Oregon Chip Seal

Design and Specifications

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Project Acknowledgements

- Oregon Department of Transportation
- Jon Lazarus and Larry Ilg.
- Binder suppliers for these projects
- Chip seal contractors for their help on the construction site.
- R. Christopher Williams, Paul Ledtje, Ben Claypool, Marie Grace Mercado, Jinhua Yu, and Jesse Studer at Iowa State University

Project Introduction

- <u>Objectives</u>
  - Document methods of chip sealing
  - Report the performance of chip seals
  - Apply Chip Seal Design
  - Identify best practices for implementation

Project Introduction

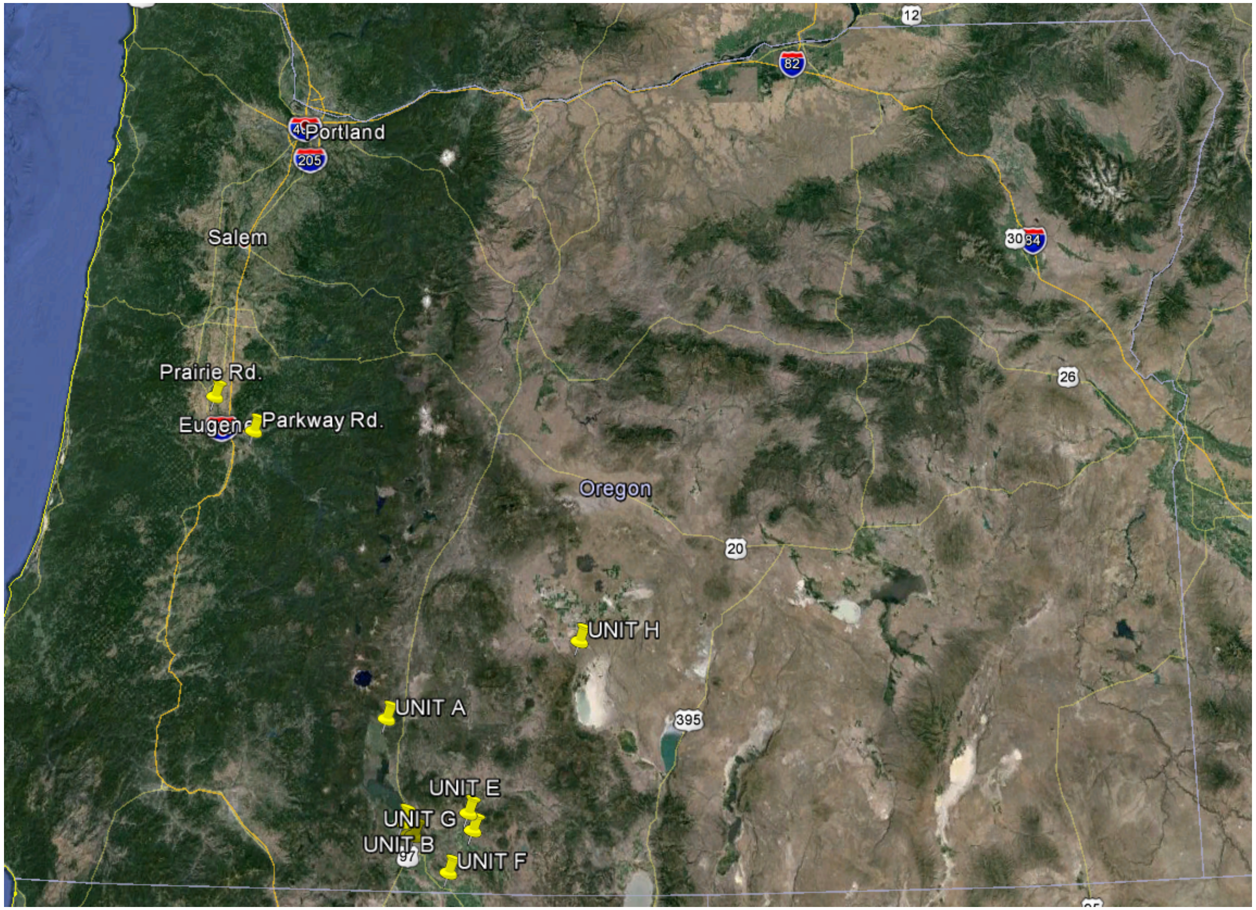
- **Benefits**
  - Improve the cost effectiveness of chip seals by increasing performance
  - Improved roadway surfaces
  - Integrate a rational method for binder and aggregate application rates

Project Introduction

- Literature Review and Best Practices
  - Design Methods
  - NCHRP Synthesis 342
  - Performance Specifications
  - Specification Review and Comparison
- Experimental Plan
  - Hot Applied and Emulsified Chip Seal
  - Various Regions in Oregon
  - Variety of ADT

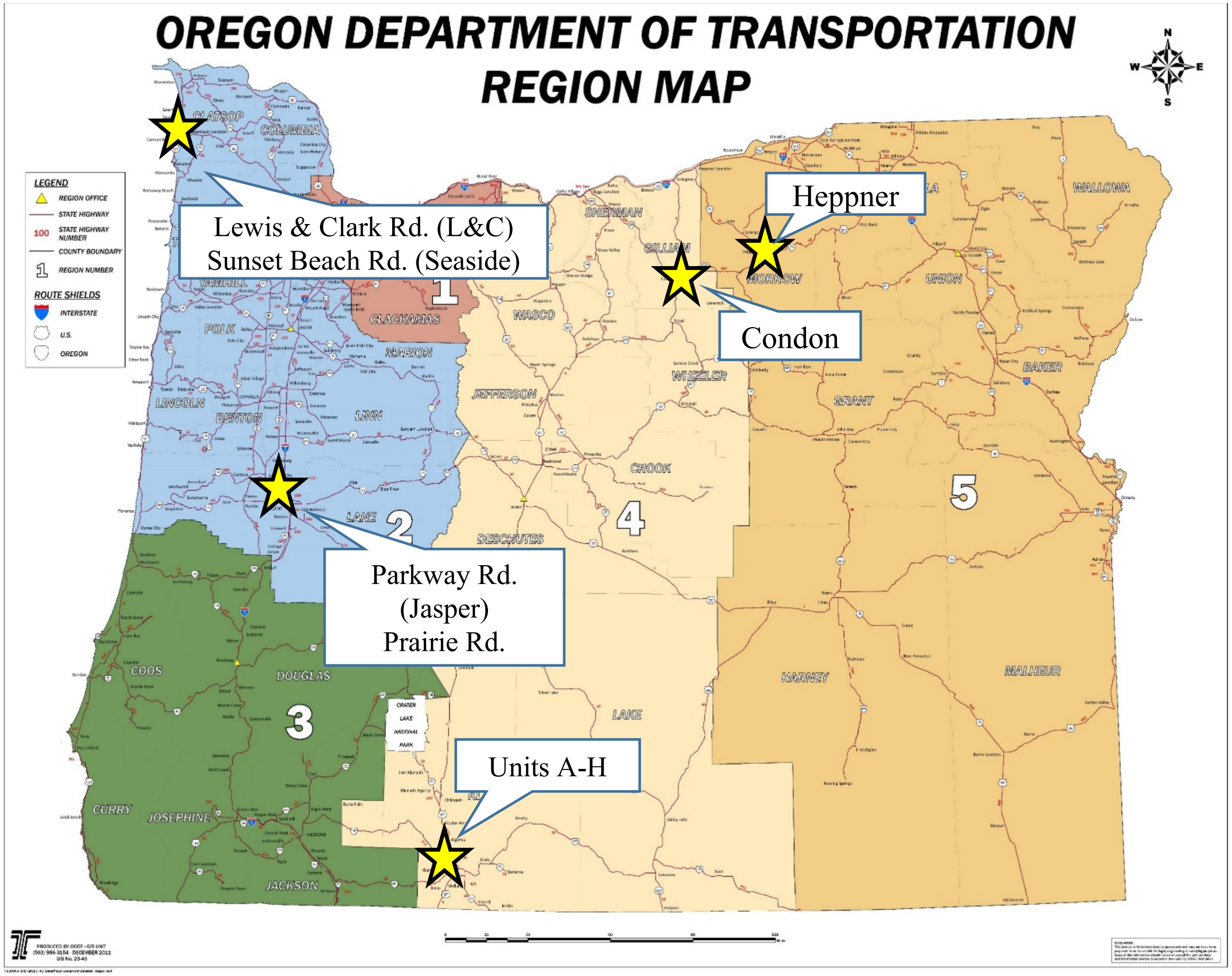
Chip Seal Locations

- **Map of 2014 Chip Seal Projects**



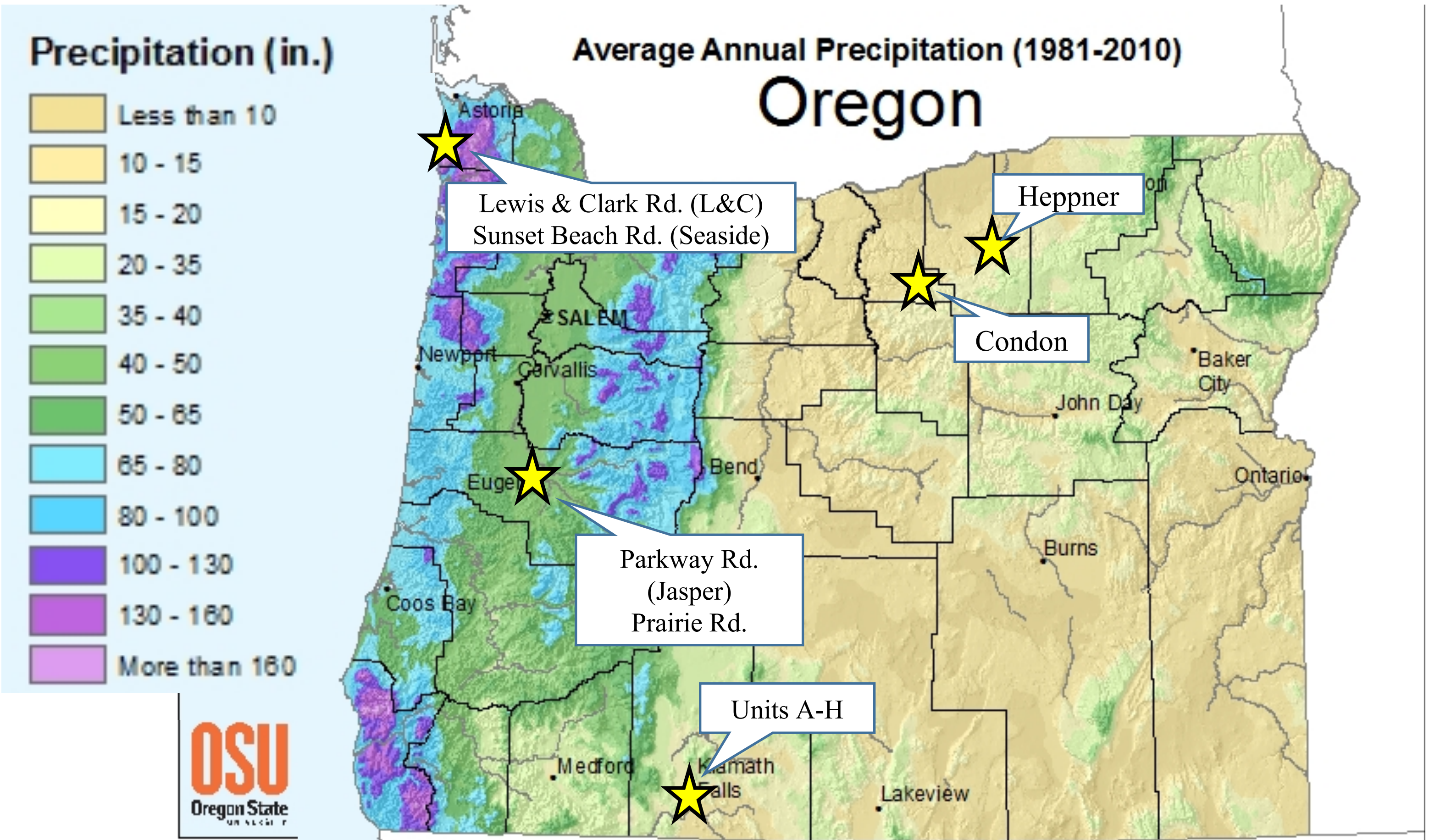
Chip Seal Locations

- Map of All Project Locations



Chip Seal Locations

- **Map of All Project Locations and Rainfall**



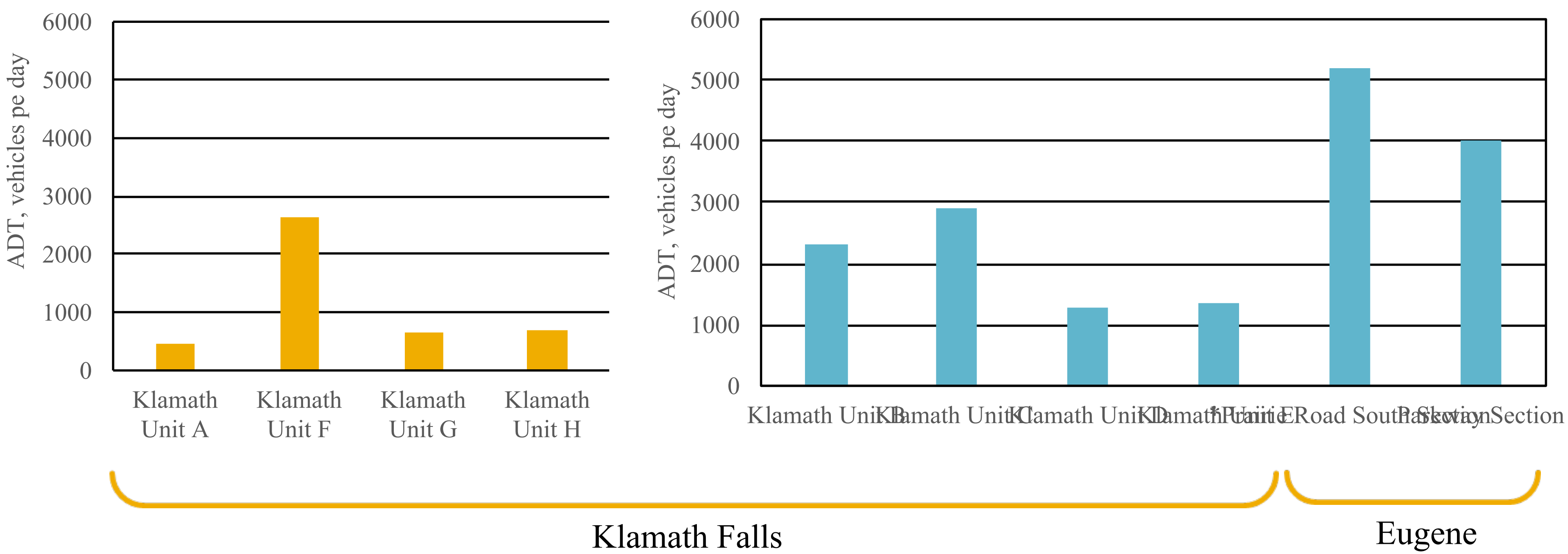
Rainfall Map developed by: PRISM Climate Group. Oregon State University. 2014. http://www.prism.oregonstate.edu/gallery/view.php?state=OR

Types of Chip Seals

- **ADT for 2014 Sections**

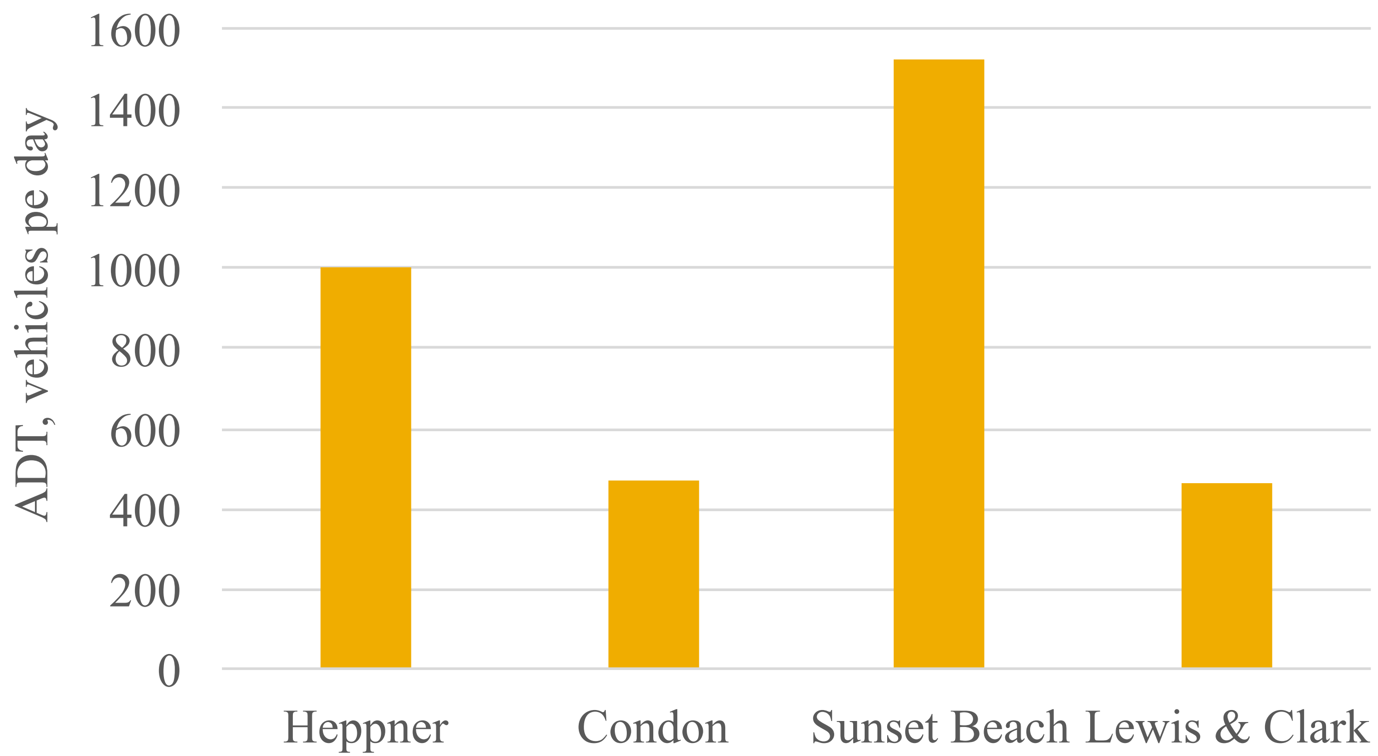
Emulsion

Hot Apply



Types of Chip Seals

- **ADT for 2015 Sections – Emulsion**

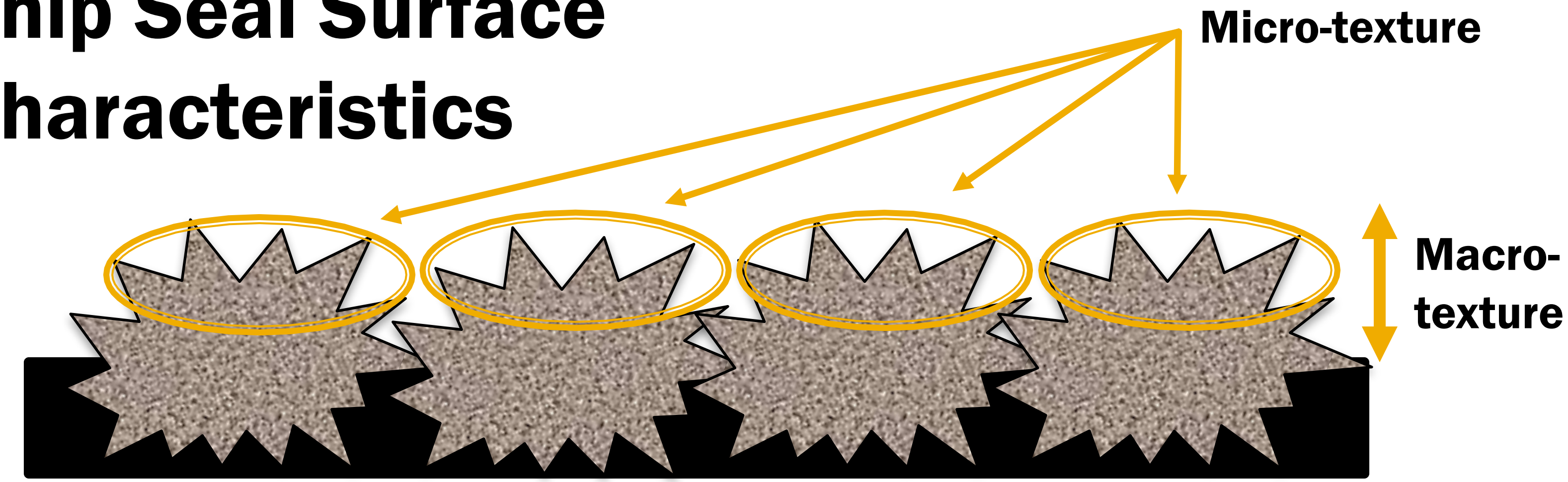


Types of Chip Seals

- Single Layer Chip Seals Studied
  - Hot Applied
  - Emulsified Asphalt
  - All sections used polymer modified binders

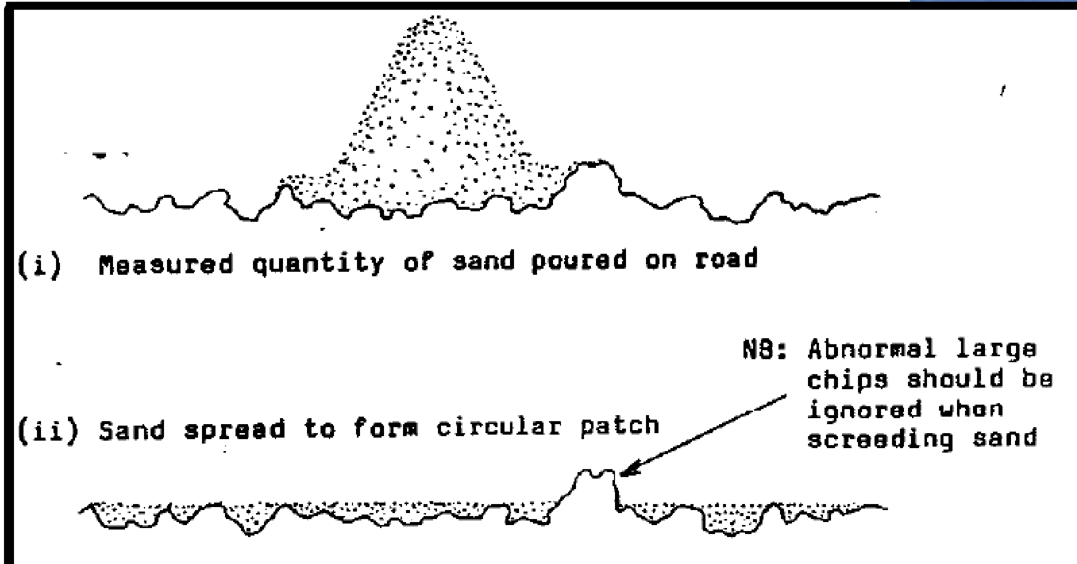
Chip Seal Performance

- Characterization of Existing Pavement
  - Pavement Condition Surveys
  - Oregon DOT Pavement Management System Rating
- Chip Seal Surface Characteristics

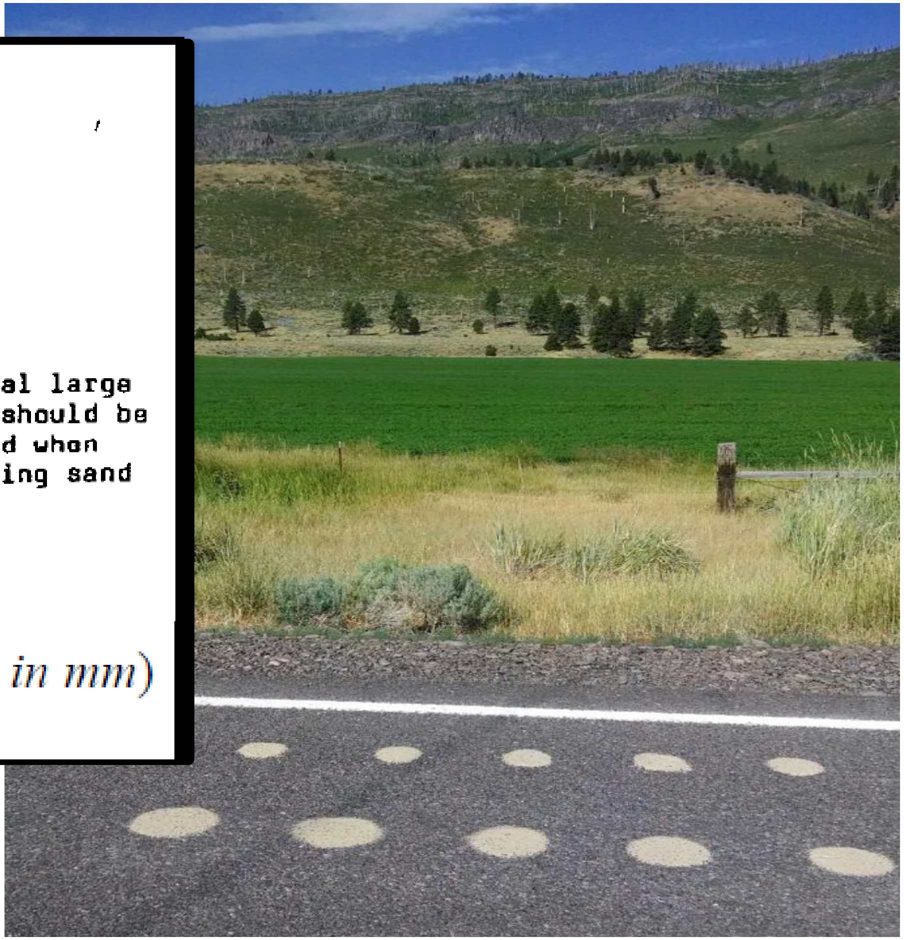


Chip Seal Performance

- **Macro-texture – Sand Circles**

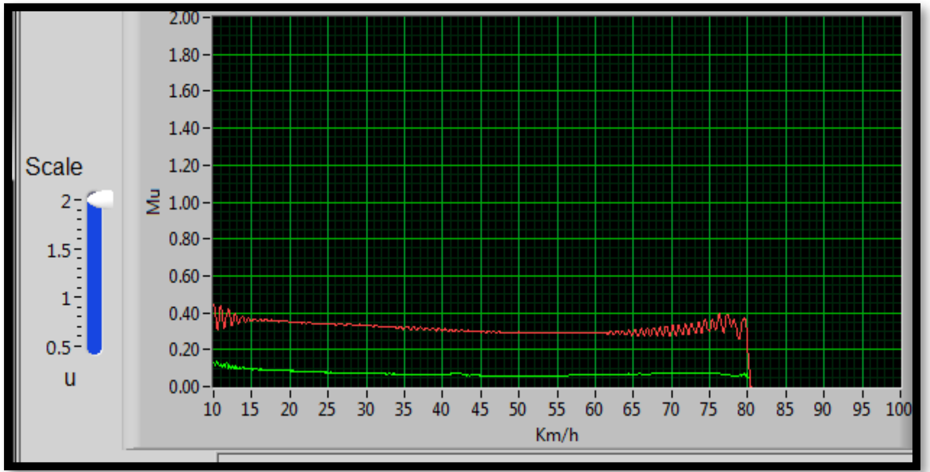


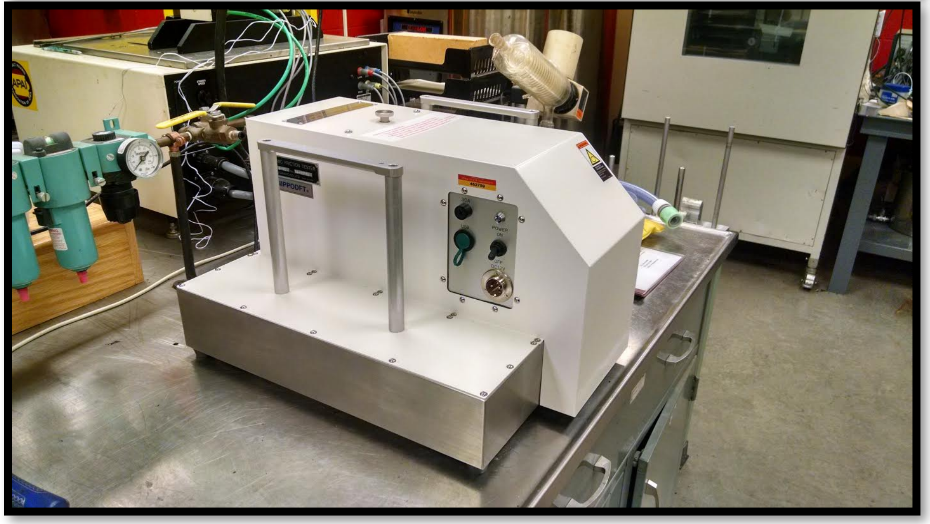
$$Average\ texture\ depth = \frac{57300}{D^2}\ mm \qquad (D\ in\ mm)$$



Chip Seal Performance

- **Micro-texture – Dynamic Friction Tester**





Chip Seal Specifications

- **Can a Macrotexture performance specification be applied in Oregon?**
- **New Zealand Performance Specification**

New Zealand Transport Agency – P/17 Performance Specification for chip seal macrotexture deterioration

$$Td_{1} = 0.07\, ALD\ \log Y_d + 0.9$$

Where:

Td_1 = texture depth in one year (mm)

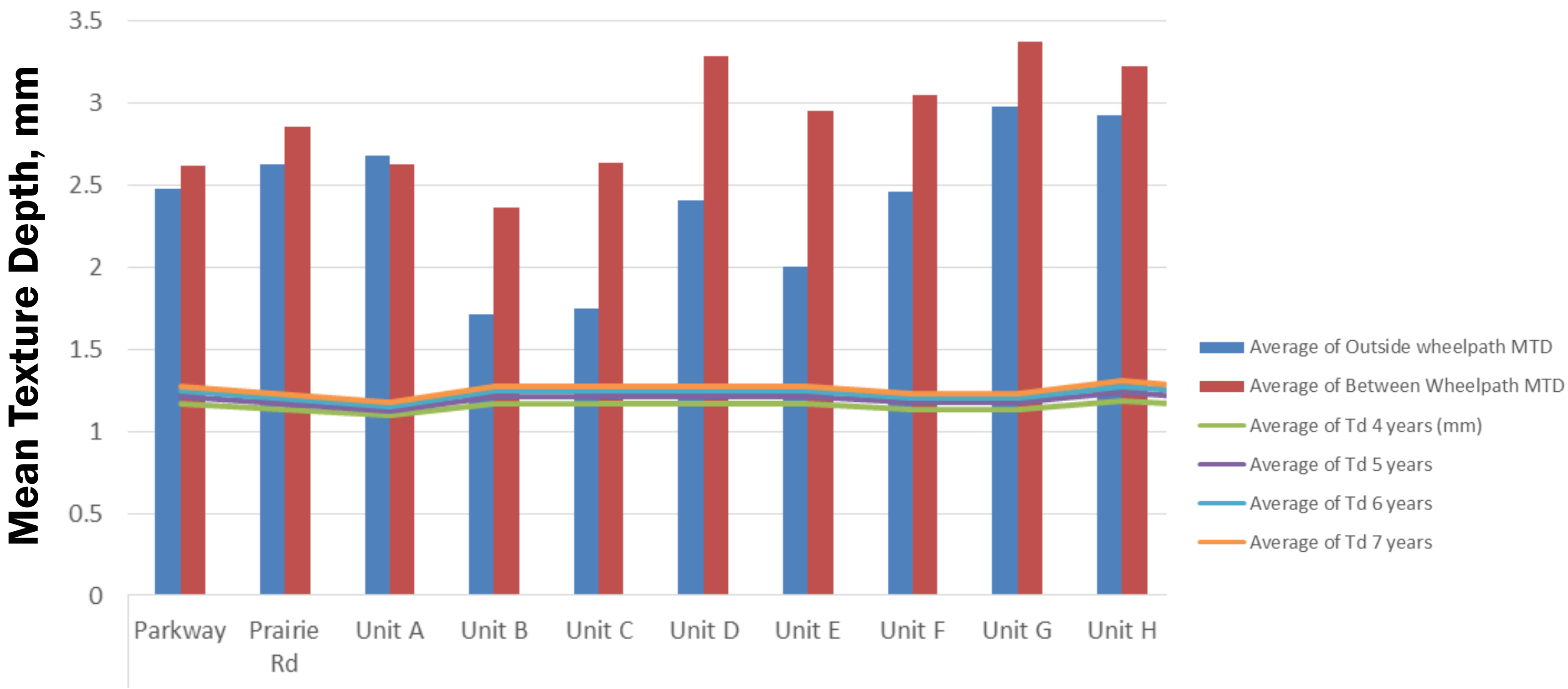
Y_d = design life in years

ALD = average least dimension of the aggregate (mm)

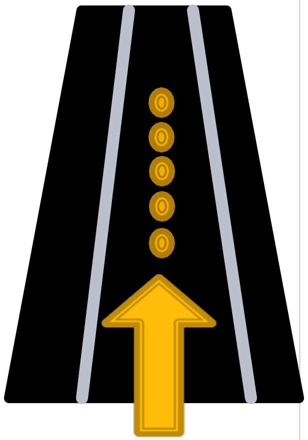
0.9 mm is considered failure

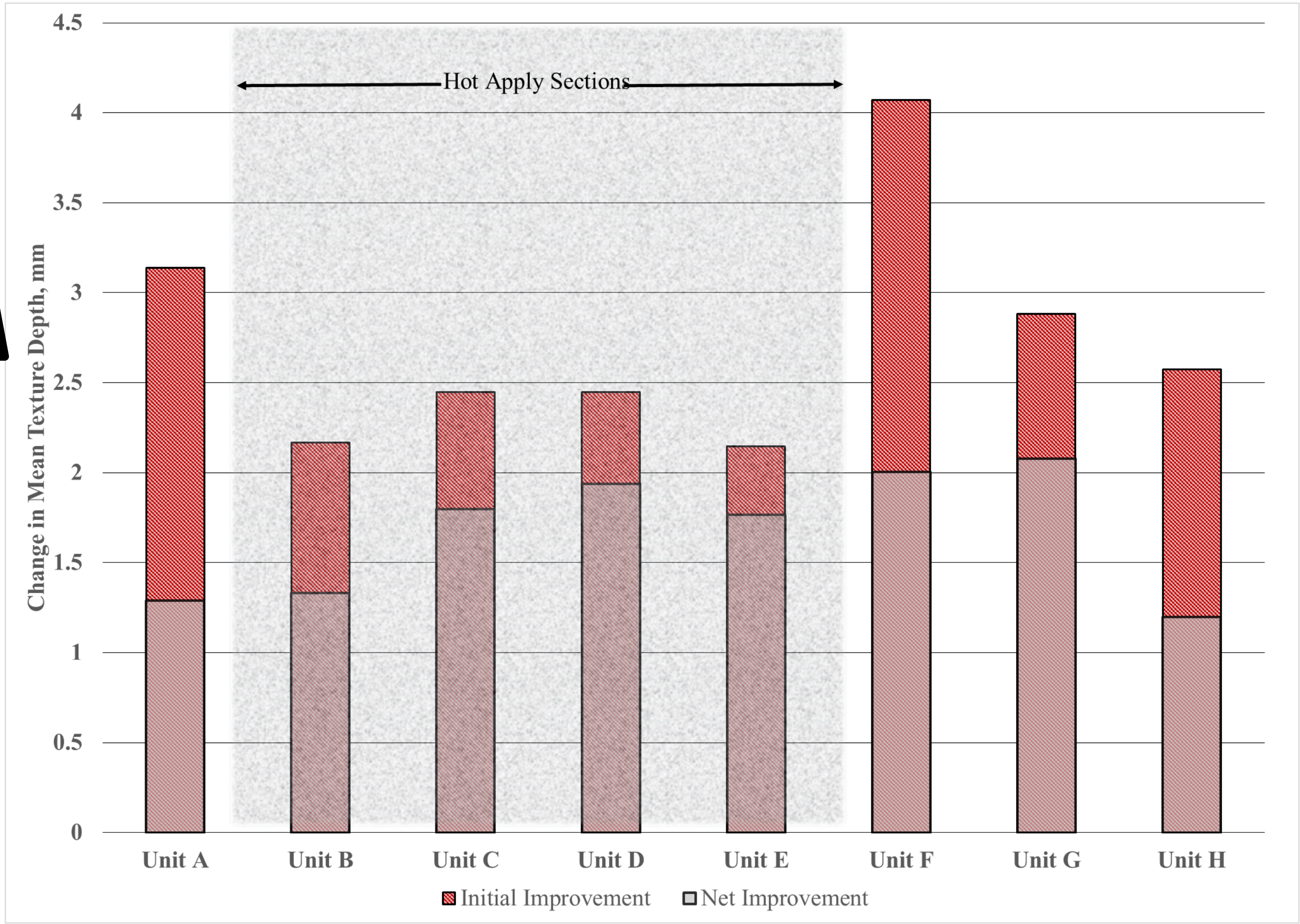
Chip Seal Specification

- New Zealand Performance Specification
  - Blue is the performance specification
  - Red is shown for illustration

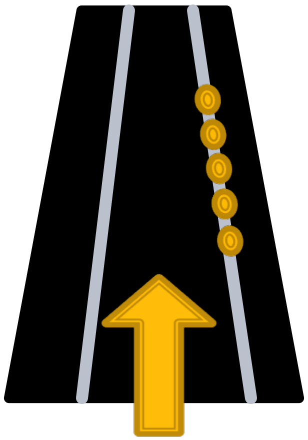


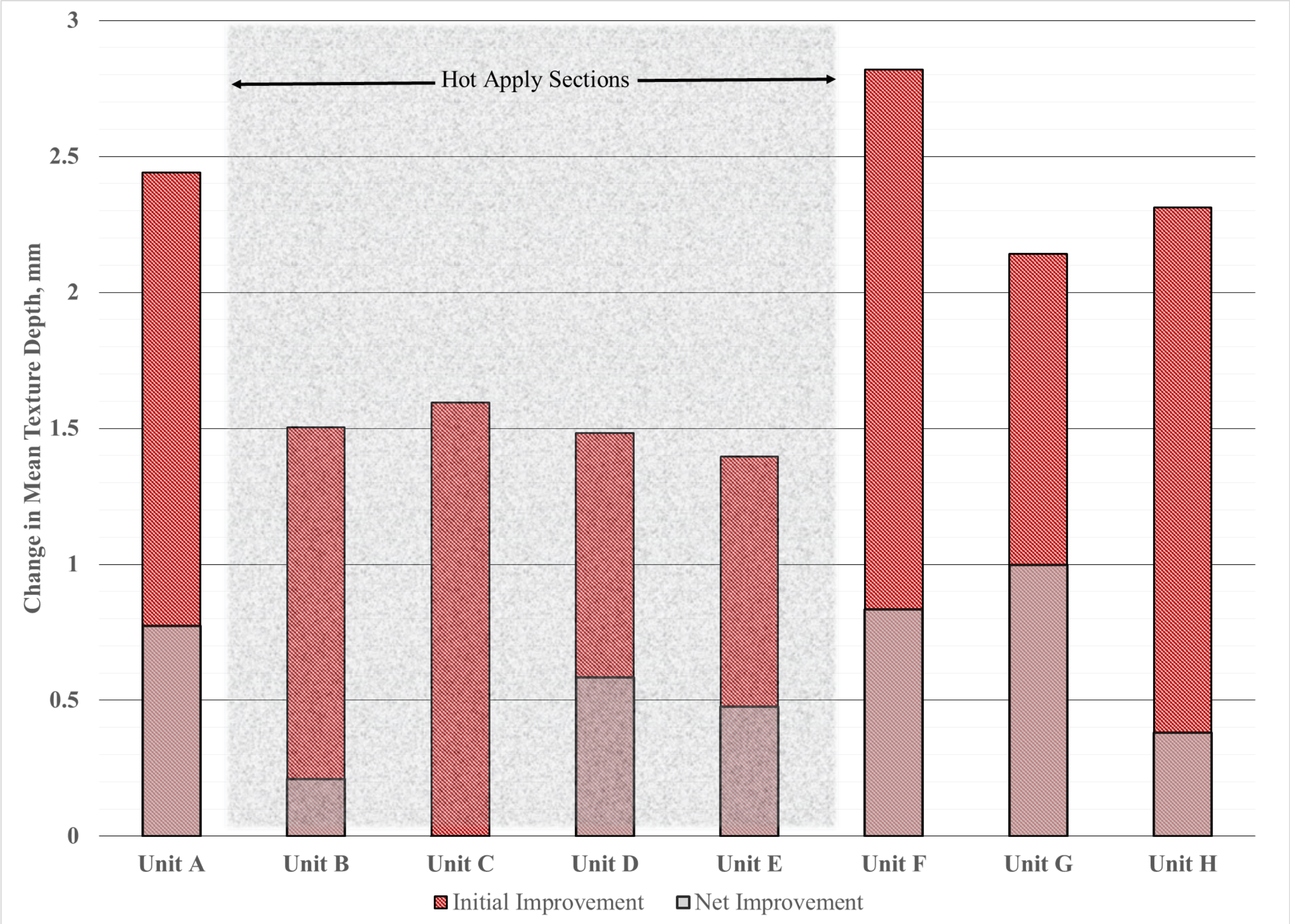
Macrotexture Changes over Time – Between WP



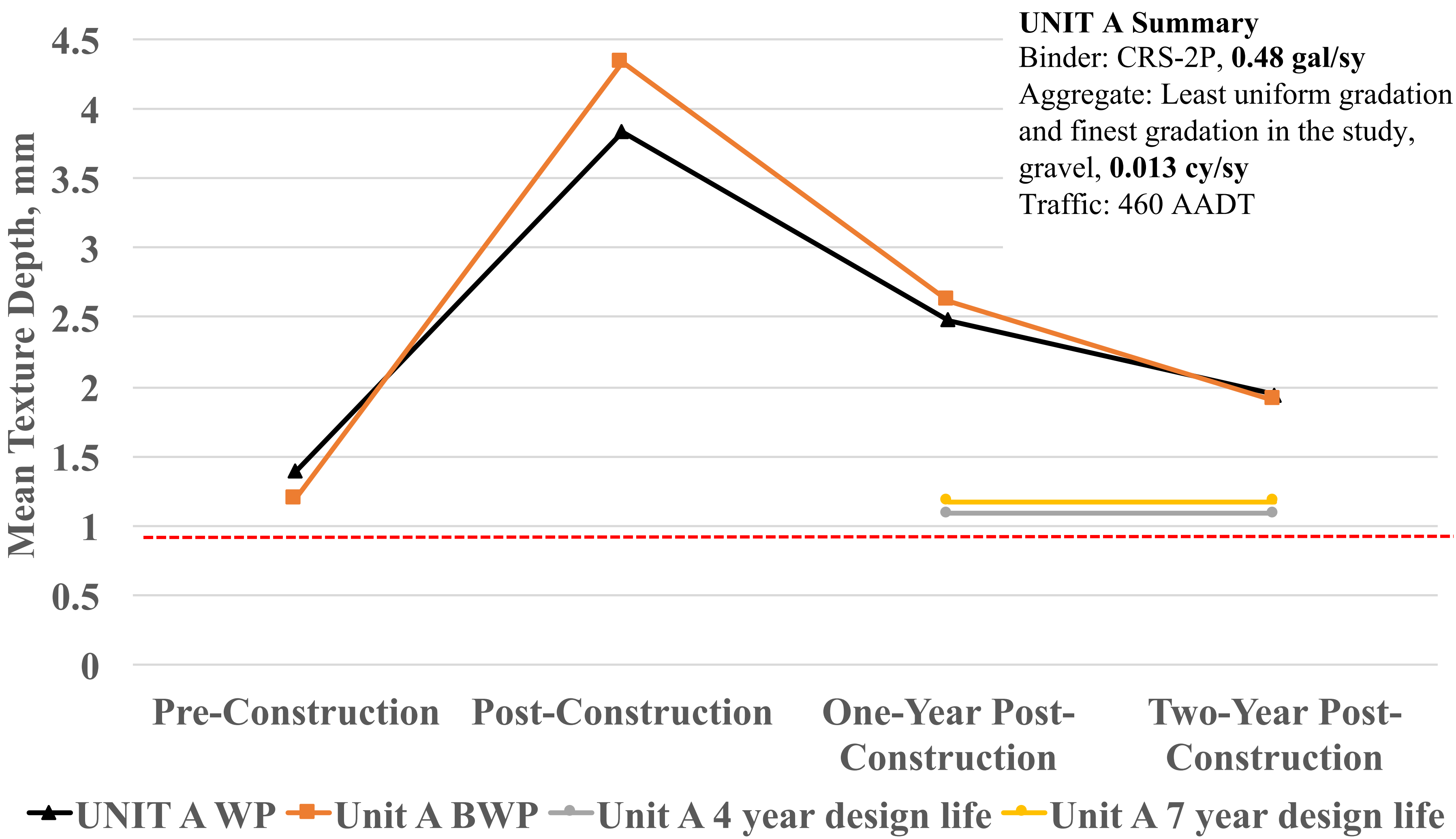


Macrotexture Changes over Time – In the WP

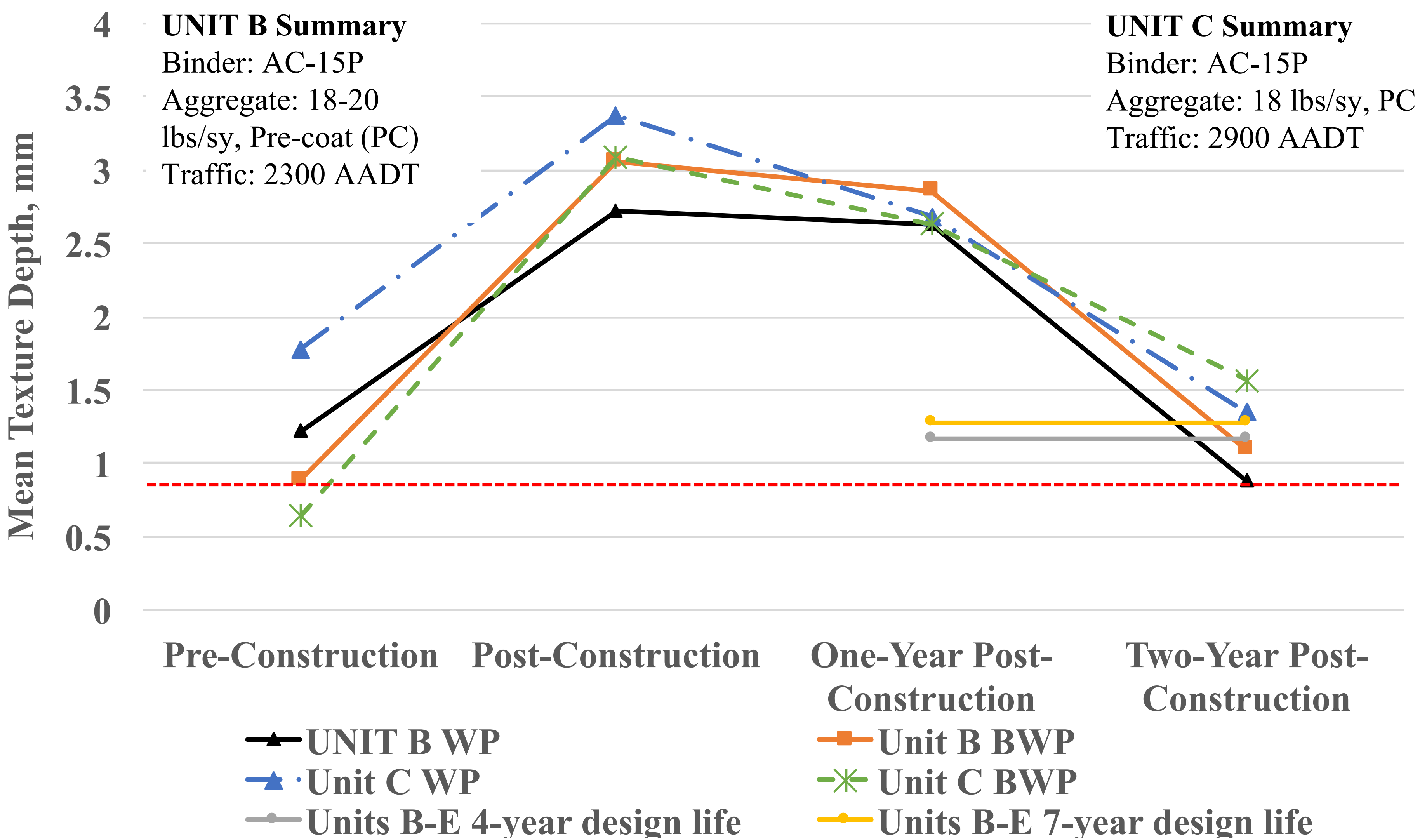




Macrotexture Changes over Time – Unit A

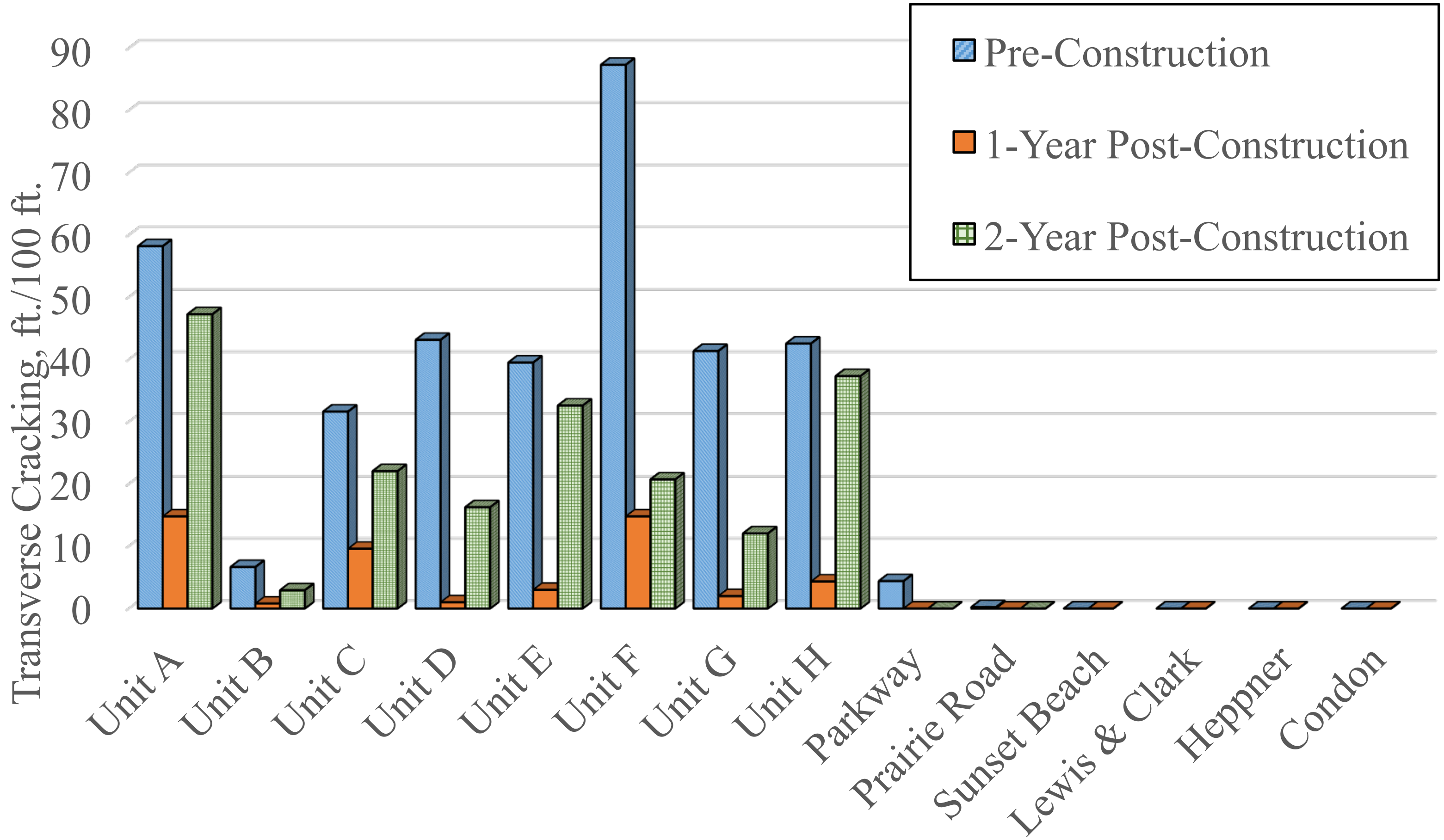


Macrotexture Changes over Time – Units B and C



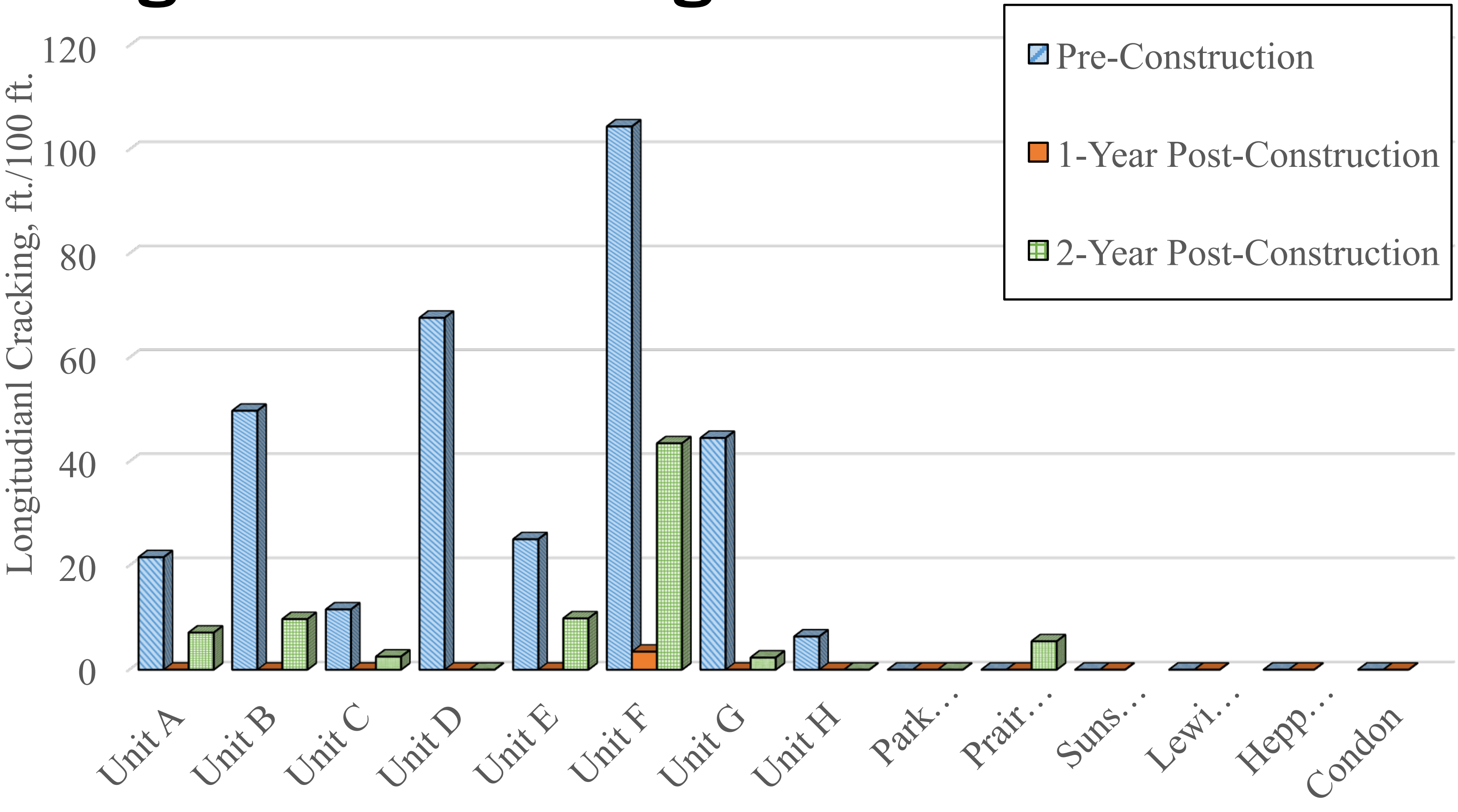
Performance Surveys

- **Transverse Cracking**



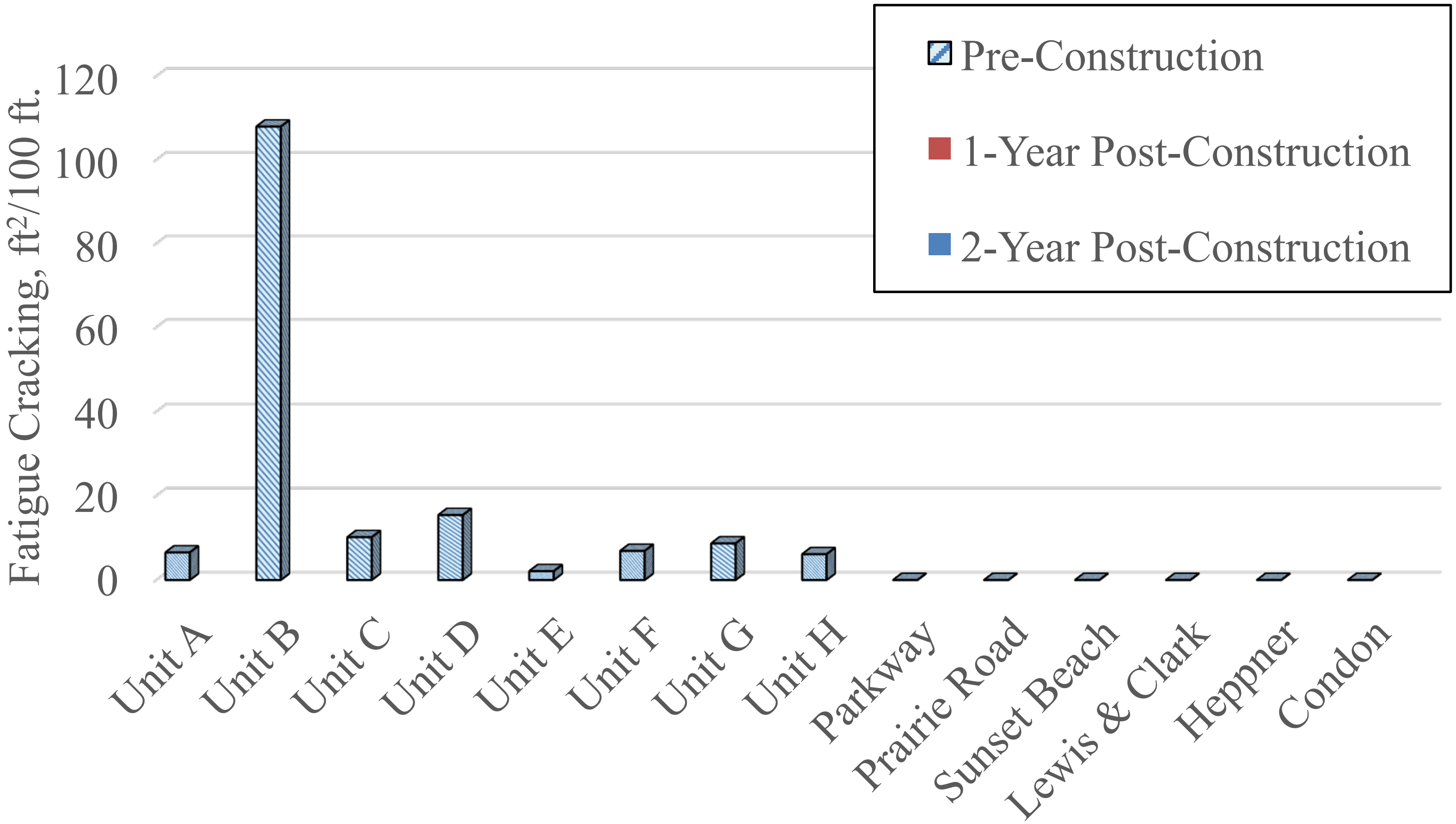
Performance Surveys

- **Longitudinal Cracking**



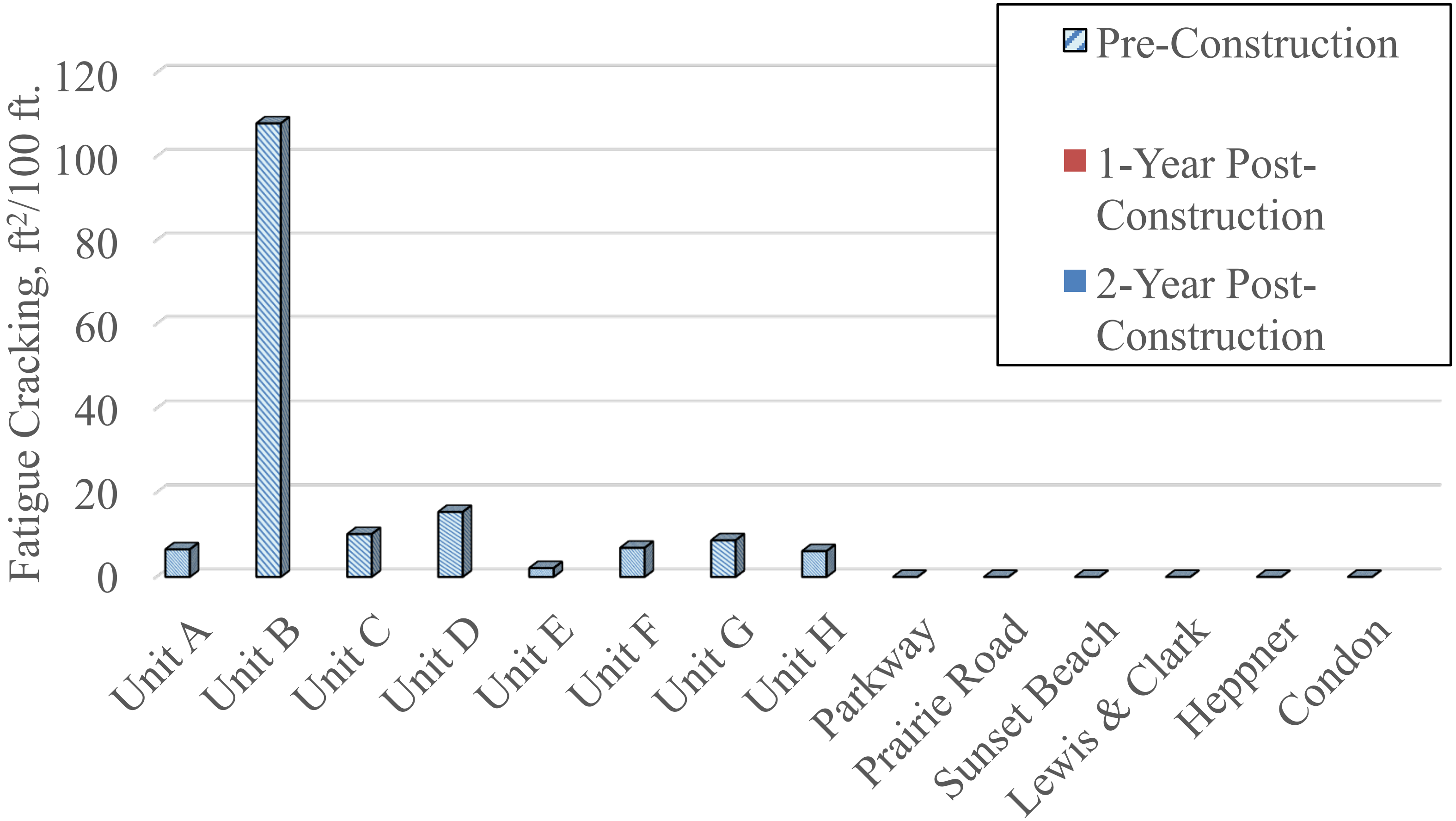
Performance Surveys

- **Fatigue Cracking**



Performance Surveys

- **Fatigue Cracking**



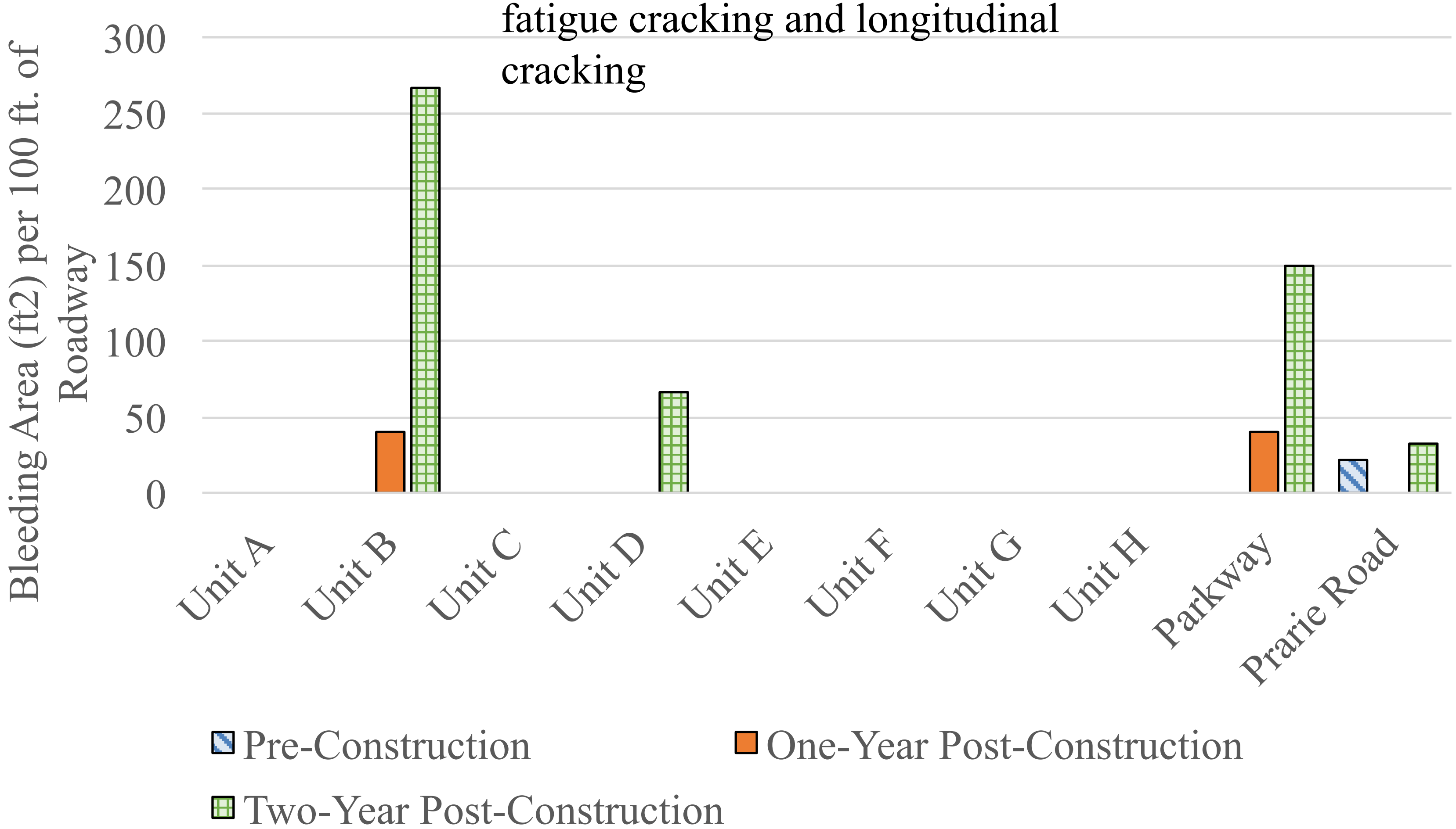
Performance Surveys

- **Patching Area**

Performance Surveys

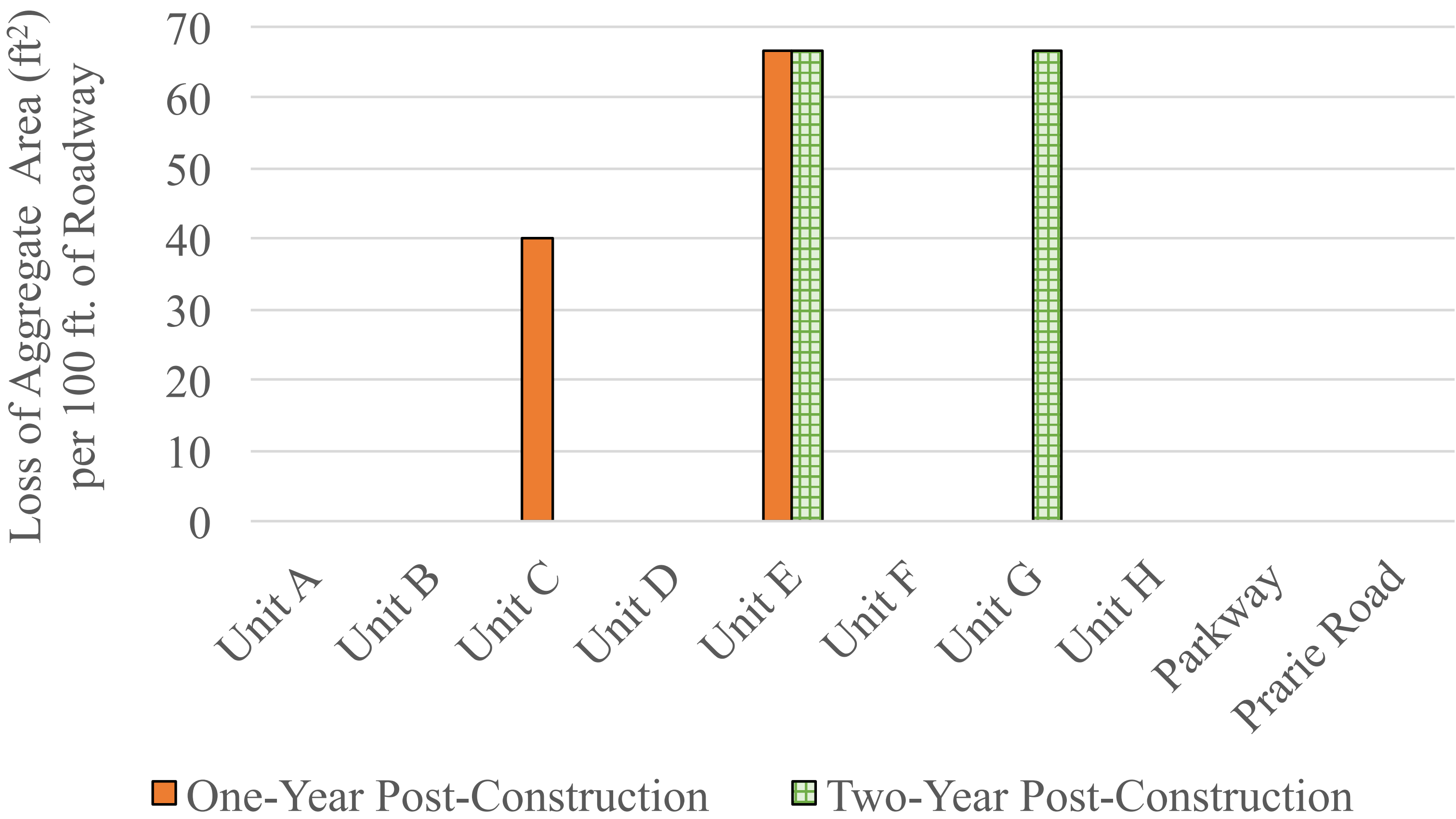
- **Bleeding**

Unit B had highest pre-construction fatigue cracking and longitudinal cracking



Performance Surveys

- **Chip Seal - Loss of Aggregate**

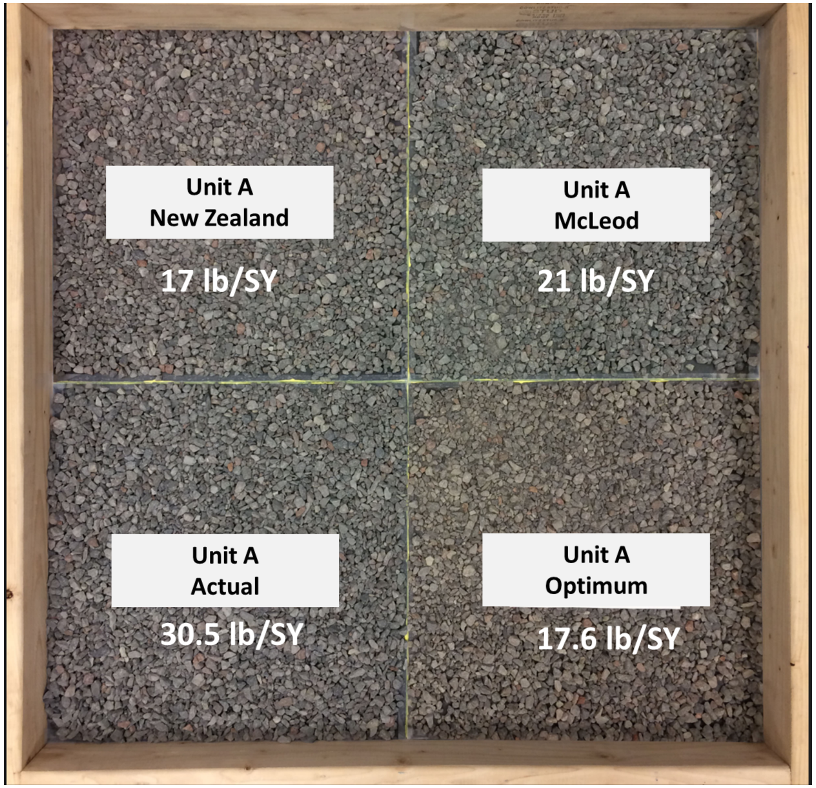


Chip Seal Design

- Back calculate the chip seal design using:
  - McLeod Method (MnDOT Seal Coat Design Manual)
  - New Zealand Design Method
  - Optimal one-stone thick
- Compare with actual applied rates

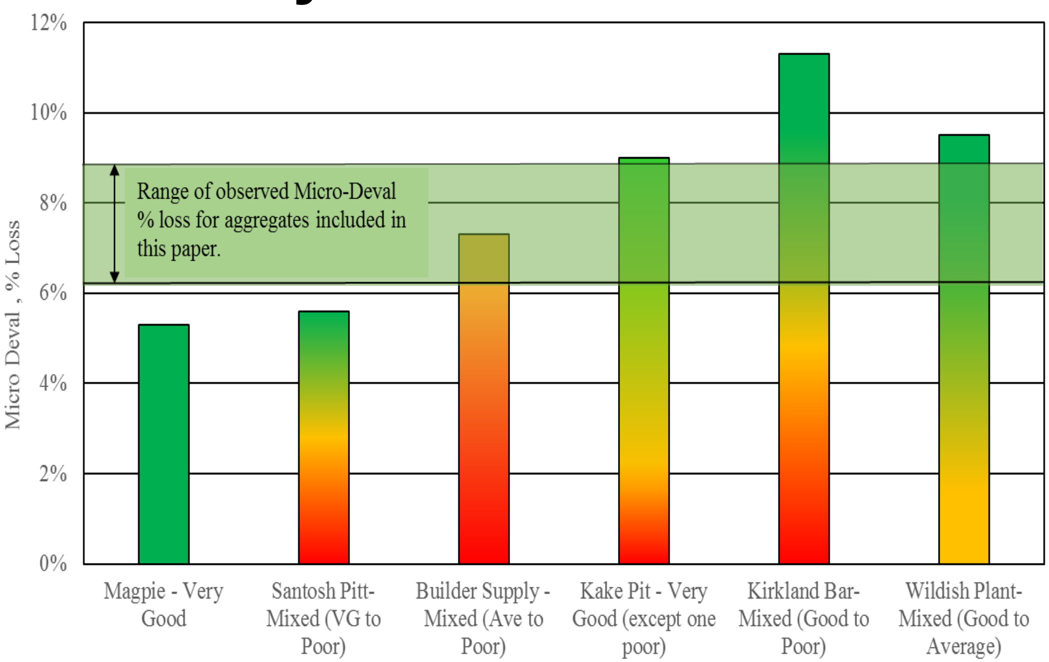
Laboratory Investigation

- Aggregate Properties



Micro-Deval Testing

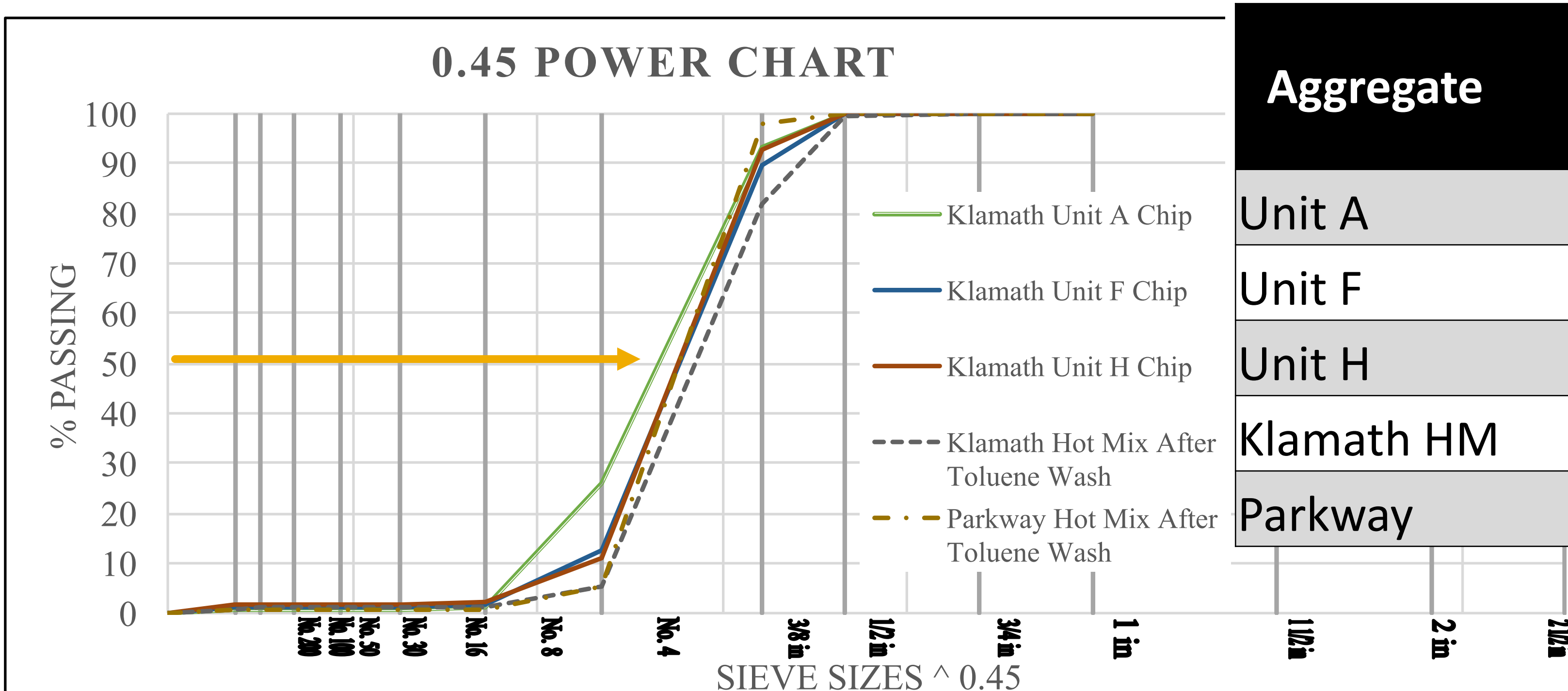
- Micro-Deval Testing
  - Similar Values for all aggregates tested
  - Compared with previous Oregon Aggregate Study



Sample ID	Percent Loss
Unit A Klamath Chips	6.09
Unit F Klamath Chips	7.45
Unit H Klamath Chips	8.60
Hot Applied Klamath Chips	7.21
Parkway Eugene Chips	6.76

Aggregate Gradation and PUC

- **Performance Uniformity Coefficient**
  - **Indicates Aggregate Size Uniformity**
  - **Lower PUC = More Uniform Gradation**



Aggregate	PUC
Unit A	0.41
Unit F	0.12
Unit H	0.12
Klamath HM	0.20
Parkway	0.11

Aggregate Gradation and PUC

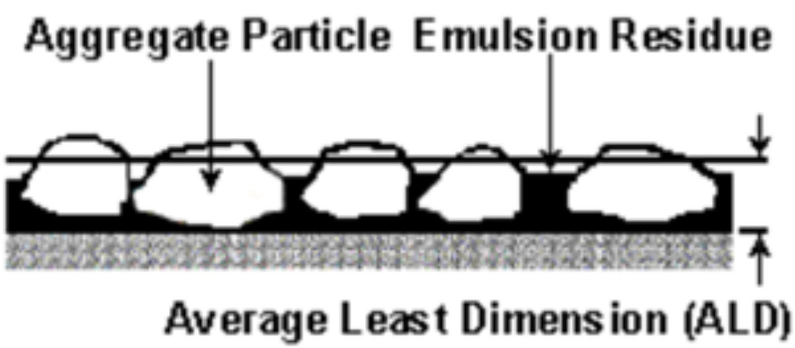
Aggregate	Aggregate contributing to **bleeding** (P_{EM}), %	Aggregate contributing to **loss** (100-P_{2EM}), %	PUC
Unit A	33	20	0.41
Unit F and G	11	10	0.12
Unit H	11	6	0.12
Klamath Hot Applied Sections (Units B-E)	16	18	0.20
Parkway	11	2	0.11

McLeod: Flakiness Index

Test Section	Flakiness Index	AADT
Parkway	5.2	4000
Unit A	13.1	460
Unit B	5.2	2300
Unit C	5.2	2900
Unit D	5.2	1280
Unit E	5.2	1345
Unit F	6.4	2650
Unit G	6.4	670
Unit H	12.1	690

McLeod and New Zealand Average Least Dimension

- New Zealand and Austroads measure each aggregate particle
- Flakiness index provides relationship
- The average least dimension is determined by:
  - H = [M / 1.139285 + (0.011506)*FI]
    - H = Average Least Dimension (ALD)
    - M = Median Particle Size
    - FI = Flakiness Index



(California Division of Maintenance 2003; FHWA 1992)

Loose Unit Weight

- **A metal cylinder with a known volume of is loosely filled with aggregate until full. The weight of the aggregate was determined.**
- **Find Voids in Loose Aggregate**

Test Section	LUW
Parkway	89.3
Unit A	86.9
Unit B	85.4
Unit C	85.4
Unit D	85.4
Unit E	85.4
Unit F	87.7
Unit G	87.7
Unit H	82.6

McLeod Traffic Considerations

- Traffic Volume
  - Factor accounts for the role that traffic volumes play in achieving the ultimate embedment of 80 percent (20 percent void space).

Test Section	AADT	McLeod Traffic Correction Factor	Traffic whip-off factor, E
Parkway	4000	0.60	1.1
Unit A	460	0.75	1.05
Unit B	2300	0.60	1.1
Unit C	2900	0.60	1.1
Unit D	1280	0.65	1.1
Unit E	1345	0.65	1.1
Unit F	2650	0.60	1.1
Unit G	670	0.70	1.1
Unit H	690	0.70	1.1

Vehicles/Day	0-100	101-500	501-1000	1001-2000	>2000
Correction Factor	0.85	0.75	0.70	0.65	0.60

(Wood et al. 2006)

Traffic Considerations

- Traffic Whip-Off (Similar to NZ)
  - Assume 5% for low volume, residential type traffic
  - Assume 10% for higher speed roads such as county roads.

McLeod Aggregate Design Equation

- **Aggregate Application Rate:**
- **C= (1 - 0.4V) × H × G × E**
  - **C = Cover Aggregate (kg/m2)**
  - **V = Voids in Loose Agg. (%)**
  - **H = ALD (mm)**
  - **G = Bulk Specific Gravity**
  - **E = Wastage Factor (%)**

Test Section	**McLeod** Cover Aggregate Rate (lbs/yd^2)	Actual Rate (lbs/yd2)	Rates given in CY/SY
Parkway	26	20	
Unit A	21	30.5**	0.013
Unit B	27	19	
Unit C	27	18	
Unit D	27	20	
Unit E	27	19	
Unit F	25	30.8**	0.013
Unit G	25	30.8**	0.013
Unit H	23	23	

- ****Values based on LUW**

New Zealand Chip Seal Agg. Spread Rate

- **For Single Coat Seals (Chipsealing in New Zealand)**
- $Rate = \frac{750}{ALD}\ m^2/m^3$

Test Section	ALD (mm)	Rate m2/m3	Chip Rate lbs/SY
Parkway	5.9	127.5	21
Unit A	5.0	149.8	17
Unit B	6.3	119.4	21
Unit C	6.3	119.4	21
Unit D	6.3	119.4	21
Unit E	6.3	119.4	21
Unit F	5.8	128.5	20
Unit G	5.8	128.5	20
Unit H	5.5	136.5	18

Aggregate Absorption

- **McLeod suggests an absorption correction factor, A, of 0.02 gal/yd^2 if the aggregate absorption is around 1%.**
- **MnDOT Seal Coat Handbook recommends if absorption is 1.5 percent or higher.**

Test Section	Aggregate Absorption
Parkway	1.49
Unit A	2.01
Unit B	1.63
Unit C	1.63
Unit D	1.63
Unit E	1.63
Unit F	2.06
Unit G	2.06
Unit H	2.65

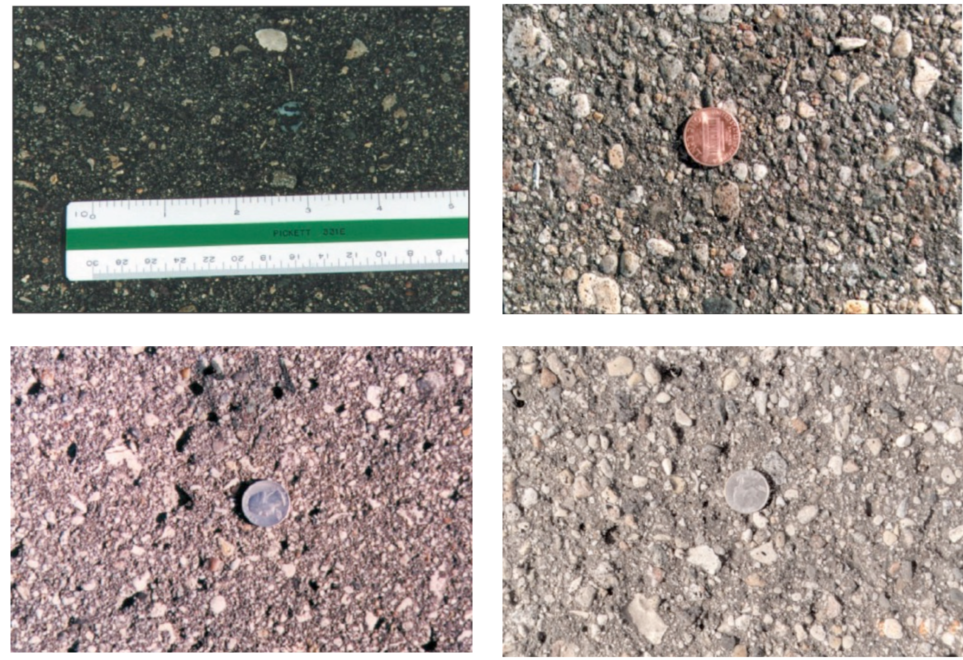
Aggregate type		Class A			Class B		Class C
		Granite	Quartzite	Trap Rock	Limestone	Red Rock	Pea Rock
Percent Absorption	Min.	0.40	0.61	0.31	1.75	no data	1.14
	Max.	0.92	0.72	0.59	5.44	no data	2.32
	Avg.	**0.59**	**0.67**	**0.43**	**2.80**	**-**	**1.69**

(Wood et al. 2006)

Surface Correction Factor, S

- New surfaces will not absorb much binder
- Older surfaces can absorb a lot of binder
- Must be included in design

- Not all roads in a project will need same amount of asphalt binder



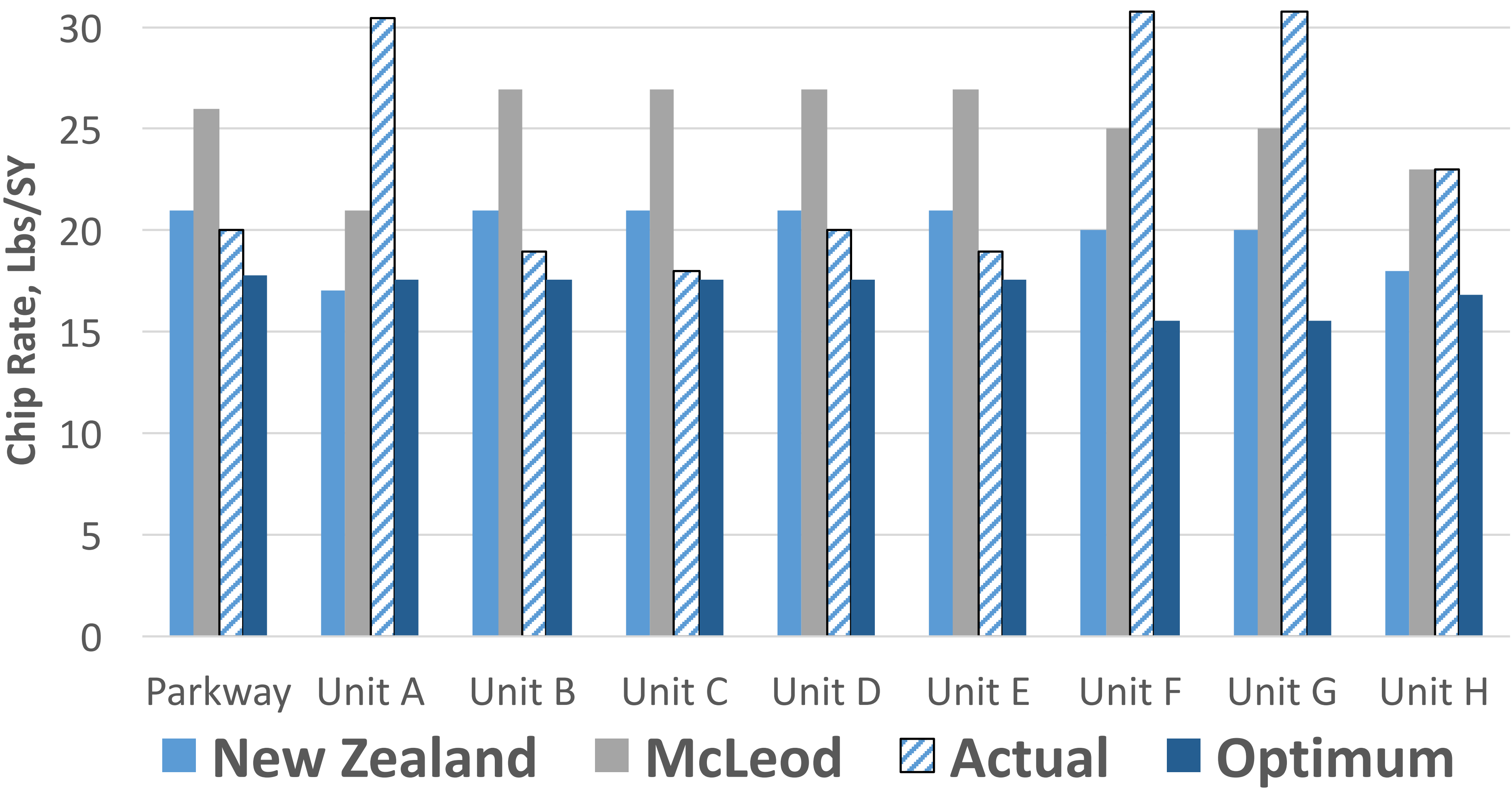
(Wood et al. 2006)

Existing Pavement Texture	*Correction, S*	
	S.I. Metric (L/m^2)	*U. S. Customary (gal/yd^2)*
Black, flushed asphalt	*-0.04 to -0.27*	*-0.01 to -0.06*
Smooth, non-porous	*0.00*	*0.00*
Slightly porous & oxidized	*+0.14*	*+0.03*
Slightly pocked, porous & oxidized	*+0.27*	*+0.06*
Badly pocked, porous & oxidized	*+0.40*	*+0.09*

Comparison of All Chip Application Rates

Test Section	**New Zealand** Chip Rate Lbs/SY	**McLeod** Cover Aggregate Rate (lbs/yd^2)	**Actual** Applied Rate (lbs/yd^2)	Rates given in CY/SY
Parkway	21	26	20	
Unit A	17	21	30.5**	0.013
Unit B	21	27	19	
Unit C	21	27	18	
Unit D	21	27	20	
Unit E	21	27	19	
Unit F	20	25	30.8**	0.013
Unit G	20	25	30.8**	0.013
Unit H	18	23	23	

Chip Seal Design Findings

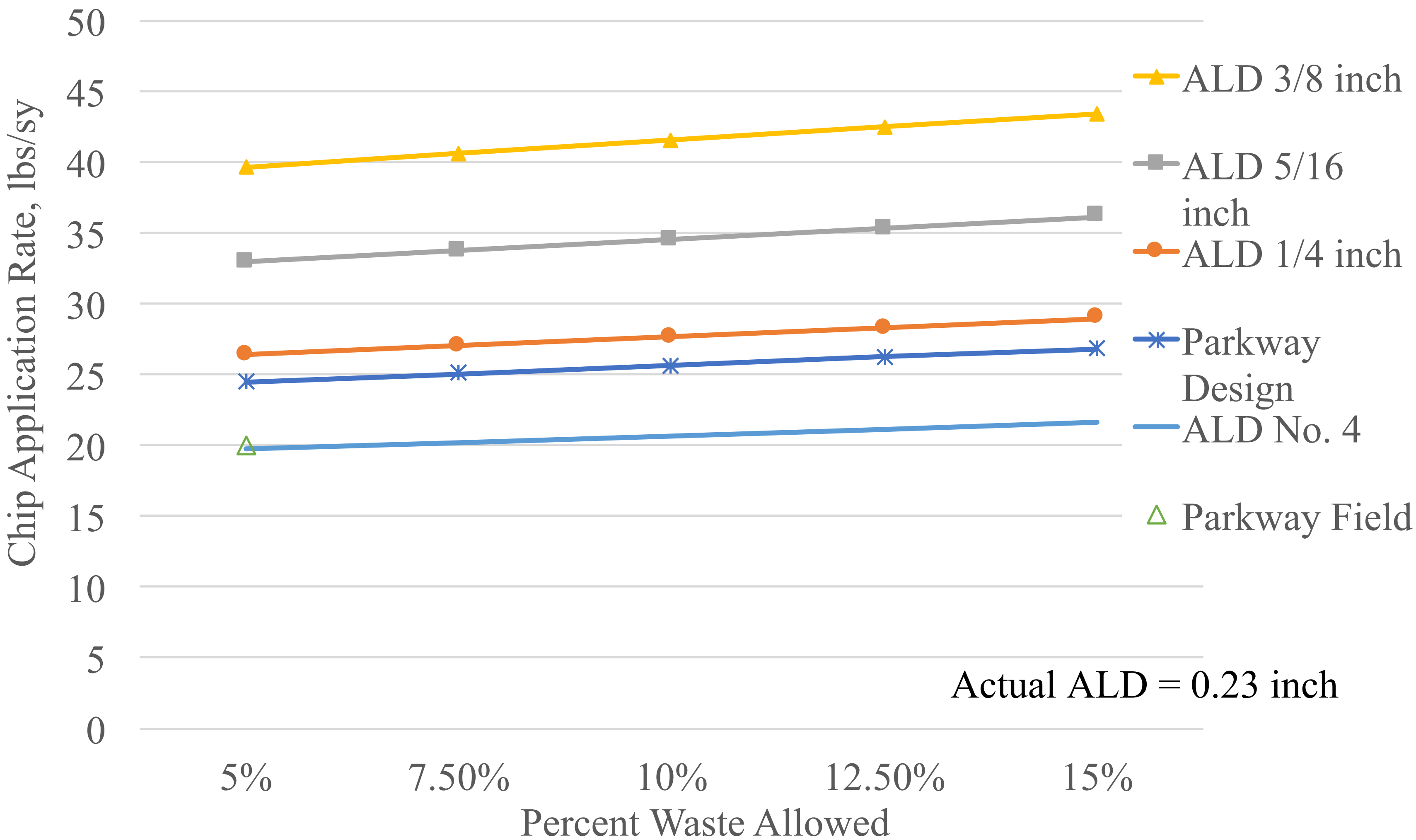


Comparison of All Binder Application Rates

Test Section	Binder Application Starting Rate in Field (gal/sy) (Different surface factors: S=0.06 / S=0.09)	New Zealand Method (gal/sy)	Actual Binder Rate (gal/sy)
Parkway	0.24/0.25	*	0.41 gallons / sy
Unit A	0.43/0.44	0.36	0.48 gallons / sy
Unit B	0.25/0.27	0.37	0.37 gallons / sy
Unit C	0.25/0.27	0.36	0.37 - 0.38 gallons / sy
Unit D	0.26/0.28	0.40	0.37 gallons / sy
Unit E	0.26/0.28	0.39	0.36 gallons / sy
Unit F	0.39/0.42	0.34	0.50 gallons / sy
Unit G	0.44/0.46	0.39	0.50 gallons / sy
Unit H	0.44/0.45	0.41	0.52 gallons / sy

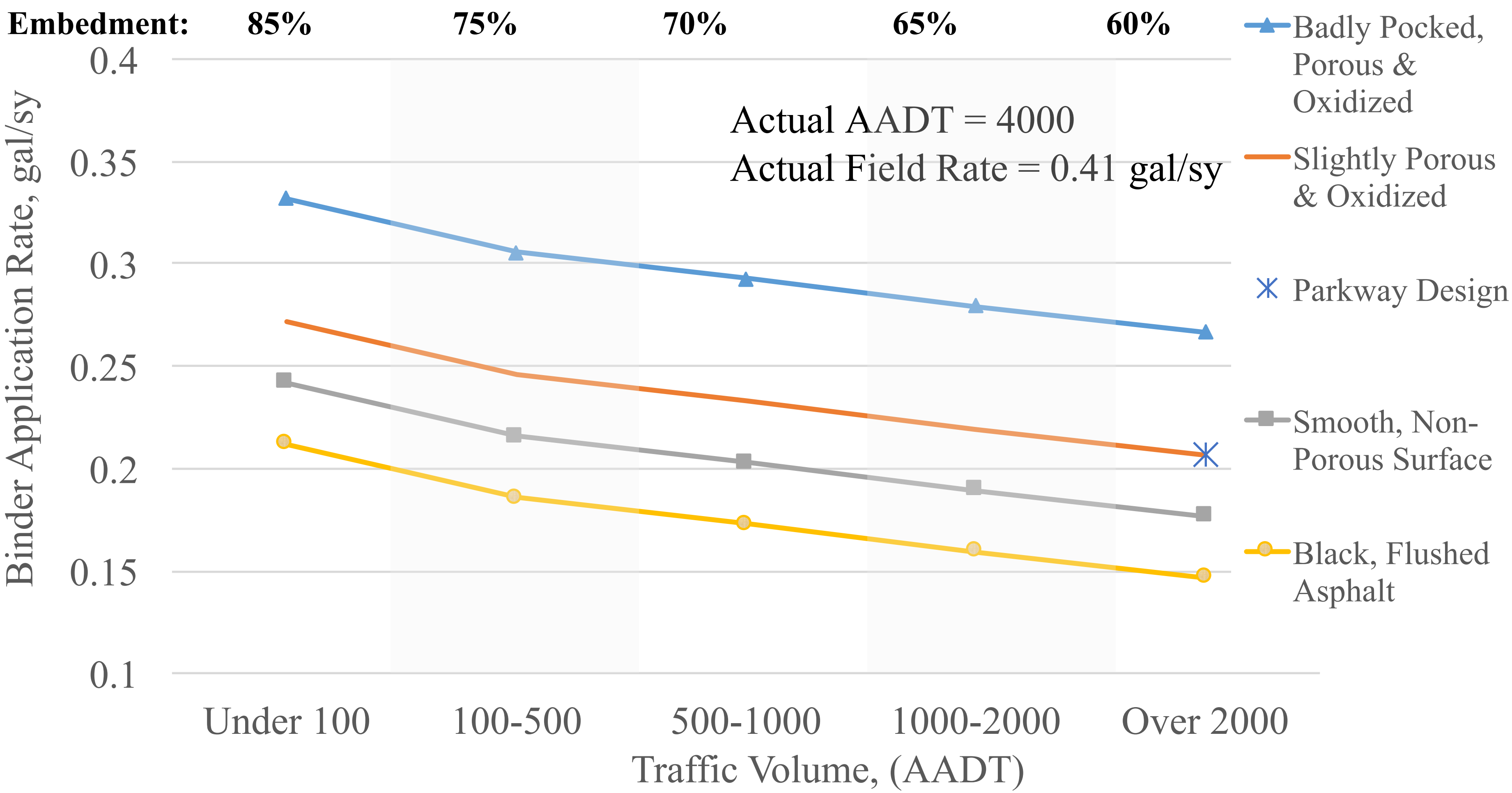
Chip Application Rate on a Hot-Applied Chip Seal

- **ALD and Percent Waste**



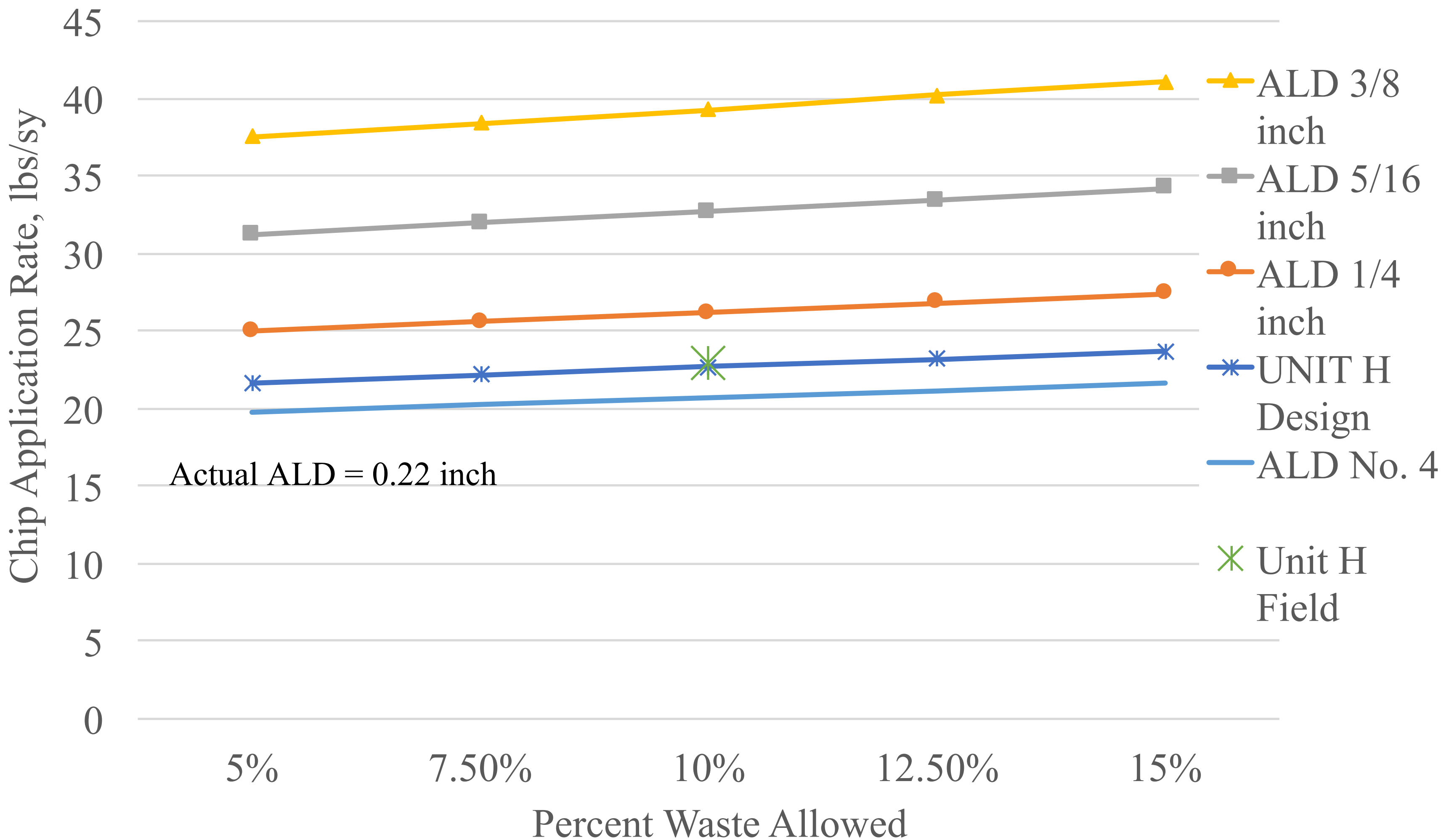
Binder Application Rate on a Hot-Applied Seal

- **Traffic and Surface Texture**



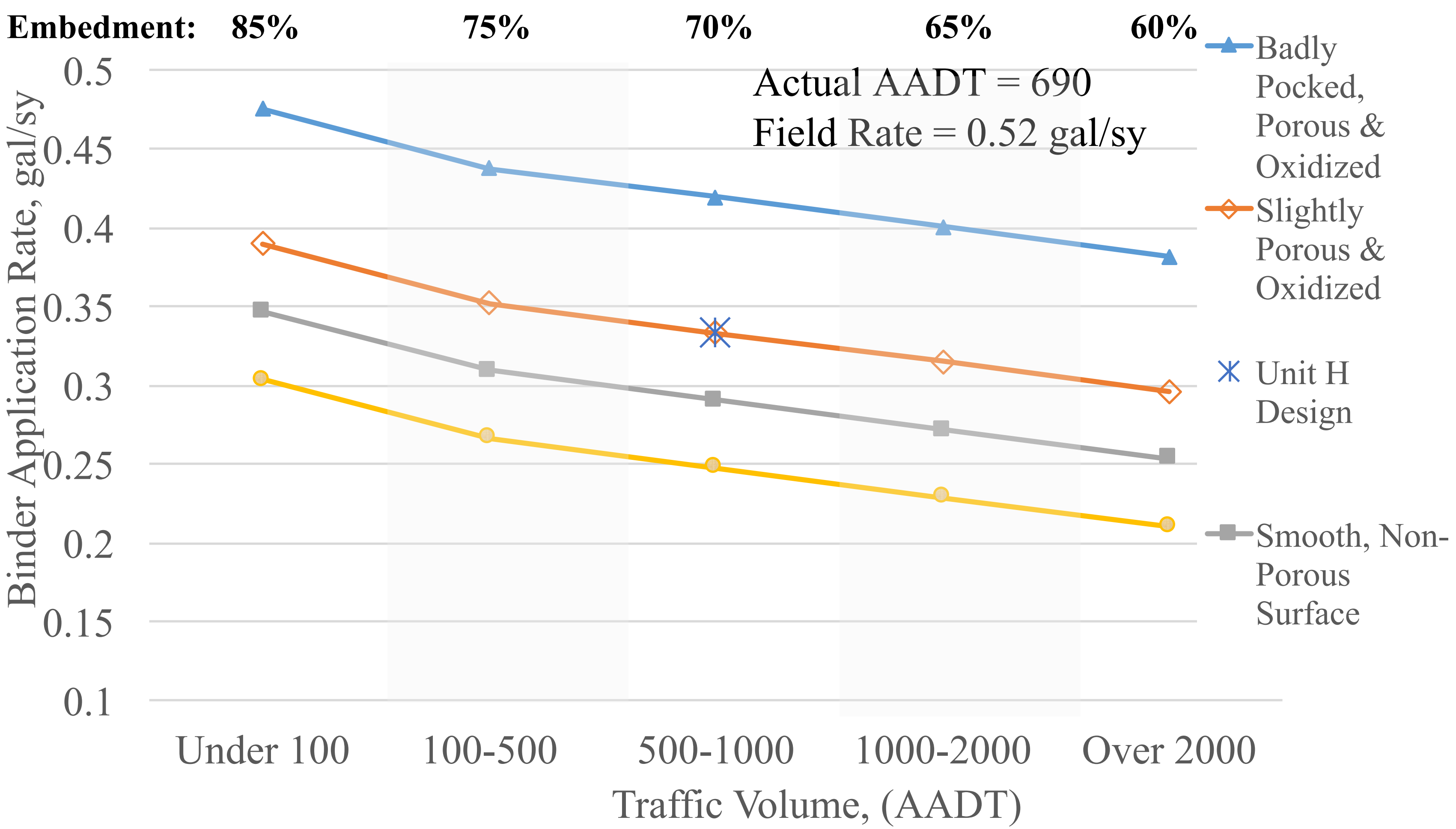
Chip Application Rate on a Emulsified Chip Seal

- **ALD and Percent Waste**



Binder Application Rate for an Emulsified Chip Seal

- **Traffic and Surface Texture**



Preliminary Findings

- All three chip seals with chip-seal related distresses are hot-apply
- Both chip seal types show an overall improvement in pavement condition
- Dynamic Friction Data was consistent between sections- inconsistent between years.
- All chip seals passed the New Zealand one-year performance specification
- Emulsified chip seals tended to be over-chipped whereas Hot-apply were close to the design

Recommendations

- Know the materials
- Pre-seal pavement condition plays a key role
- Projects demonstrate performance specification proof of concept
- Design methods provide engineering approach and a framework for chip seal education

Next Steps

- Finalize Design Guide
- Phase II Implementation Phase
  - Chip Seal Workshops
  - Teach Chip Seal Design Methodology
  - Design Lab-Field Validation
  - Introduce New Zealand Performance Specification

Thank you!