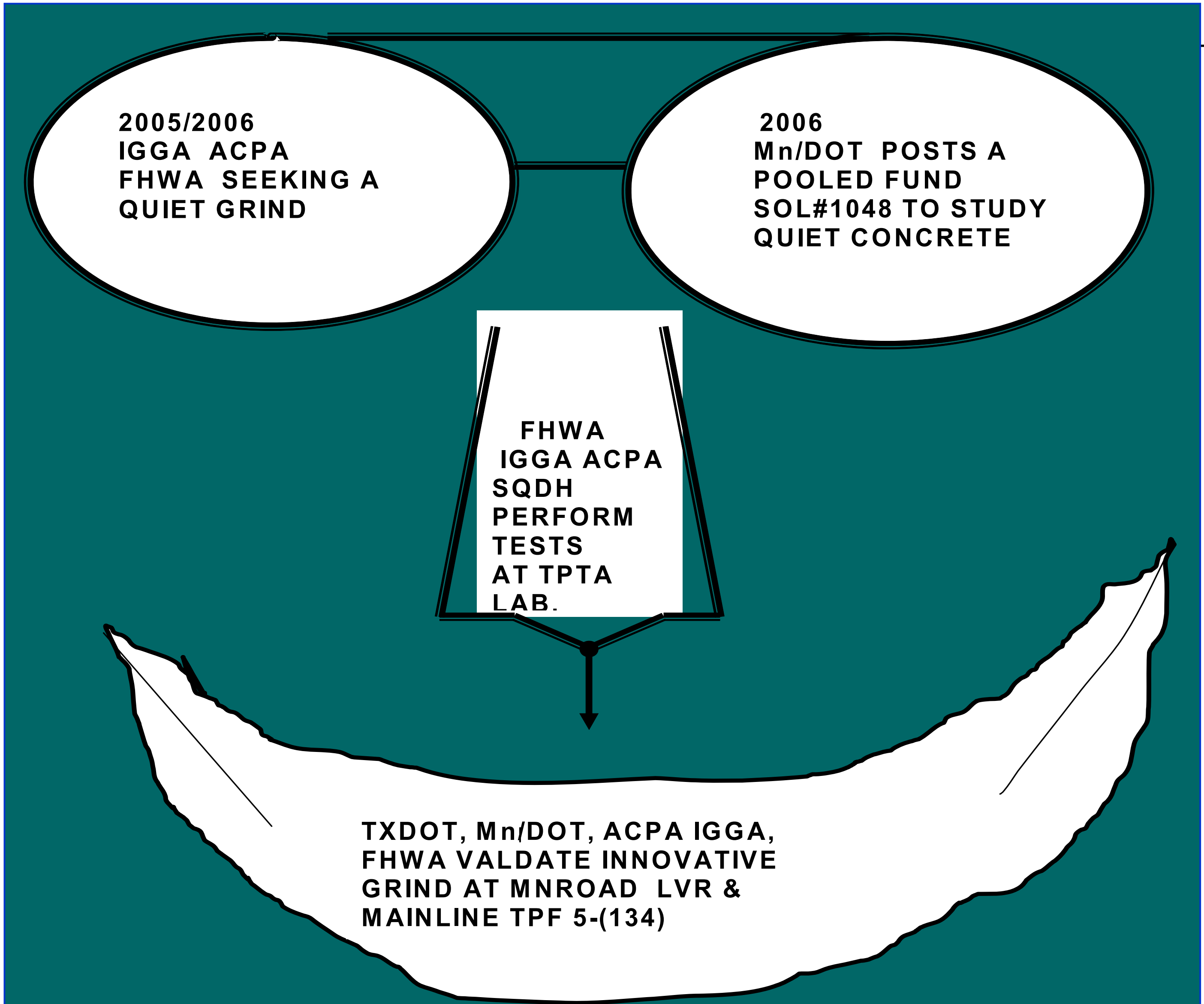
What is Diamond Grinding?

- A process of bump removal and direct texture impartation on a hardened concrete surface with the use of diamond-tipped cutters systematically stacked on a rotary drum.
- Diamond Grooving is the impartation of longitudinal grooves without the intent of bump removal.
- Ordinarily, grooves are deeper and wider than Bump removal grinds
- Diamond Grooving patterns are similar to longitudinal tining configuration but geometrically consistent.
- To achieve desired configuration, blade setting is important.

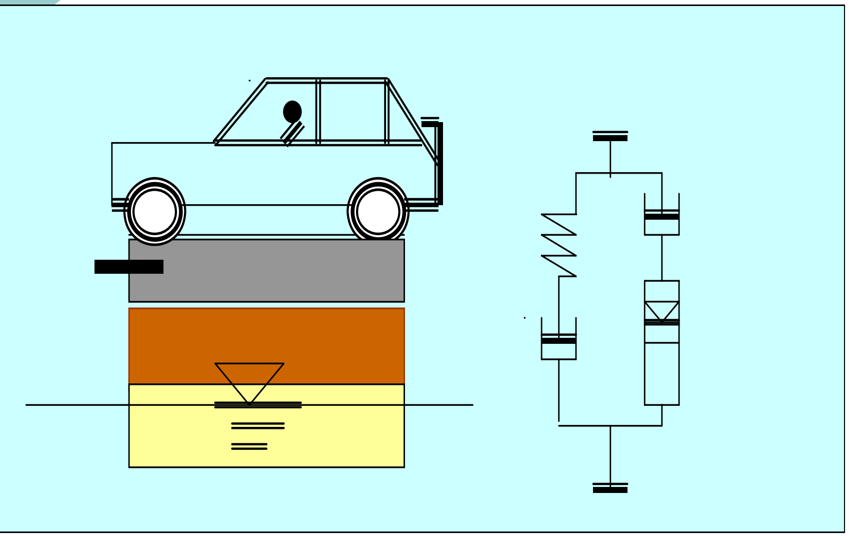
Conventional Usage Of Diamond Grinding

- Originally Invented in the 1950s for bump removal.
- Restoration of Ride Quality.
- Removal of Faults and Bumps.
- Restoration or Establishment Of Texture and Friction.
- **Was not historically a quiet pavement tool.**

THE QUIET PAVEMENT INITIATIVE



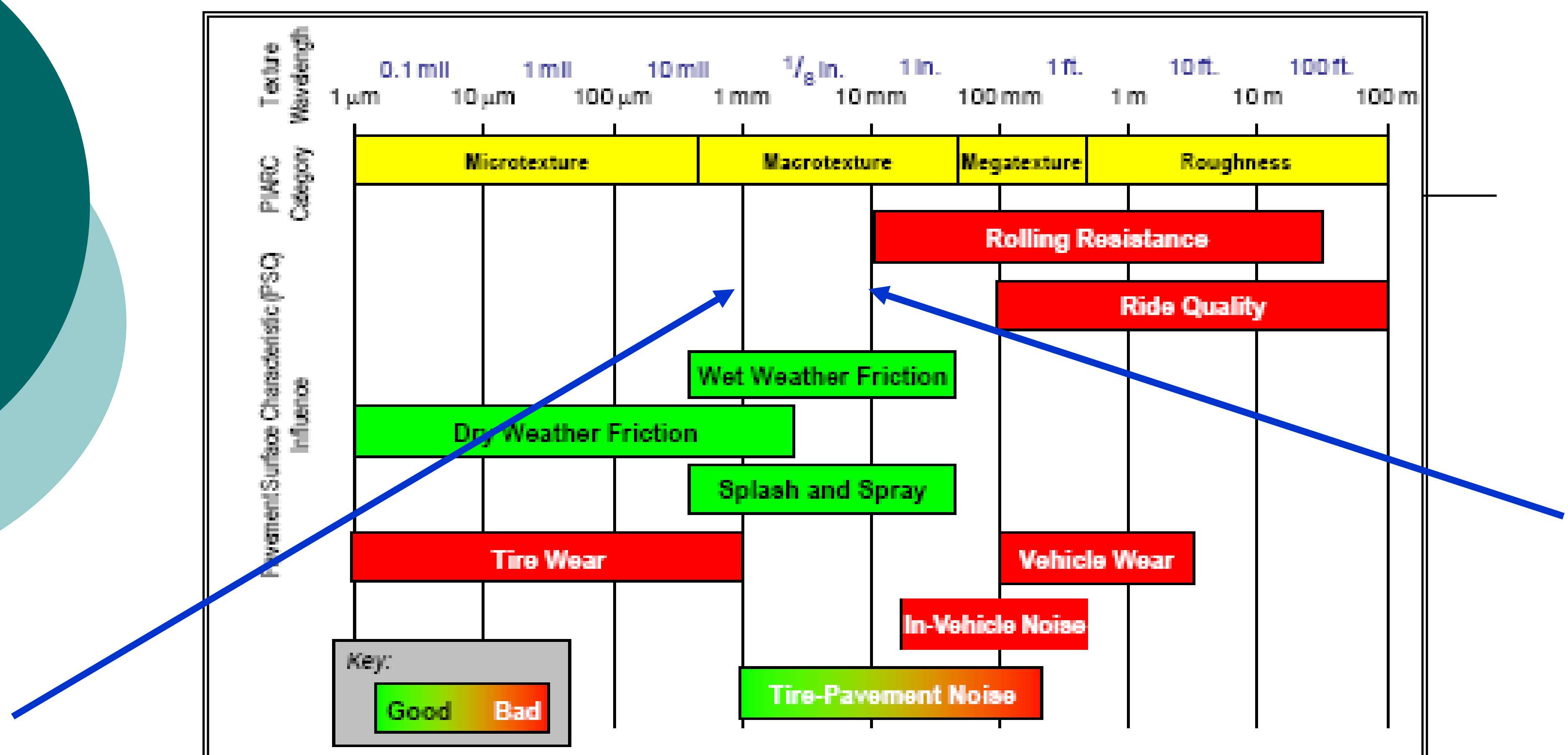
RELEVANCE TO CP ROADMAP & Mn/DOT VISION



CP ROADMAP TRACK 4

Optimized Surface Characteristics for Safe, Quiet, and Smooth Concrete Pavements. This track will result in a better understanding of concrete pavement surface characteristics. It will provide tools to enable engineers meet or exceed predetermined requirements for friction/safety, pavement-tire noise, smoothness, splash and spray, wheel path wear (hydroplaning), light reflection, rolling resistance, and durability (longevity). Each of the functional elements of a pavement listed above is critical. The challenge is to improve one characteristic without compromising another characteristic, especially when it comes to safety of the public.

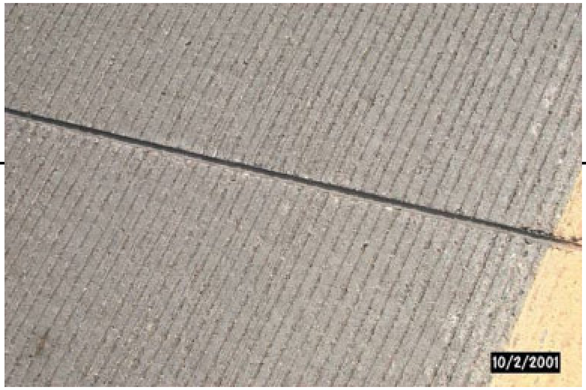
TEXTURE AFFECTS SURFACE CHARACTERISTICS



- Typical Textures Measured With ASTM E-965 Range From 0.4mm to 3mm.
- Some Texturing are Within the Macro Texture Band That Govern Wet Weather Friction and Skid Resistance..
- Above 10mm MTD Undesirable Tire Pavement Noise Is Generated

TYPICAL TEXTURES

Burlap drag



Diamond Grinding

Pervious Concrete

Astro Turf Drag

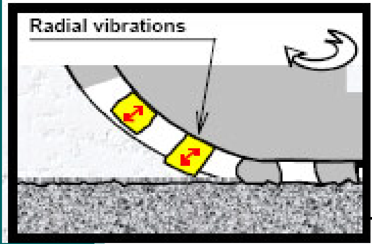
Longitudinal Tine

Random Transverse Tine

Transverse Tine

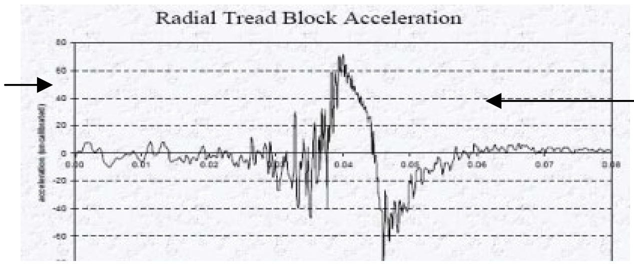
Exposed Aggregate Process and Finish

TIRE-PAVEMENT NOISE GENERATION MECHANISMS



Hammer Mechanism due to radial vibration

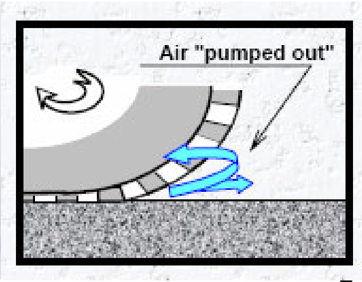
Hammer Radial block acceleration



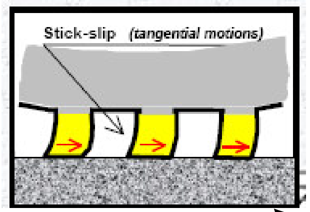
The spike is a tone similar to uniform transverse texturing

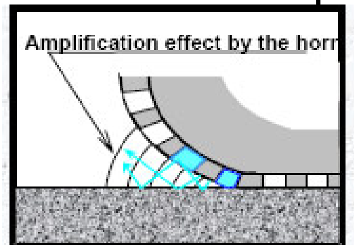
Adhesion

Stick Snap



Clapper:As Air Gets Pumped out of the Contact Area





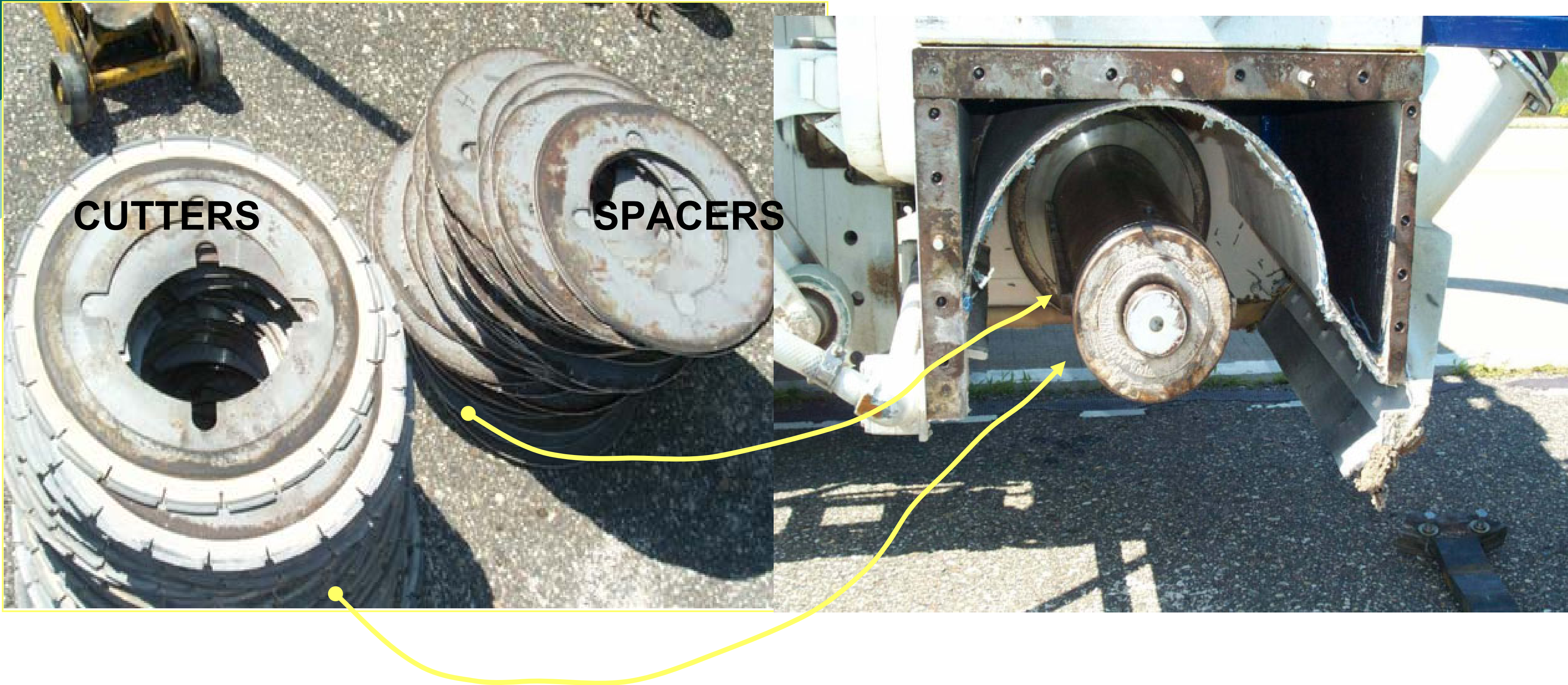
High Frequency squeals

Horn: Tire Road Geometry serves as An Amplifier

Courtesy: SQDH Purdue university

THE DIAMOND GRINDING PROCESS

- BLADE STACKING



DIAMOND GRINDING PROCESS

Setting and Initialization

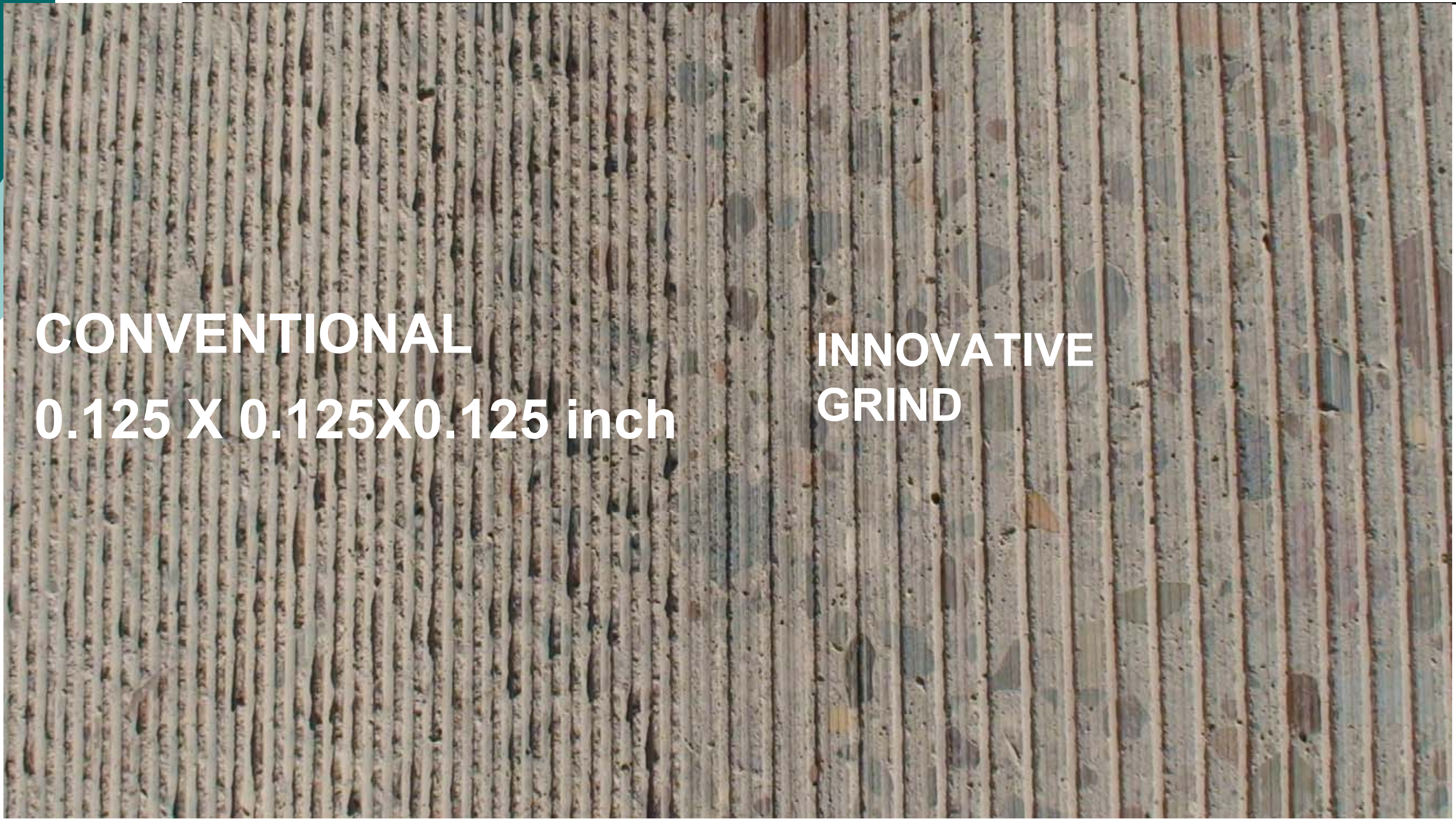
Grinding Process

CUTTER

CELL 7 & and 8 RESEARCH MATRIX

- Flush-grind Of Both Cells 7 and 8 + Transition With Conventional Grind
- Innovative Grind On Cell 7
    - Different Passing & Driving Lane Traffic
    - Similar traffic on Longitudinal matrix Cells 7 and 8
    - Passing Lane has Similar traffic across cells
    - Driving lane has same traffic across Cells
    - Texture Degradation Studies
- Partial Grind On Tied Inside Shoulder Cell 7
    - Study the effect of partial grinding
    - Texture Degradation Studies

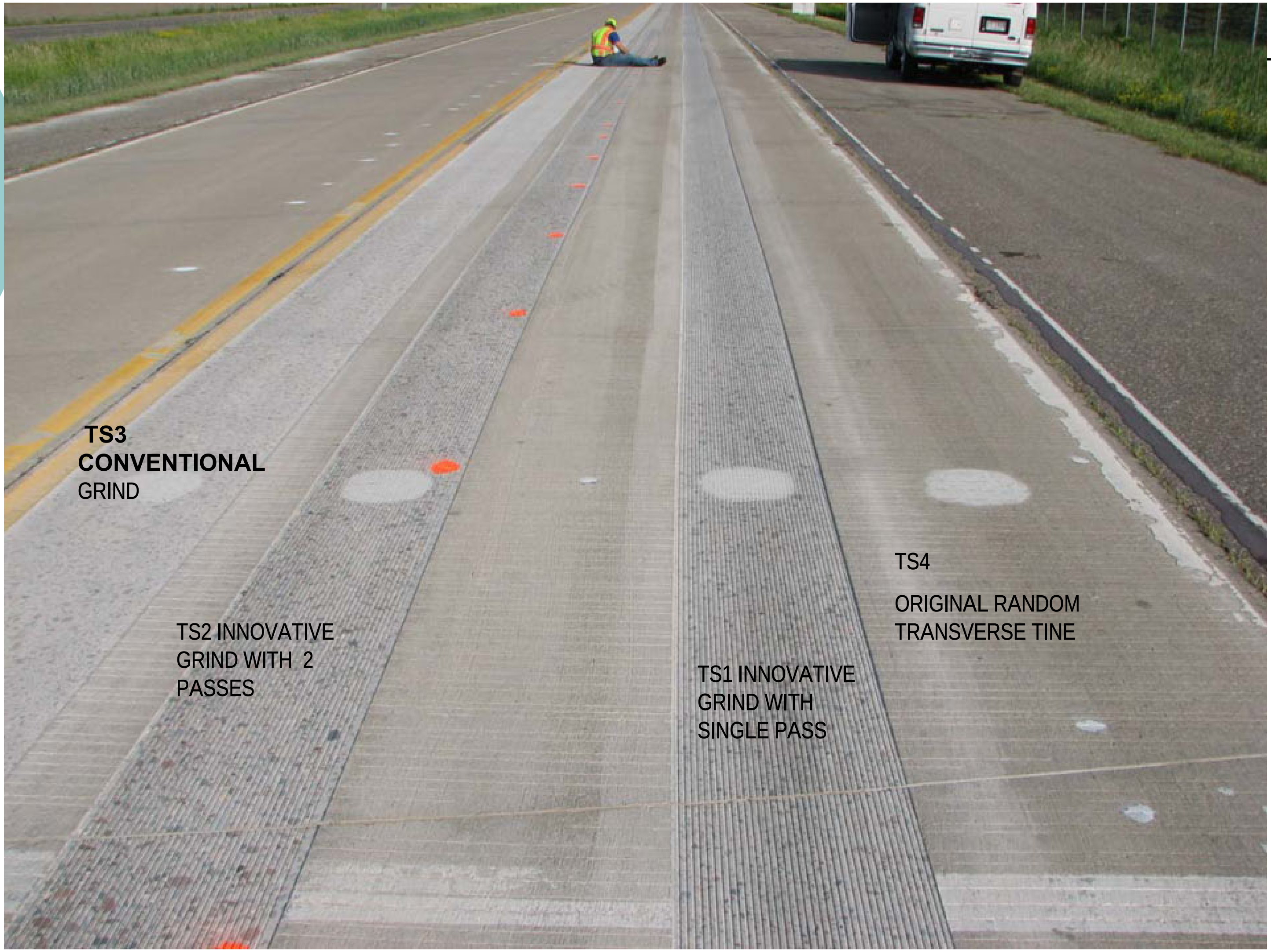
CONVENTIONAL GRIND



INNOVATIVE GRIND IN PERSPECTIVE

S ≈ 0.1 X 0.25X0.125

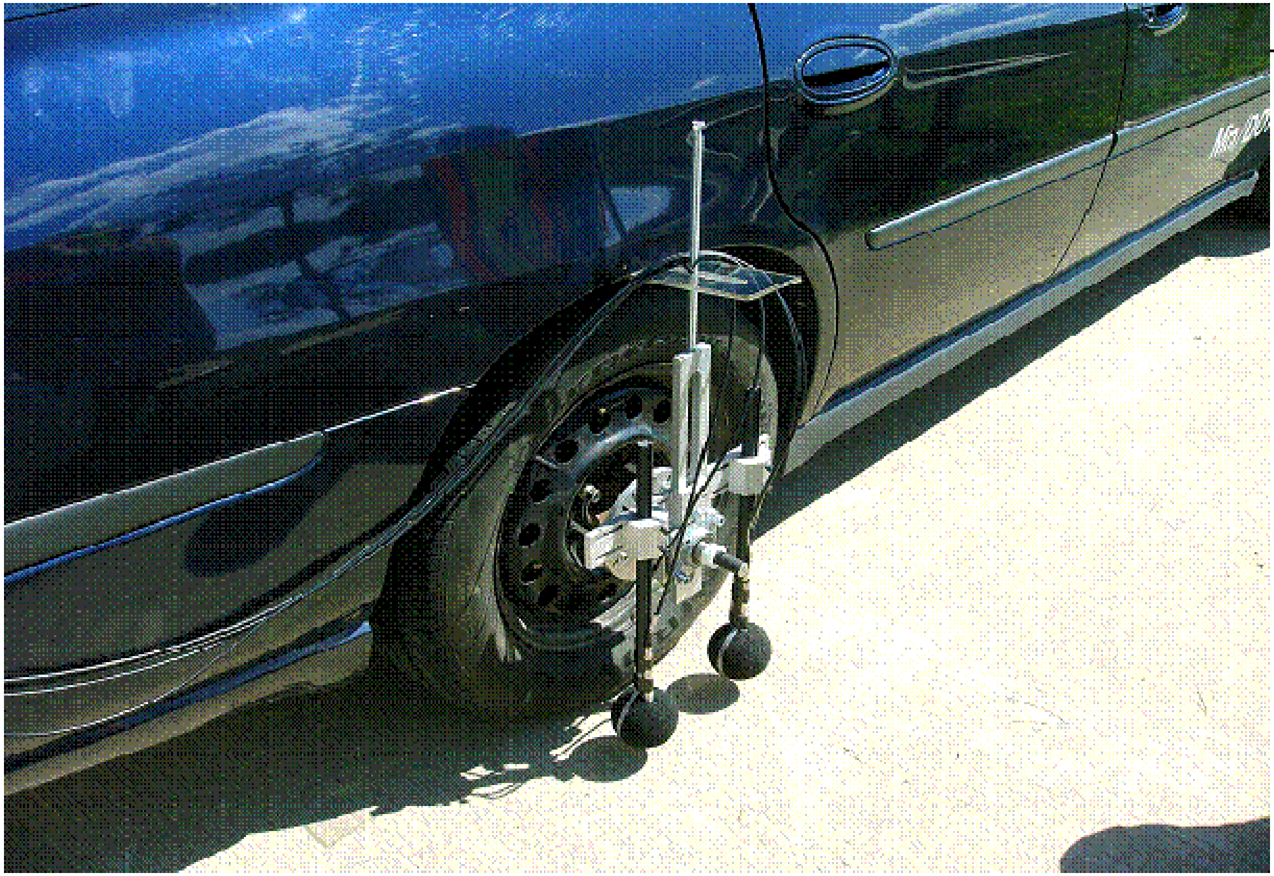
CELL 37 MNROAD AFTER INNOVATIVE GRIND



USING OBSI TO MEASURE TIRE PAVEMENT NOISE

- OBSI = On-Board Sound Intensity Microphones are mounted near Tire pavement interface.
- Tire pavement noise Is dominant at freeway speeds
- OBSI Preferred to SPB for pavement Evaluation

Mn/DOT OBSI Set Up



Each sphere holds 4 powerful Intensity meters that are connected to the front end analyzer via cables. Measurement is done at 60 miles per hour

MnROAD Cell 7 & 8 Post Grind

INNOVATIVE Cell 7

	Leading Edge			Trailing Edge			AVG	
	IL	PI	Coh	IL	PI	Coh	IL	
250	87.0	-0.9	0.4	77.9	9.1	0.5	84.5	
315	81.0	3.6	0.5	85.1	1.1	0.6	83.5	
400	83.2	1.4	0.7	82.3	2.5	0.7	82.7	
500	82.3	1.9	0.9	79.5	4.8	0.8	81.1	
630	83.1	2.2	1.0	81.1	4.0	0.9	82.3	
800	88.1	1.2	1.0	88.4	1.4	1.0	88.3	
1000	93.9	0.8	1.0	93.5	0.9	1.0	93.7	
1250	89.8	0.7	1.0	92.9	0.7	1.0	91.6	
1600	88.9	1.1	1.0	88.8	1.0	1.0	88.8	
2000	88.6	1.2	1.0	88.9	1.0	1.0	88.7	
2500	86.2	1.1	1.0	87.6	0.6	1.0	87.0	
3150	80.9	0.8	1.0	82.1	0.6	0.9	81.5	
4000	77.3	1.3	0.8	78.6	0.9	0.9	78.0	
5000	74.1	1.6	0.7	74.1	1.2	0.8	74.1	
A-wtd	98.2			98.7			98.5	

CONVENTIONAL Cell 8

	Leading Edge			Trailing Edge			AVG	
	IL	PI	Coh	IL	PI	Coh	IL	
250	82.8	4.5	0.6	82.4	5.1	0.5	82.6	
315	87.0	1.4	0.8	89.2	-0.8	0.7	88.2	
400	90.3	0.9	1.0	88.2	0.5	0.8	89.4	
500	91.5	1.3	1.0	89.7	1.6	1.0	90.7	
630	95.8	1.2	1.0	92.9	1.6	1.0	94.6	
800	100.3	0.4	1.0	97.5	0.5	1.0	99.1	
1000	95.3	0.9	1.0	96.9	0.8	1.0	96.2	
1250	92.7	0.5	1.0	94.6	0.8	1.0	93.8	
1600	89.4	0.8	1.0	90.1	0.8	1.0	89.7	
2000	86.8	1.1	1.0	85.9	1.2	1.0	86.4	
2500	83.9	1.1	1.0	83.3	1.3	1.0	83.6	
3150	80.2	1.0	0.9	79.4	1.2	0.9	79.8	
4000	76.4	1.3	0.8	75.8	1.6	0.8	76.1	
5000	73.8	1.8	0.7	72.6	2.0	0.7	73.2	
A-wtd	103.6			102.6			103.1	

THE CRUX OF THE MATTER

INNOVATIVE DIAMOND GRINDING RESEARCH

STUDY MATRIX

- Flush-grind Of Both Cells 7 , 8 & Transition With Conventional Grind.
- Innovative Grind On Cell 7.
    - Different Passing & Driving Lane Traffic loading.
    - Similar Traffic On Longitudinal Matrix Cells 7 And 8.
    - Lanes Have Similar Traffic Across Cells.
    - Texture Degradation Studies.
- Partial Grind On Tied Inside Shoulder Cell 7.

CELL 37 WITH 3 CONFIGURATIONS

INNOVATIVE DIAMOND GRINDING RESEARCH

POOLED FUND STUDY TPF 5-(134)

- Mn/DOT, TXDOT FHWA, ACPA, IGGA
- Develop a Quiet Grinding Configuration
- Friction, Noise Texture Ride Quality
- Compare innovative to conventional
- Study Durability of Innovative Grind

COMPARISON OF INNOVATIVE (CELL 7) TO CONVENTIONAL GRIND (CELL 8)

INTERIM RESULTS

- High Ribbed Tire Friction Numbers
- Very High Smooth Tire Friction
- 4.5db(a) Quieter Than Conventional Grind
- 4.5 dB(A) ≈ Reducing Traffic volume by 67%
- Improved Ride Quality

Location	Test No.	Leading Edge	Trailing Edge	Average
Cell 8 D.L.	1	103.6	102.6	**103.1**
	3	104.0	103.0	**103.5**
	5	103.7	102.9	**103.3**
Cell 7 D.L.	2	98.8	99.7	**99.3**
	4	98.1	98.8	**98.5**
	6	98.5	99.0	**98.7**
Cell 7 Midlane	7	98.6	99.0	**98.8**
	8	98.4	99.0	**98.7**
	9	98.2	98.7	**98.5**
Cell 8 P.L.	10	103.4	102.5	**103.0**
	12	103.5	102.6	**103.1**
	14	104.1	103.3	**103.7**
Cell 7 P.L.	11	98.2	99.2	**98.7**
	13	98.2	99.2	**98.7**
	15	98.7	99.6	**99.2**

TH 94 in BRANDON MN

- TH 35 in Duluth
- TH 94 in Brandon

O.B.S.I. Data Sheet

I-94 @ Brandon M.P. 79-78 D.L.
Lane was not ground

Date:10/10/2007
Operator: J. Pantelis, T. Snyder

Location	Test No.	Leading Edge	Trailing Edge	Average
M.P. 78.9	11	107.4	107.0	**107.2**
	31	108.4	108.2	**108.3**
	51	108.3	107.9	**108.1**
M.P. 78.8	12	108.6	108.2	**108.4**
	32	108.7	108.5	**108.6**
	52	108.1	107.8	**107.9**
M.P. 78.7	13	107.9	107.4	**107.6**
	33	108.1	107.6	**107.8**
	53	107.7	107.3	**107.5**
M.P. 78.6	14	108.6	108.3	**108.5**
	24	108.7	108.3	**108.5**
	54	107.9	107.5	**107.7**
M.P. 78.5	15	107.4	107.0	**107.2**
	35	108.0	107.8	**107.9**
	55	108.3	108.0	**108.1**
M.P. 78.4	16	107.8	107.4	**107.6**
	36	107.9	107.6	**107.8**
	56	107.6	107.4	**107.5**
M.P. 78.3	17	108.1	107.6	**107.8**
	37	108.4	107.9	**108.1**
	57	108.3	107.8	**108.1**
M.P. 78.2	18	107.8	107.4	**107.6**
	38	108.1	107.5	**107.8**
	58	108.1	107.7	**107.9**
M.P. 78.1	19	107.0	106.5	**106.8**
	39	107.9	107.5	**107.7**
	59	107.7	107.5	**107.6**
M.P. 78.0	20	108.4	108.0	**108.2**
	40	108.0	107.7	**107.8**
	60	108.5	108.1	**108.3**

O.B.S.I. Data Sheet

I-94 @ Brandon M.P. 86-85 P.L.
Lane was ground.

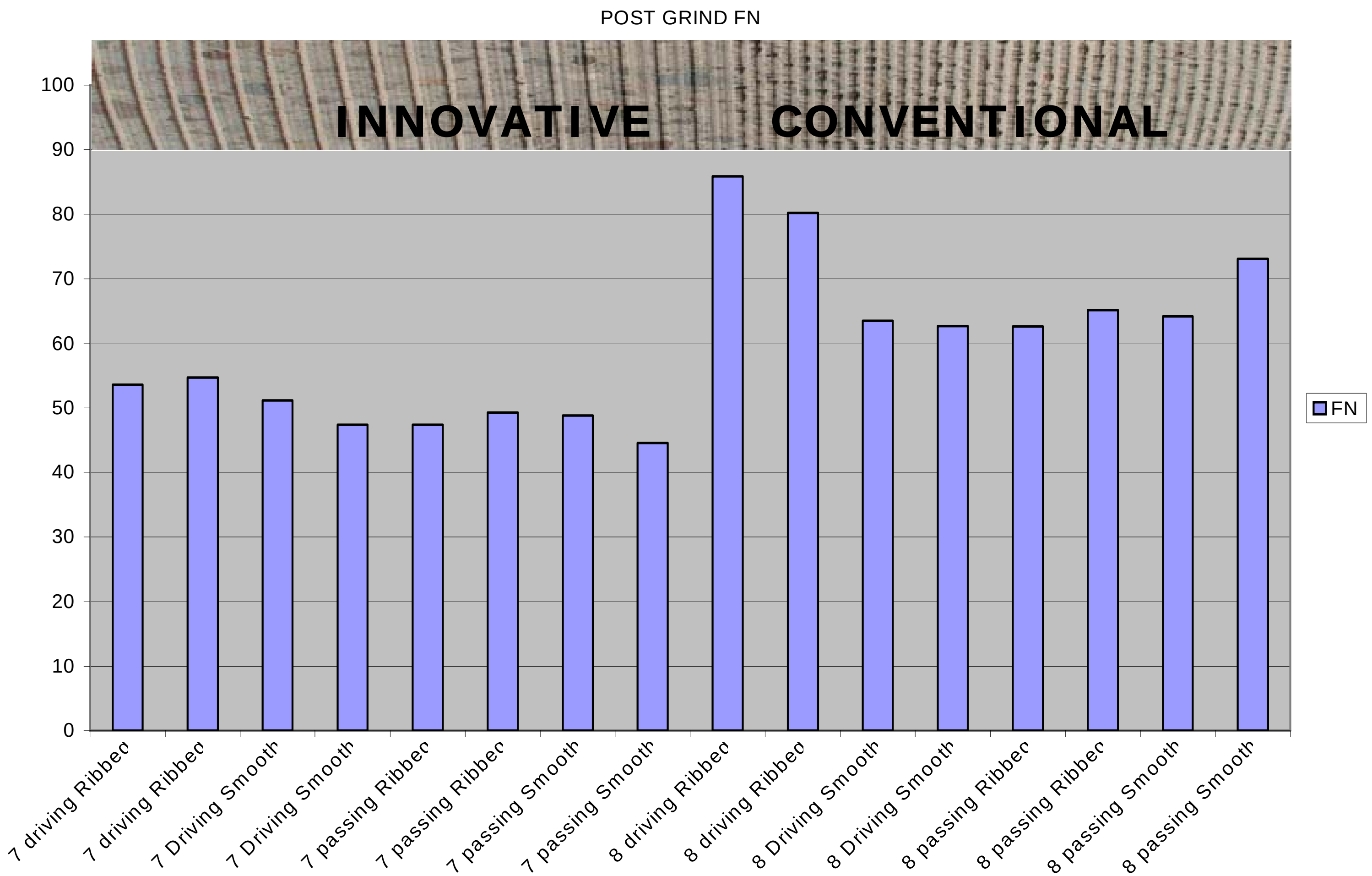
Date:10/10/200
Operator: J.Pantelis, T.Snyde

Location	Test No.	Leading Edge	Trailing Edge	Average
M.P. 85.9	1	104.3	103.6	**103.9**
	21	104.1	103.4	**103.7**
	41	104.2	103.5	**103.9**
M.P. 85.8	2	103.4	102.7	**103.1**
	22	103.3	102.6	**103.0**
	42	103.1	102.5	**102.8**
M.P. 85.7	3	102.3	101.8	**102.1**
	23	102.7	102.0	**102.4**
	43	102.7	102.1	**102.4**
M.P. 85.6	4	103.0	102.2	**102.6**
	24	103.4	102.7	**103.1**
	44	102.9	102.2	**102.5**
M.P. 85.5	5	102.8	102.2	**102.5**
	25	103.0	102.4	**102.7**
	45	103.2	102.6	**102.9**
M.P. 85.4	6	103.3	102.5	**102.9**
	26	103.1	102.4	**102.8**
	46	103.2	102.6	**102.9**
M.P. 85.3	7	103.1	102.4	**102.7**
	27	103.8	103.1	**103.5**
	47	103.2	102.5	**102.8**
M.P. 85.2	8	104.2	103.5	**103.9**
	28	104.4	103.6	**104.0**
	48	103.7	103.1	**103.4**
M.P. 85.1	9	104.2	103.5	**103.9**
	29	104.3	103.5	**103.9**
	49	104.0	103.3	**103.7**
M.P. 85.0	10	104.2	103.6	**103.9**
	30	104.2	103.5	**103.9**
	50	104.5	103.7	**104.1**

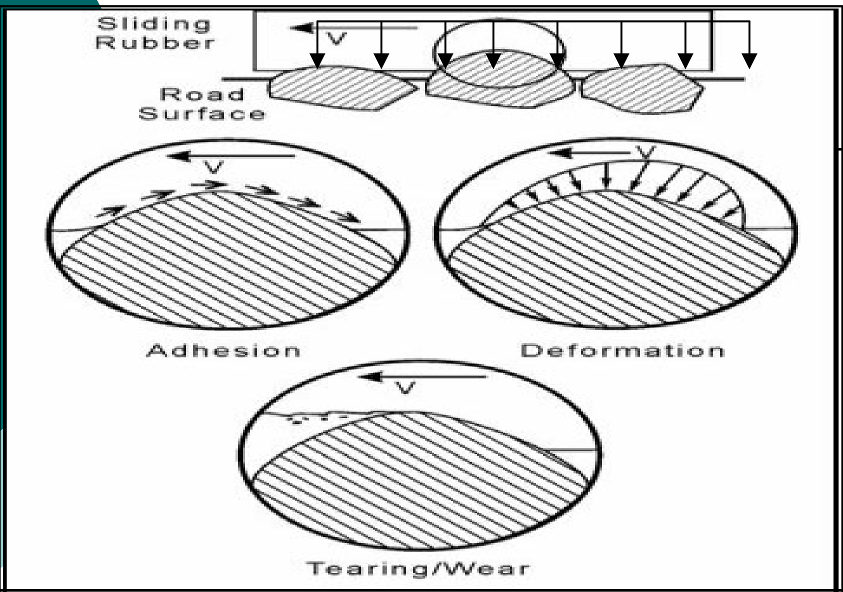
ODINARILY, CONVENTIONAL GRIND QUIETENS PAVEMENTS

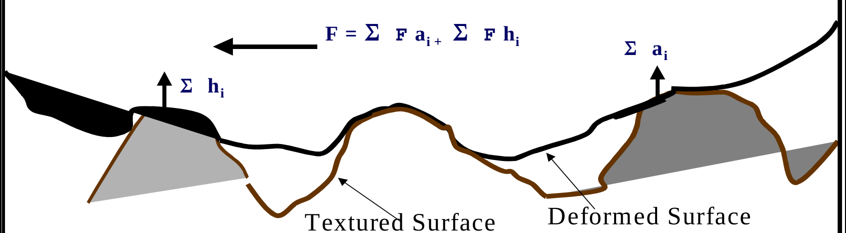
Evidence of Hysteresis in Friction

- Occurrence of loss of asperities in surface texture without a corresponding reduction in friction number.
- Smooth tire friction and ribbed tire friction for some textures are similar
- Unexpectedly high friction in untextured surfaces
- ASTM E-274 data is not reasonably correlated to ASTM E-965 data. (Hysteristic friction is preponderant in some combinations of speed and texture configurations.)



Mechanism Of Hysteretic Friction





F_a= A.S /A_n. P

F_h =QD/ A_n bP where Q=volume of deformed rubber

D is Energy per unit volume dissipated by damping,

A_n is nominal area and b is sliding distance. P is pressure on rubber block

F_a =A. S/. pA_n
F_{we} = Wearing force
F_h = QD/$A_n$bp

f_a = Adhesion Coefficient = F_a/W
f_h = Hysteresis Coefficient = F_h/W
f_h = Hysteresis Coefficient = F_{we}/W
B = Rubber Sliding Distance
W = normal reaction
A = actual Contact Area
Q =Volume of Rubber participating in the deformation
A_n = Nominal Area
S = Interface Shear Strength
D = Energy dissipated per uint volume of rubber due to damping
P =Pressure on rubber Block

$F = F_a + F_h + F_{we}$

The hysteresis mechanism is initiated by the instantaneous or transient deformation of the tire around the area of pavement contact. Adhesion forces generated are dependent on surface asperities, tires and geometry.
Hysteresis is a function of the tire stiffness, texture configuration and speed. The adhesion and hysteresis forces combine to give skid resistance. Some energy losses are accounted for in tire wear and temperature change.

RESEARCH / MONITORING

- Ride Quality
- Friction
  - ASTM E-274
  - British Pendulum

- Texture
  - ASTM E965-95
  - ASTM E-2157 CTM
- Noise
  - OBSI
  - EFR

JUSTIFICATION OF INNOVATIVE GRINDING

- European Union VTI Sweden uses
  30 Euros ($50)/ Capita/Db for Noise reduction Benefit analysis
- Cost of alternative Noise Abatement Wall
  approximately $0.75-$3million/mile of Standard Noise Abatement Wall.
- Savings of 3dBA is tantamount to 50% reduction of the Traffic Volume

SOME EARLY CONCLUSIONS

- Innovative Grind showed sufficient friction numbers but has a characteristically high Smooth tire friction.
- Innovative grinding is void of brittle fins. ubiquitous in conventional grinds. Brittle kerfs are easily removed by snow operations
- Innovative grind was quieter than conventional grind by about 4 dBA. This is equivalent to reducing the traffic volume by 67%
- Study will correlate texture degenerative curves WRT OBSI, Friction, Ride quality and Splash n' Spray Parameters.


THE ENDLESS ROAD AKA "RE-SEARCH"