Hardening Concrete Pavement Against Friction Loss Due to Aggregate Polishing

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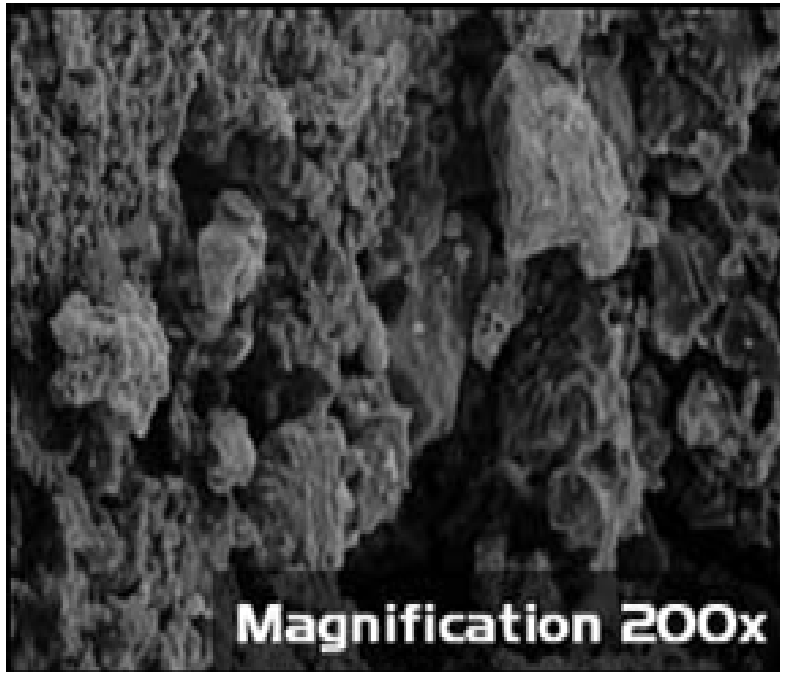
Background

- Pavement hardening through densification
- Chemical reaction between lithium in surface treatment and calcium hydroxide in pavement
  - Portland cement
  - Aggregate if present in geomorphology
- Forms a “crust” of lithium silicate
  - Hardens against abrasion
  - Decreases porosity
- Performance is related to depth of penetration

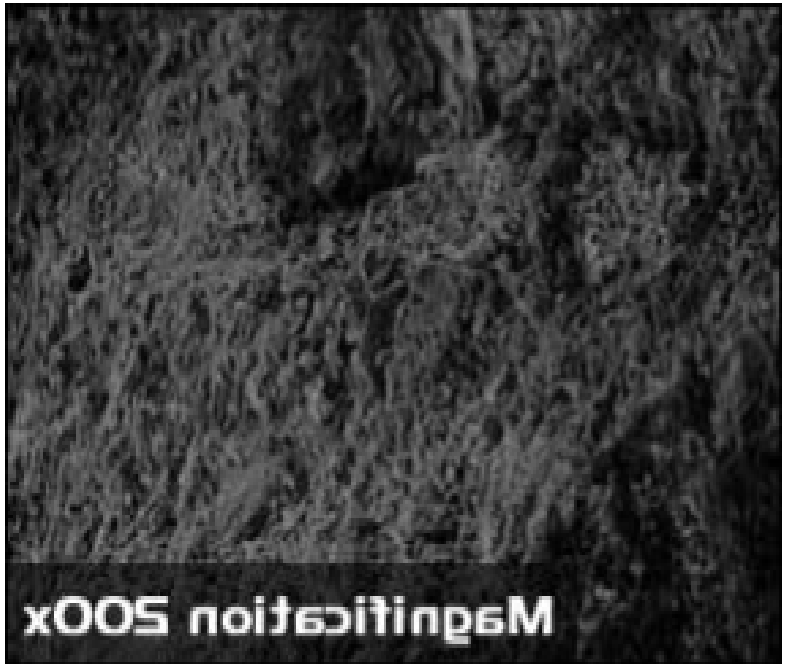
Densification Process

- Treatment applied over shotblasting or diamond grinding to enhance penetration.
- Pretreatment shotblasting enhances microtexture

Before



After



Why Use Densification

- Increases resistance to abrasion
  - Rutting, edge cracking, and tine deterioration
  - Polishing of aggregate
- Loss of skid resistance
  - Ponding water in ruts
  - Loss of aggregate microtexture
- Issue – if concrete is sealed, its surface friction is reduced. Often need to shotblast to restore microtexture after applying curing compounds or after runway rubber removal.

Aggregate Quality

- Much of the US does not have high quality aggregate available.
- As time goes on less high quality aggregate will be available
- Economic haul distance
  - Diesel cost volatility
  - Available road net
- Can't afford to haul as far as fuel cost rises

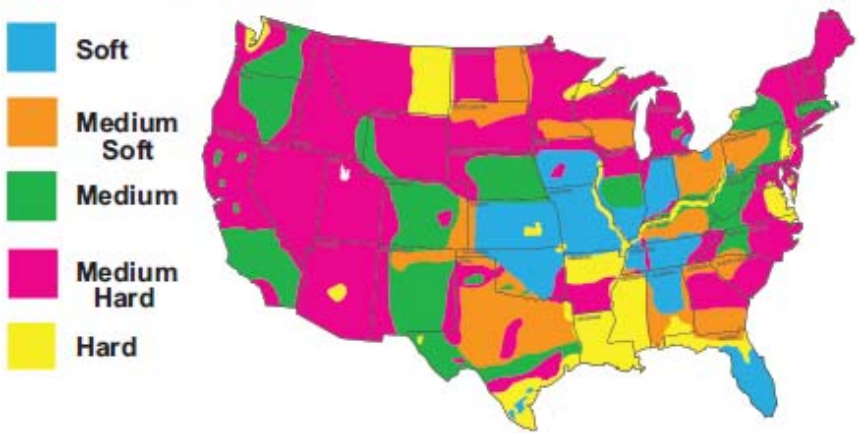
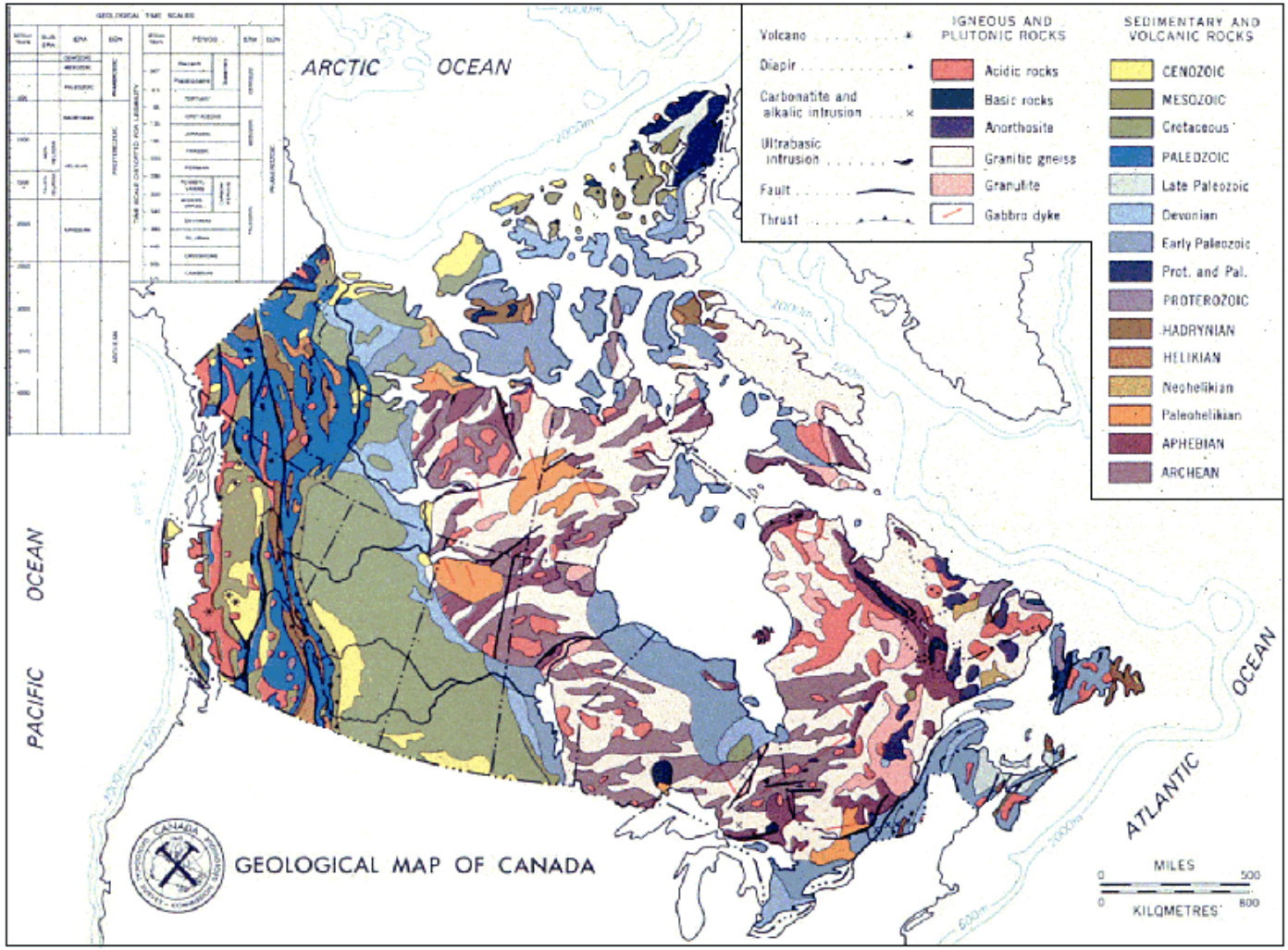


Figure 1. US Aggregate Quality Distribution

Canadian Geology



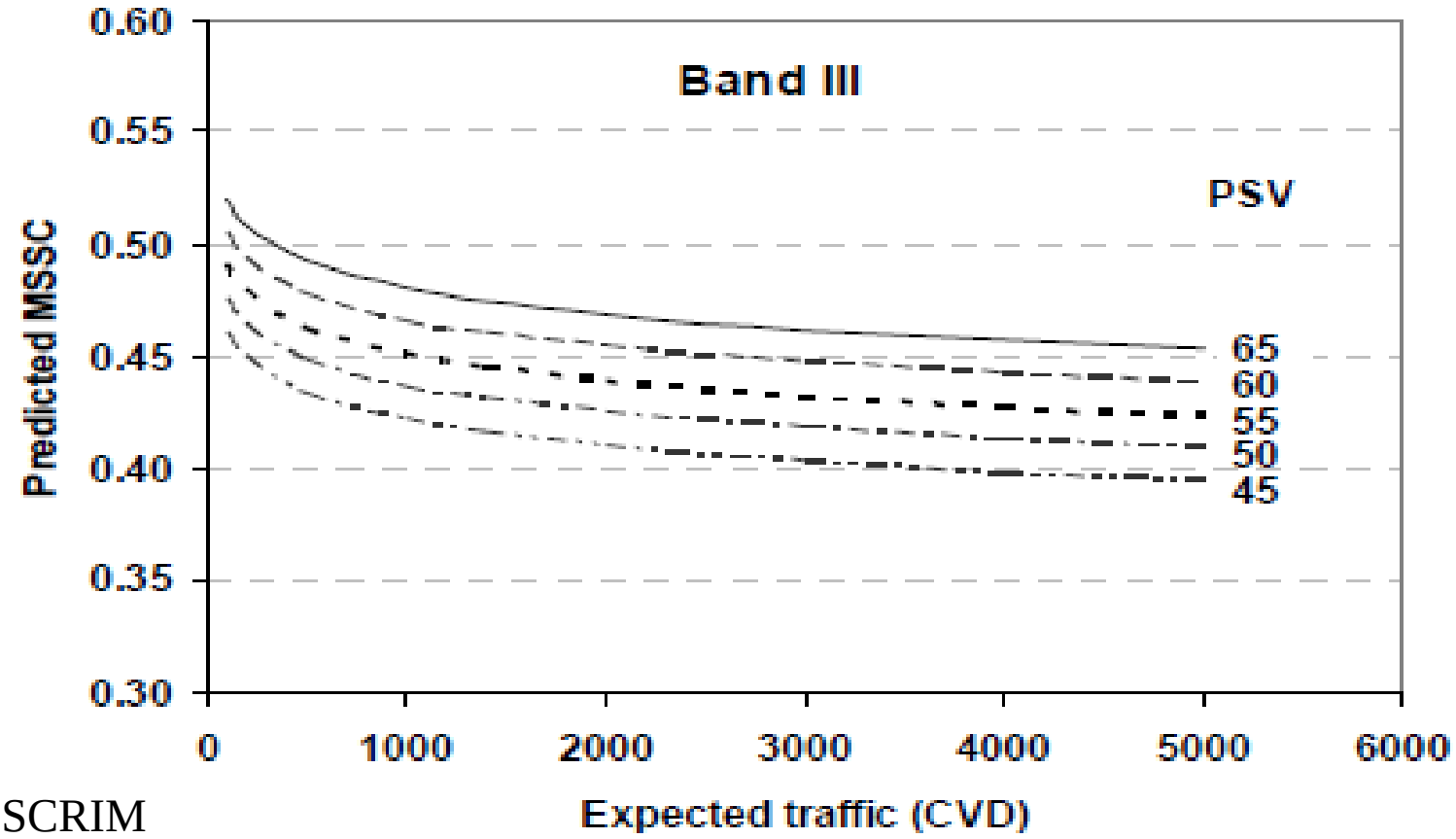
Research Question

- *Can Portland Cement Concrete Pavements be hardened to increase their service without a negative effect on pavement skid resistance?*

Methodology

- Merge the results of two studies using the same materials.
  - Caltrans I-80 Donner Pass –abrasion resistance
  - Oklahoma DOT US Highway 77 OKC – skid number
    - Both applied lithium densifer over concrete pavements
    - Both used shotblasting to prepare the pavement for the lithium densifer

Microtexture Deterioration Model



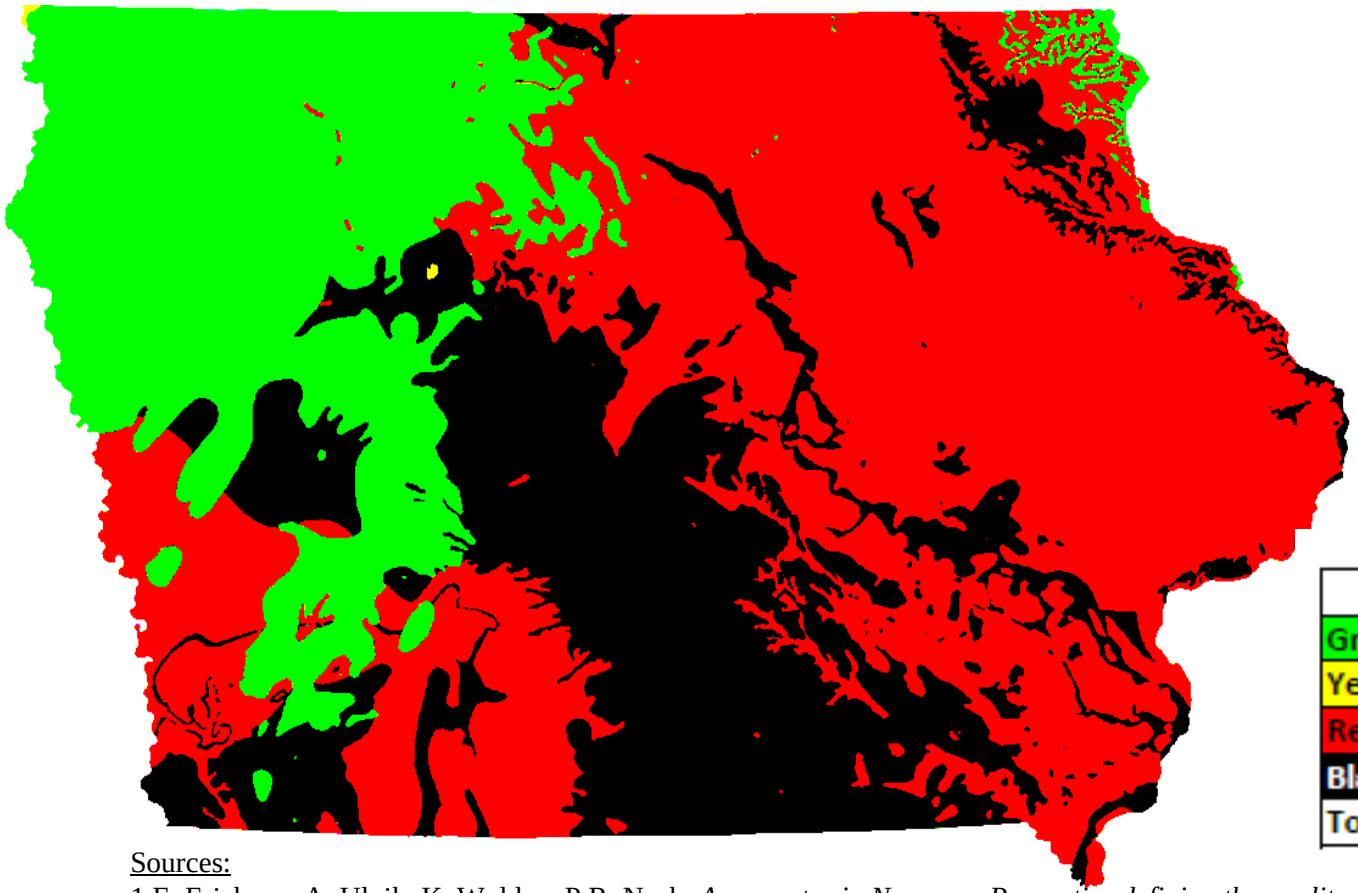
Mean Summer SCRIM Coefficient (Neaylon 2009)

Similar to Skid Number

Geologic Mapping

Quality Rating	PSV Ave	PSV min	Example Geologic Types
Good	> 55	> 45	Greywacke, Sandstone, Arkose, Amphibolite, Banded Gneiss
Marginal	< 55	> 45	Eclogite, Granitic Gneiss, Gneiss, Mylonite, Quartzite
Variable	< 55	< 45	Limestone, Augen Gneiss, Marble, Norite, Basalt, Porphyry
Unacceptable	< 45	< 45	Marl, Lamproite, Mudstone, Shale, Claystone

Iowa Geologic Polish Stone Value Map



Good Aggregates

Marginal Aggregates

Variable Aggregates

Unacceptable Aggregates

Iowa Pixel Values

	Pixel Count	% of Total
Green	34293	23.95%
Yellow	140	0.10%
Red	68629	47.94%
Black	**40104**	**28.01%**
Total	143166	

Sources:

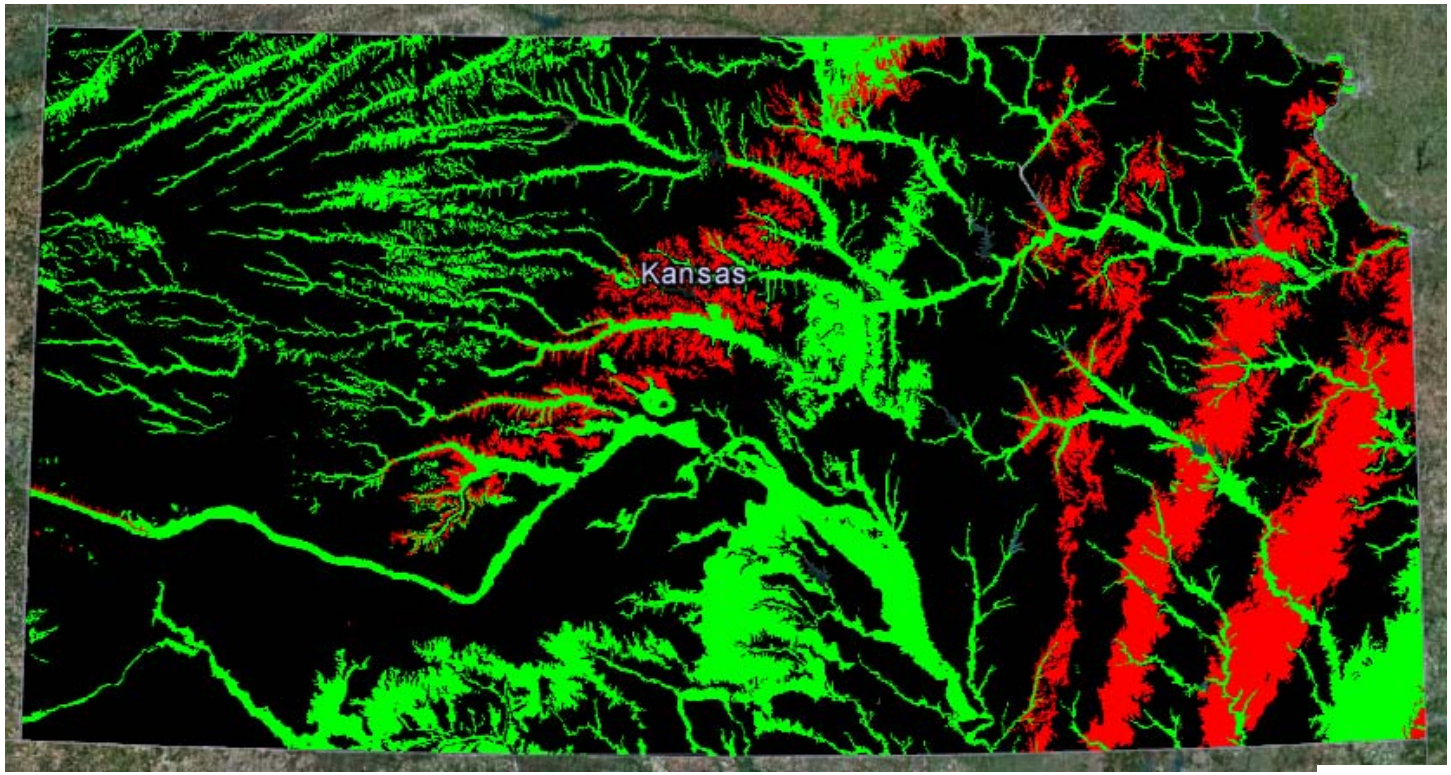
1.E. Erichson, A. Ulvik, K. Wolden, P.R. Neeb; *Aggregates in Norway—Properties defining the quality of sand, gravel and hard rock for use as aggregate for building purposes*, 2008.

2.Missouri Geologic Map Data, http://mrdata.usgs.gov/geology/state/kml/mogeol.kmz, 2005.

3.R. Hosking. *Road aggregate and skidding.* Transport Research Laboratory State-of-the-art Review 4, 1992.

4.Drawn using Google Earth.

Kansas Geologic Polish Stone Value Map



Good Aggregates

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4.R. Hosking. *Road aggregate and skidding.* Transport Research Laboratory State-of-the-art Review 4, 1992.

5.Drawn using Google Earth.

Kansas Pixel Values

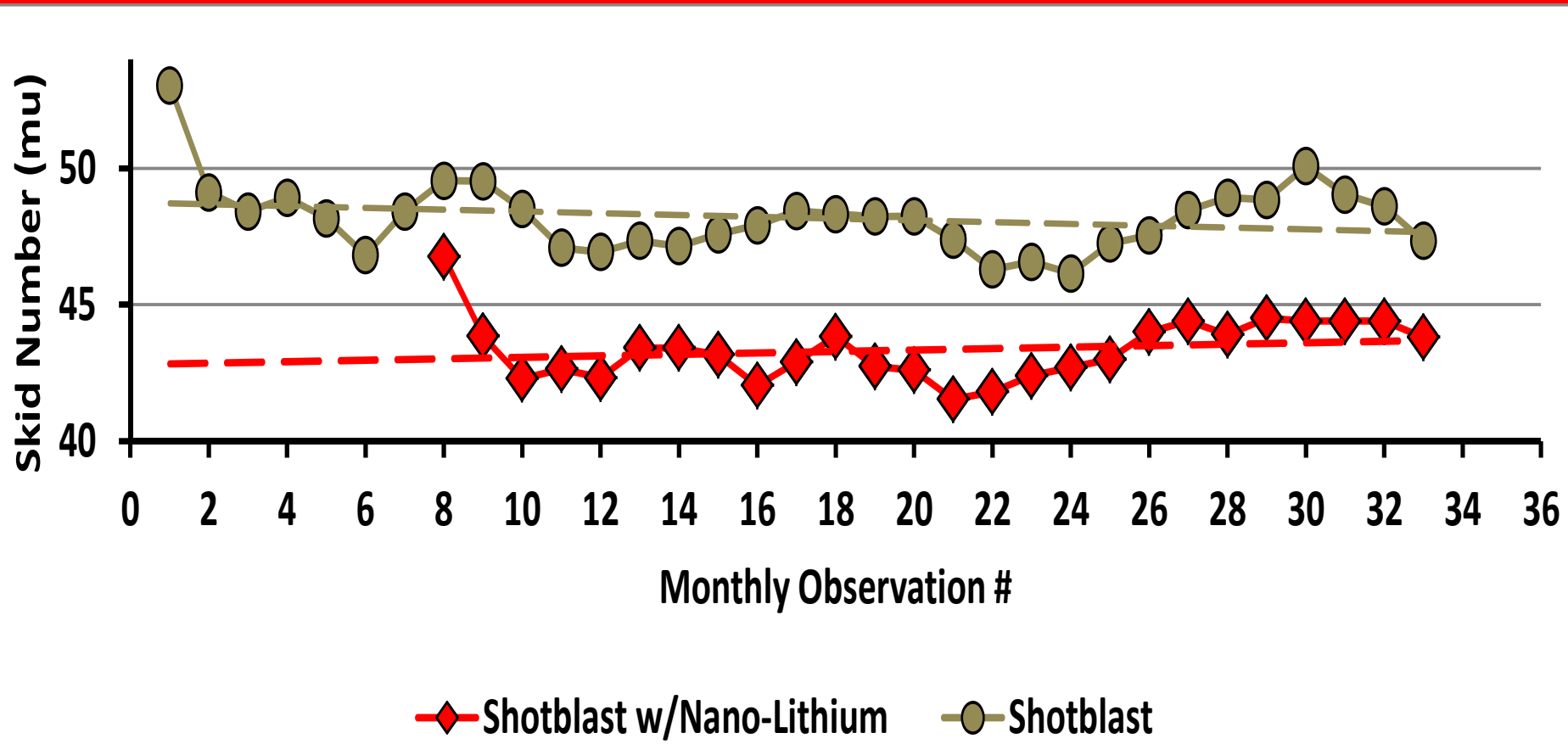
	Pixel Count	% of Total
Green	36186	21.05%
Yellow	0	0.00%
Red	16974	9.88%
Black	**118714**	**69.07%**
Total	171874	

I-80 Donner Pass Data

Core ID	Treatment	Wear (inches)	Wear (inches)	Wear (mm)
C1	No Shotblasting-No Densifier (Control)	0.1875	3/16	0.7382
C3	Control	0.2500	1/4	0.9843
C4	Control	0.2500	1/4	0.9843
C6	Control	0.2500	1/4	0.9843
C10	Control	0.1250	1/8	0.4921
C12	Control	0.1875	3/16	0.7382
	Control Section Average Wear	0.2083	3/16+	0.8202
D1	Densifier Over Shotblasting (DOS)	0.0625	1/16	0.2461
D3	DOS	0.1250	1/8	0.4921
D5	DOS	0.0625	1/16	0.2461
D6	DOS	0.0625	1/16	0.2461
D7	DOS	0.0000	0	0.0000
D8	DOS	0.0625	1/16	0.2461
	DOS Average Wear	0.0625	1/16	0.2461

DOS rutting ~ 50% of untreated in 12 months

Oklahoma US 77 Data



After initial drop, skid number stays above safe standards

Life Cycle Cost Analysis

Life Cycle Cost Analysis Input Values

Alternative	Minimum $/lane-mile	Mean $/lane-mile	Maximum $/lane-mile
12” Full-depth Replacement	$1,056,000	$1,056,000	$1,056,000
12” Full-depth Replacement with Densifier over Shotblasting	$1,069,939	$1,079,126	$1,090,214
Thin Whitetopping	$221,769	$400,340	$633,600
Thin Whitetopping with Densifier over Shotblasting	$242,011	$436,106	$643,864

Assumes DOS service life for rutting is double

Life Cycle Cost Analysis

Alternative	Minimum $/lane-mile	Mean $/lane-mile	Maximum $/lane-mile
	Deterministic Results		
Thin Whitetopping	$1,599,054	$2,607,582	$2,607,582
Thin Whitetopping with Densifier over Shotblasting	$1,335,715	$1,558,056	$1,792,816
	Stochastic Results		
Thin Whitetopping	$1,599,054	$2,081,000	$2,607,582
Thin Whitetopping with Densifier over Shotblasting	$1,343,194	$1,563,690	$1,790,942

Conclusions

- The use of lithium densifier over shotblasting will extend the life of concrete pavements by making them more wear resistant is both technically and financially viable.
- As shown in the literature and the Caltrans study, shotblasting the surface of a PCCP creates a condition where the lithium densifier is able to penetrate deeper, making the depth of the hardened surface greater and enhancing the wear-resistance of the pavement.
- Treating a new concrete surface such as a new pavement or a TWT overlay with lithium densifer applied over shotblasting is more cost effective than no treatment due to the increased service life.

Potential Airfield Applications

- Toughen surface to polishing occurring during rubber removal.
- Extend service life of tining.
- Extend runway friction numbers after retexturing by shotblasting or diamond grinding.
- Reduce edge cracking/chipping due to freeze-thaw, mechanical wear and load transfer

Potential Airfield Applications

- Reduce porosity of surfaces subject to:
  - Chemical rubber removal.
  - Deicing solutions
  - Reduce penetration of skydrol and other spills/leaks
- Protect from alkalis
- Reduce moisture penetration to resist freeze-thaw.
- Reduce FOD from pop-outs, cracking, spalling, etc.
- Promotes sealant adhesion

Questions???