Development of Prediction Models for Skid Resistance of Asphalt Pavements

Emad Kassem, Ph.D.
Sanad Aldagari
Mohammad Al-Assi

Arif Chowdhury, Ph.D.
Eyad Masad, Ph.D.

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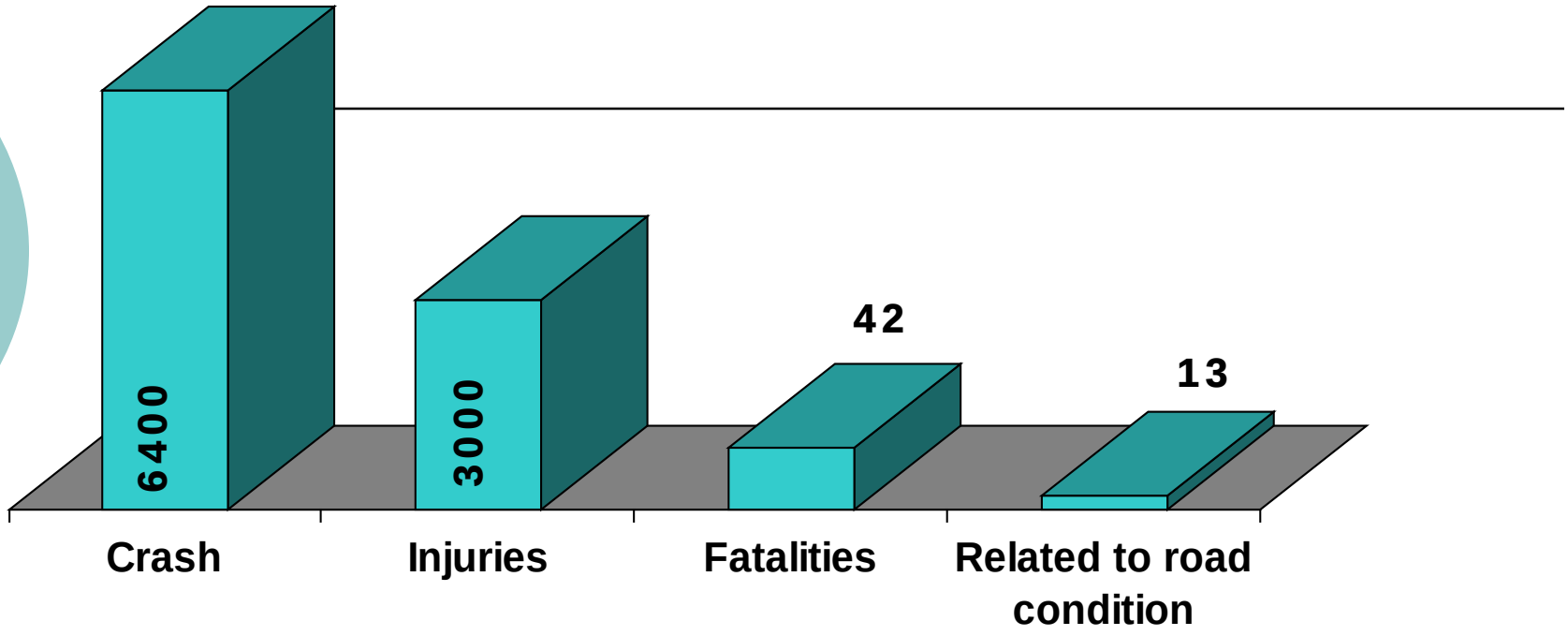
Introduction

- Pavement surface friction is a key component of road safety
- Approximately 14 percent of fatal crashes and 15 to 18 percent of all crashes occur on wet pavements [Smith, 1976; Davis et al., 2002; Chelliah et al., 2003].
- Providing acceptable level of friction leads to 50% to 60% decrease in wet weather accidents [Miller & Johnson, 1973; Kamel & Gartshore,1982]

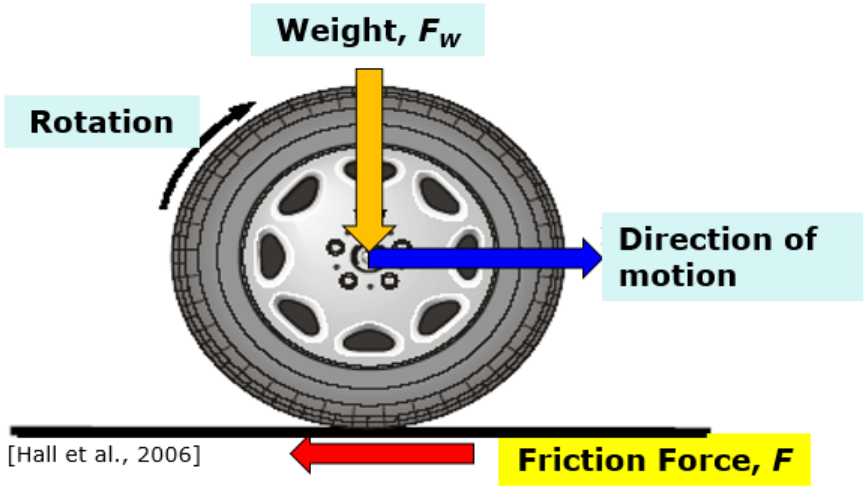


National Crash Statistics between 1993 and 2003 (thousands)

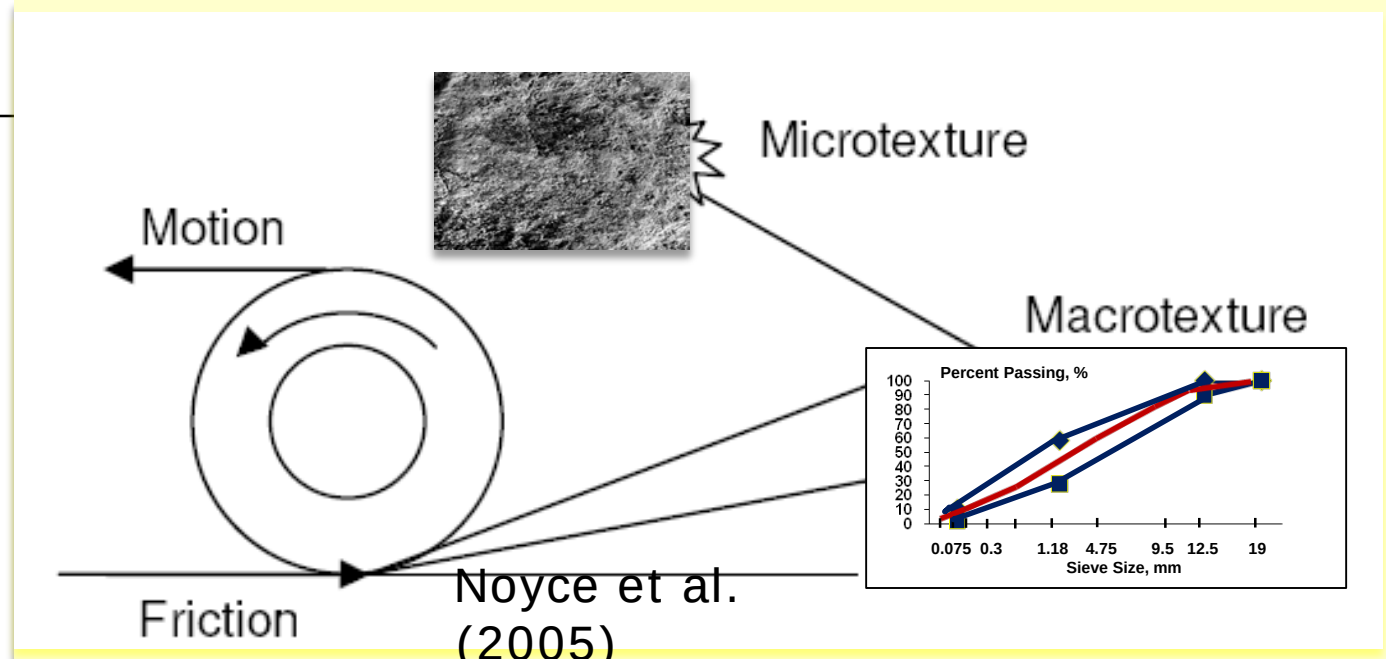
The cost of crashes is about $231 billion

Introduction

- Friction: The force that resists the relative motion between a vehicle tire and pavement surface.



$$\mu = \frac{F}{F_W}$$



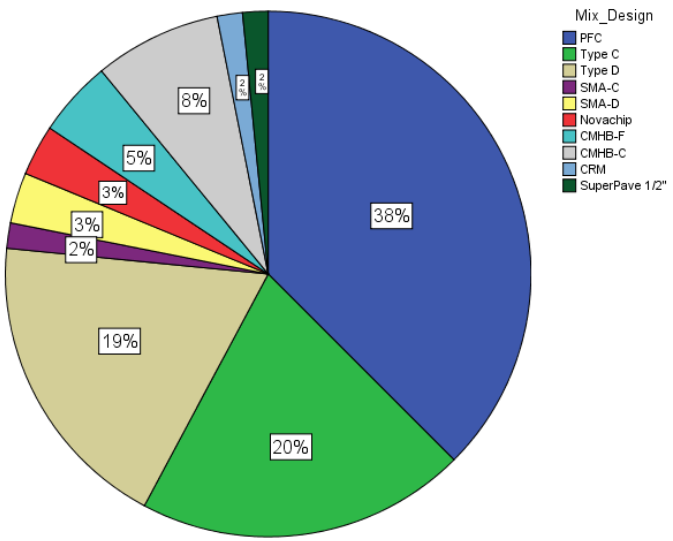
Microtexture: irregularities in the surface of rock; dependent on aggregate petrography; smooth or rough when touch

Macrotexture: larger irregularities in the road surface, dependent on aggregate gradation

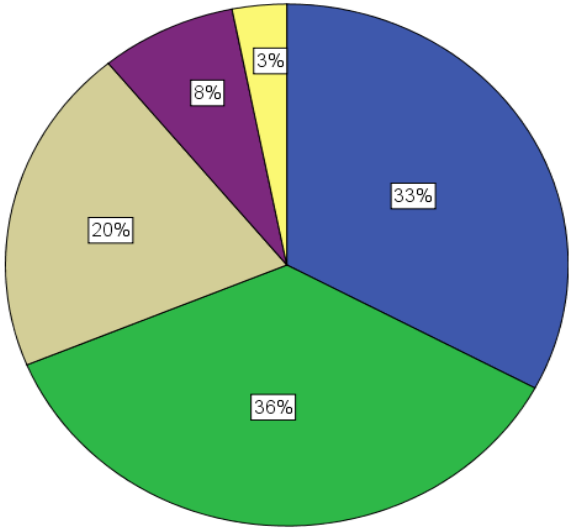
Objectives

- Validate and revise a prediction model for Skid Number of asphalt pavements as function of traffic level, aggregate characteristics, and aggregate gradation
- Develop a prediction model for Skid Number of seal coat surfaces
- Use the developed models to classify road sections based on their skid resistance

Field Experiments



Mix Designs



Traffic Levels

Aggregate Sources

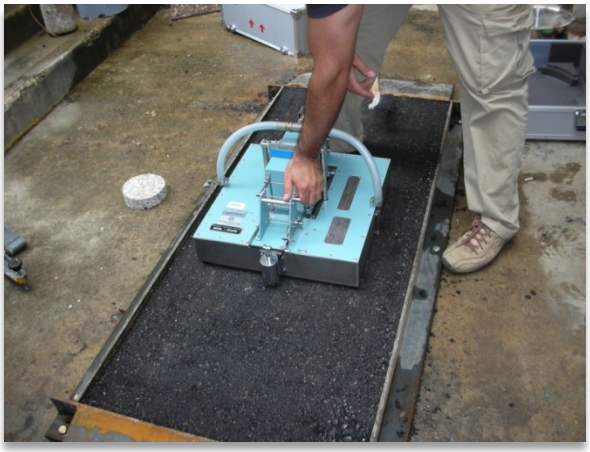
Field Friction Measurement

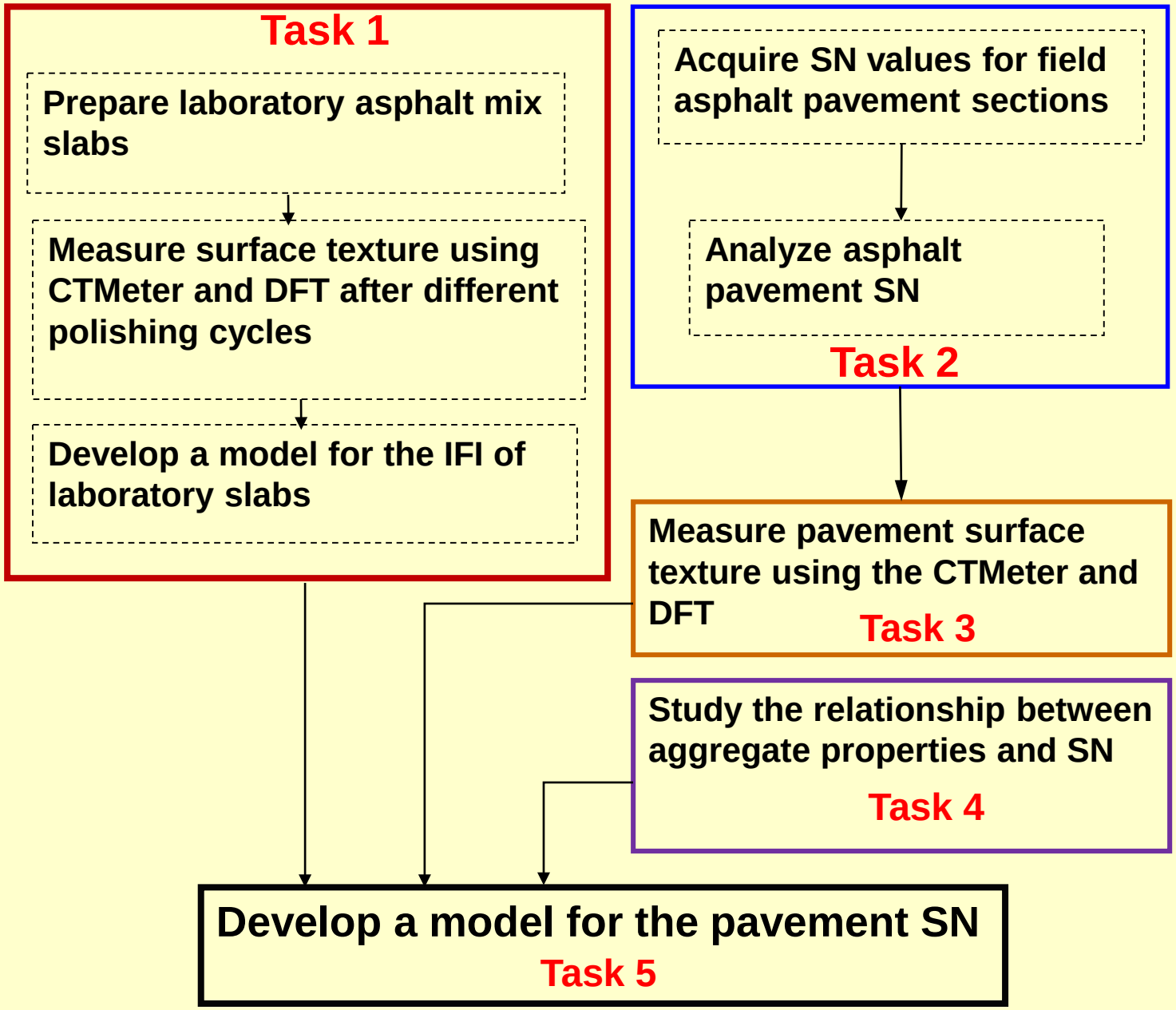
- Locked-wheel Mode
  - Skid trailer with one or two wheels are towed
  - Water is applied in front of the wheel
  - The test wheel is locked
  - The friction force is recoded for a given distance
  - The results is reported as Skid Number (SN)

Skid Trailer

SN = 100 x friction factor

Laboratory Experiments




Task 1
Prepare laboratory asphalt mix slabs
Measure surface texture using CTMeter and DFT after different polishing cycles
Develop a model for the IFI of laboratory slabs
Acquire SN values for field asphalt pavement sections
Analyze asphalt pavement SN
Task 2
Measure pavement surface texture using the CTMeter and DFT
Task 3
Study the relationship between aggregate properties and SN
Task 4
Develop a model for the pavement SN
Task 5

International Friction Index

$$IFI = 0.081 + 0.732 DFT_{20}\, e^{\frac{-40}{S_P}}$$

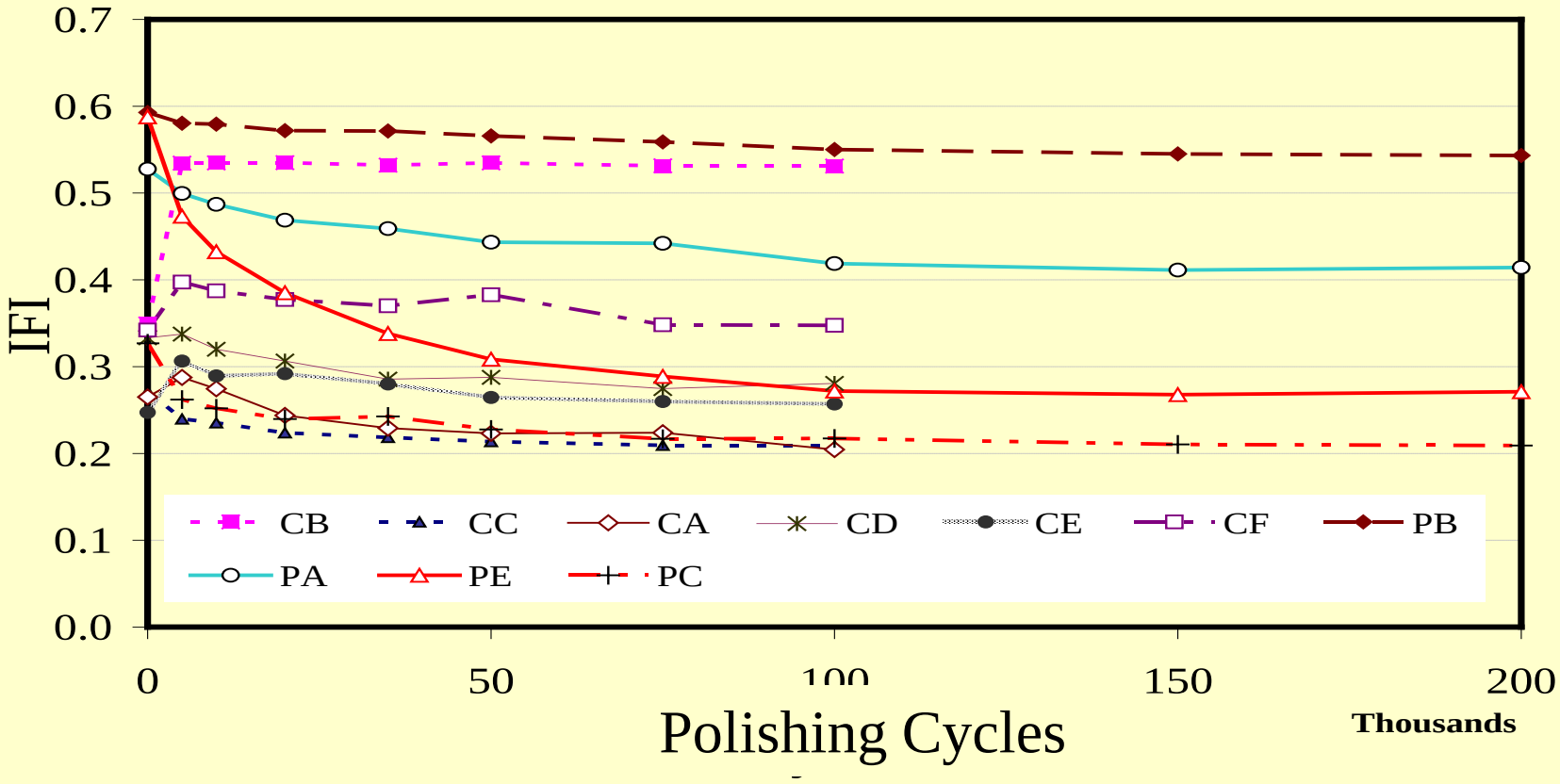
$$S_P = 14.2 + 89.7 MPD$$

$$IFI = 0.045 + 0.925 \times 0.01 \times SN(50) e^{\frac{20}{S_P}}$$

MPD is Mean Profile Depth Measured by CTMeter

DFT_{20} is Dynamic Friction at 20 km/h Measured by DFT

SN(50) is measured skid number at 50mph using skid trailer



$$IFI(N) = a_{mix} + b_{mix} \cdot \exp(-c_{mix} \cdot N)$$

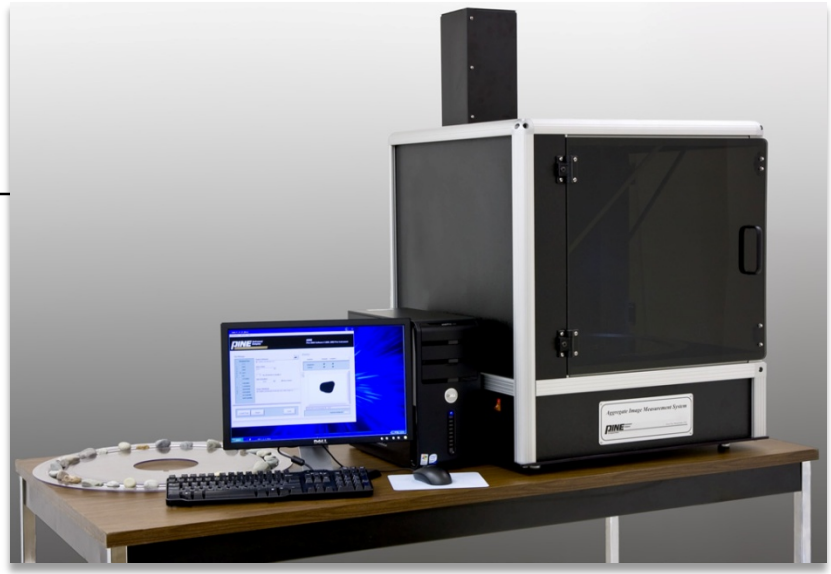
a_{mix}: Terminal IFI

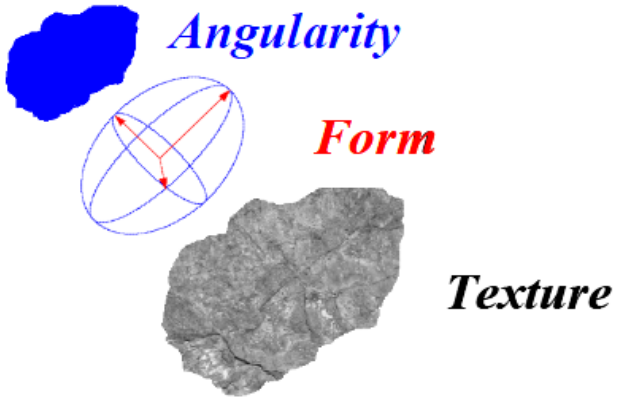
$a_{mix} + b_{mix}$: Initial IFI

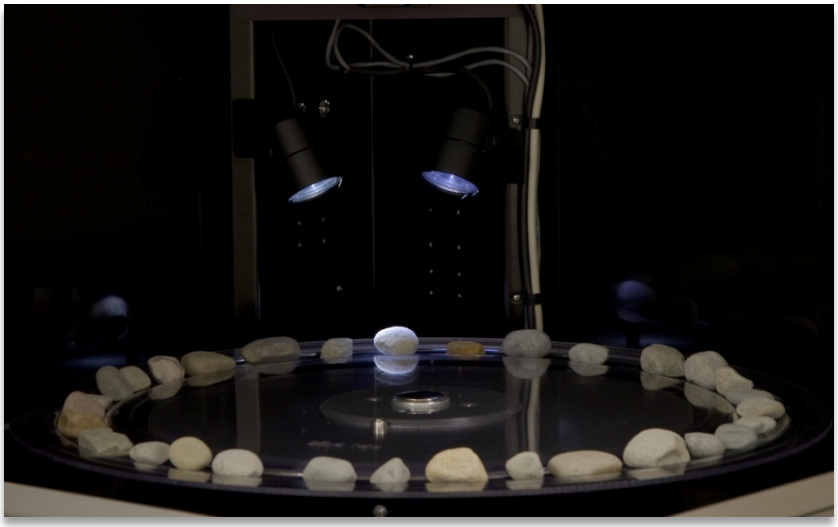
c_{mix}: Rate of IFI Change

a_{mix}, b_{mix} and c_{mix} = f (aggregate texture and gradation).

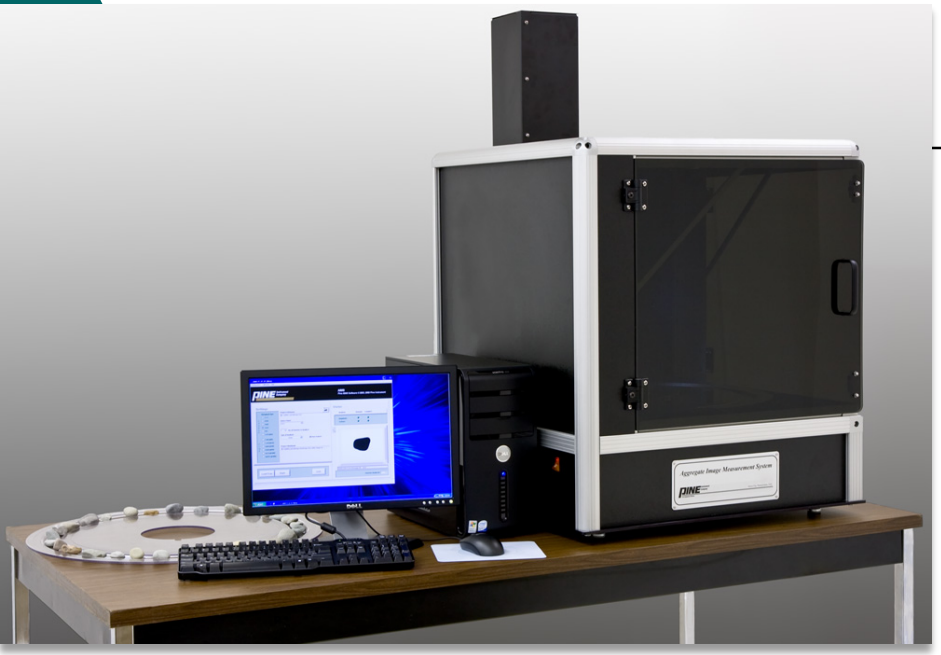
Measure Texture and Angularity before and after Micro-Deval Polishing

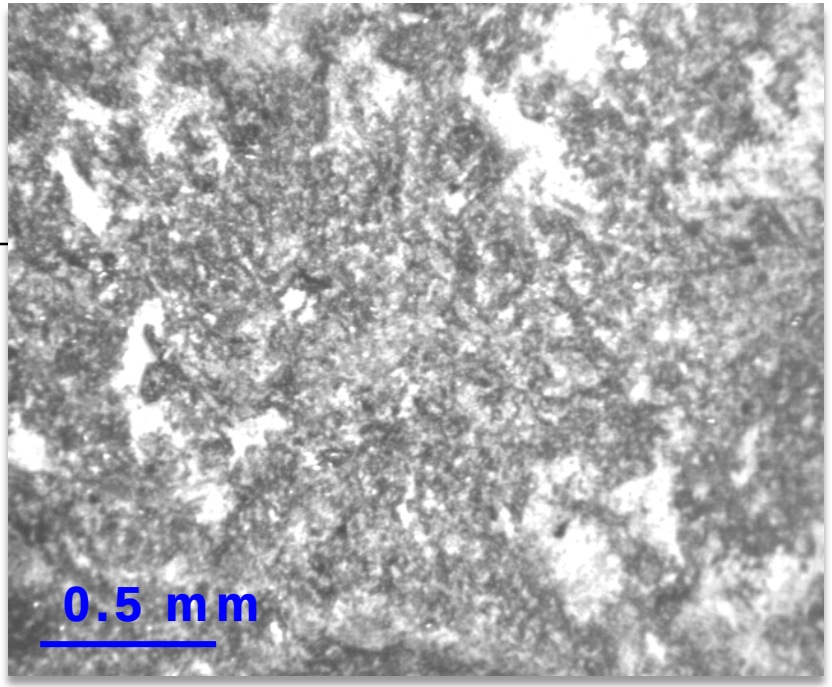


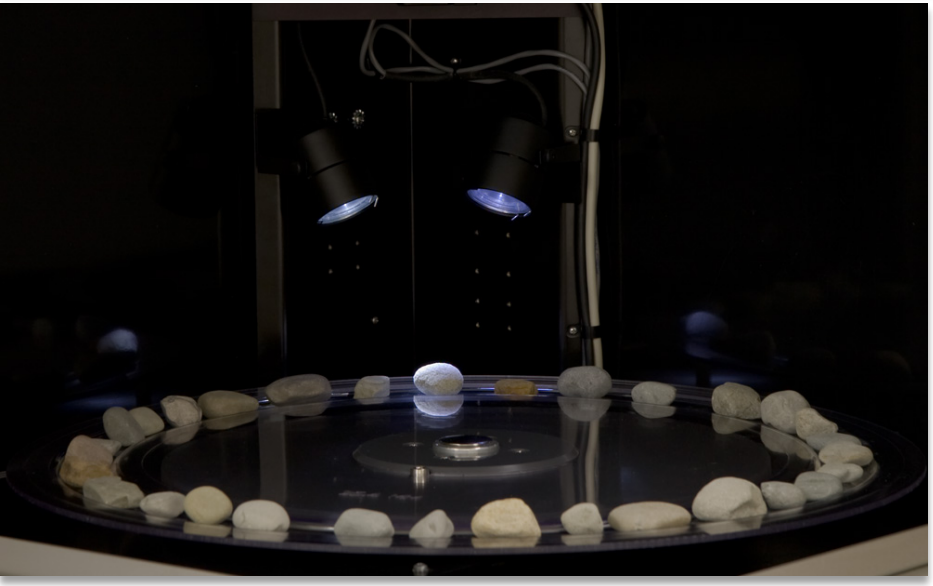


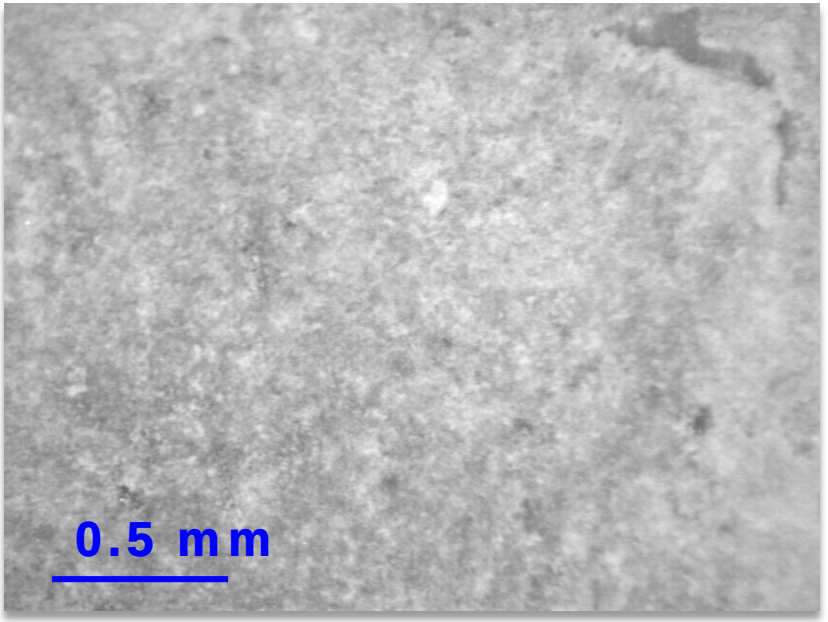


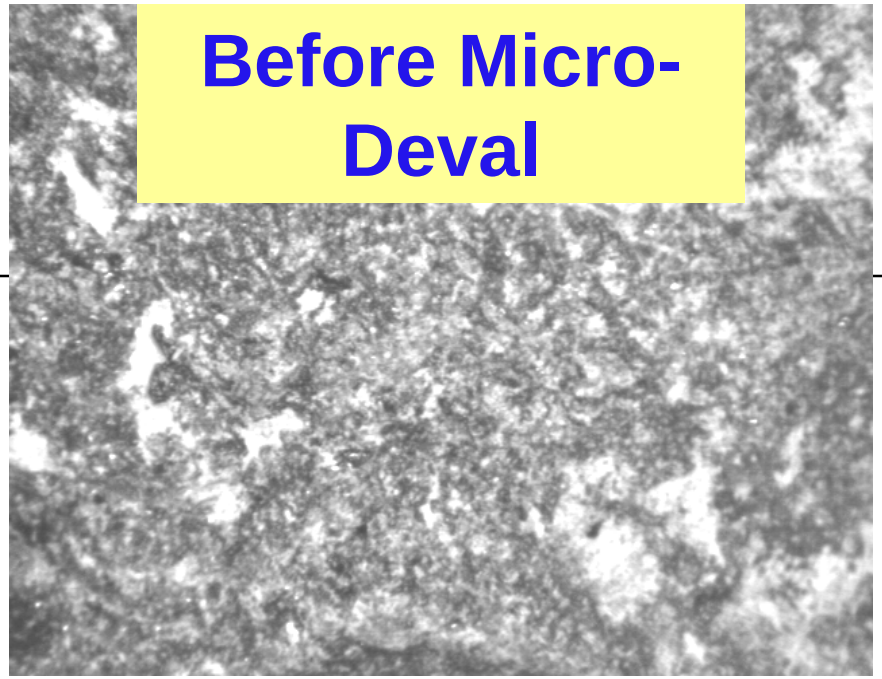
Aggregate Texture



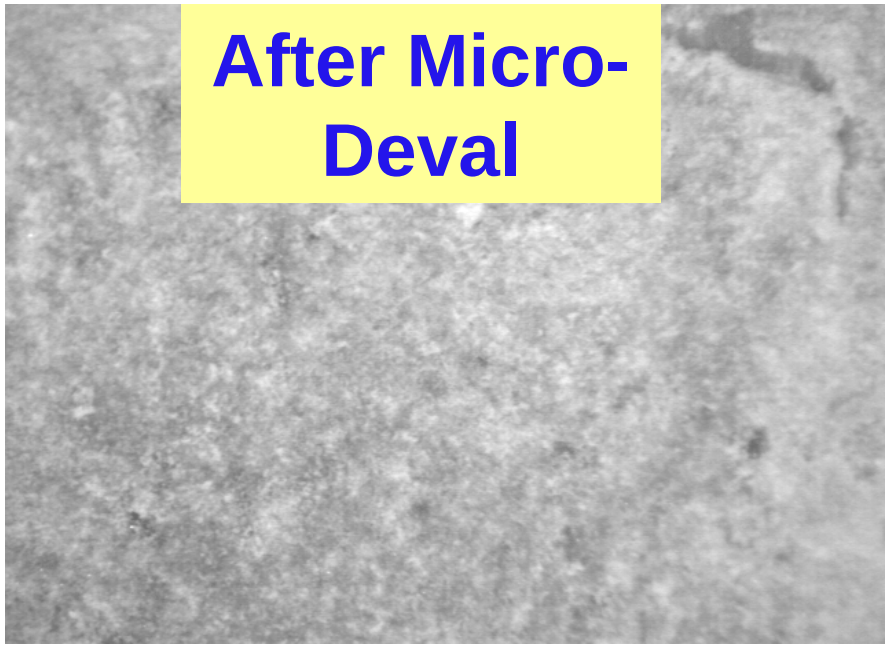




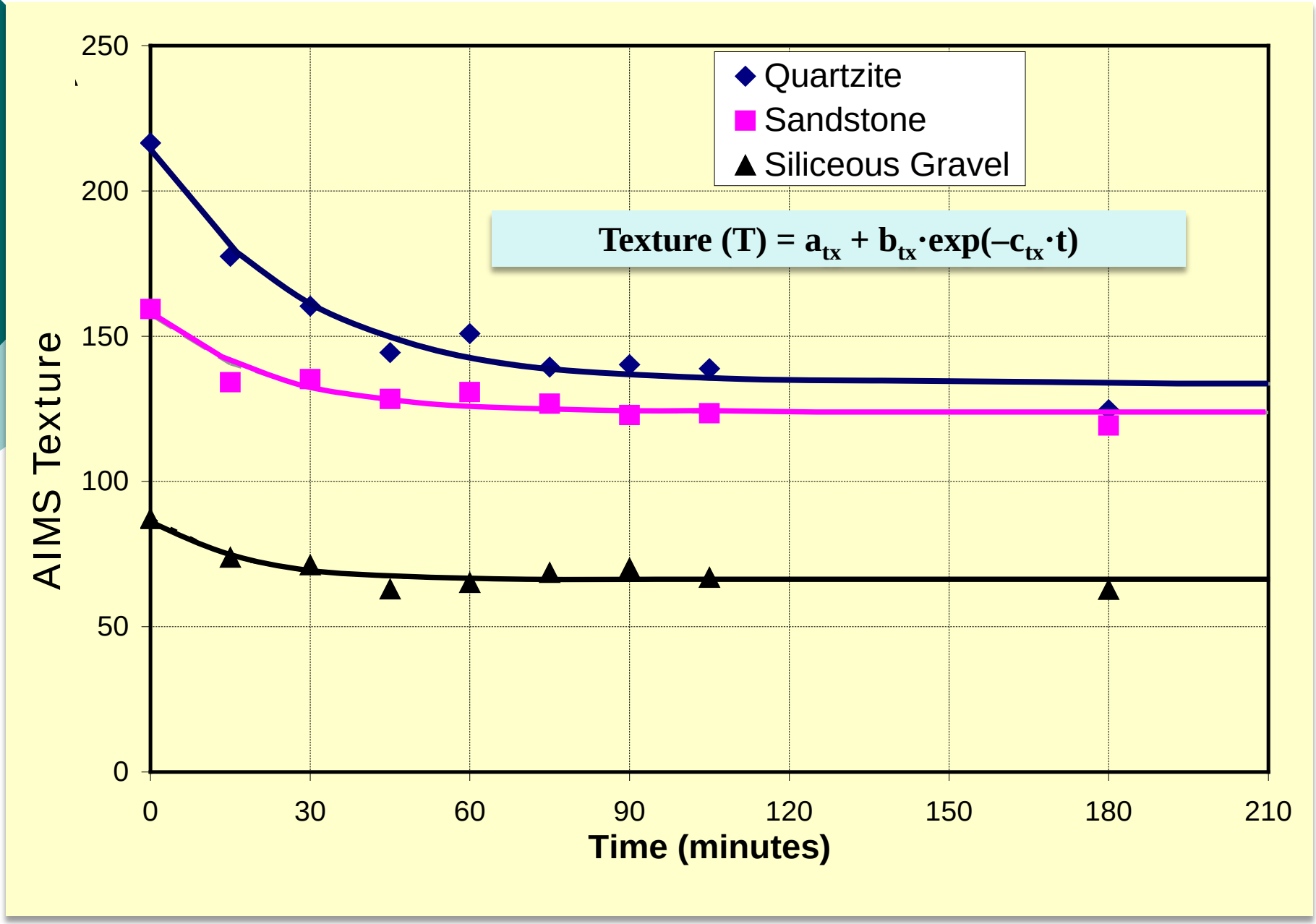




Before Micro-Deval



After Micro-Deval


Quartzite
Sandstone
Siliceous Gravel
Texture (T) = $a_{tx} + b_{tx} \cdot \exp(-c_{tx} \cdot t)$
AIMS Texture
250
200
150
100
50
0
0
30
60
90
120
150
180
210
Time (minutes)

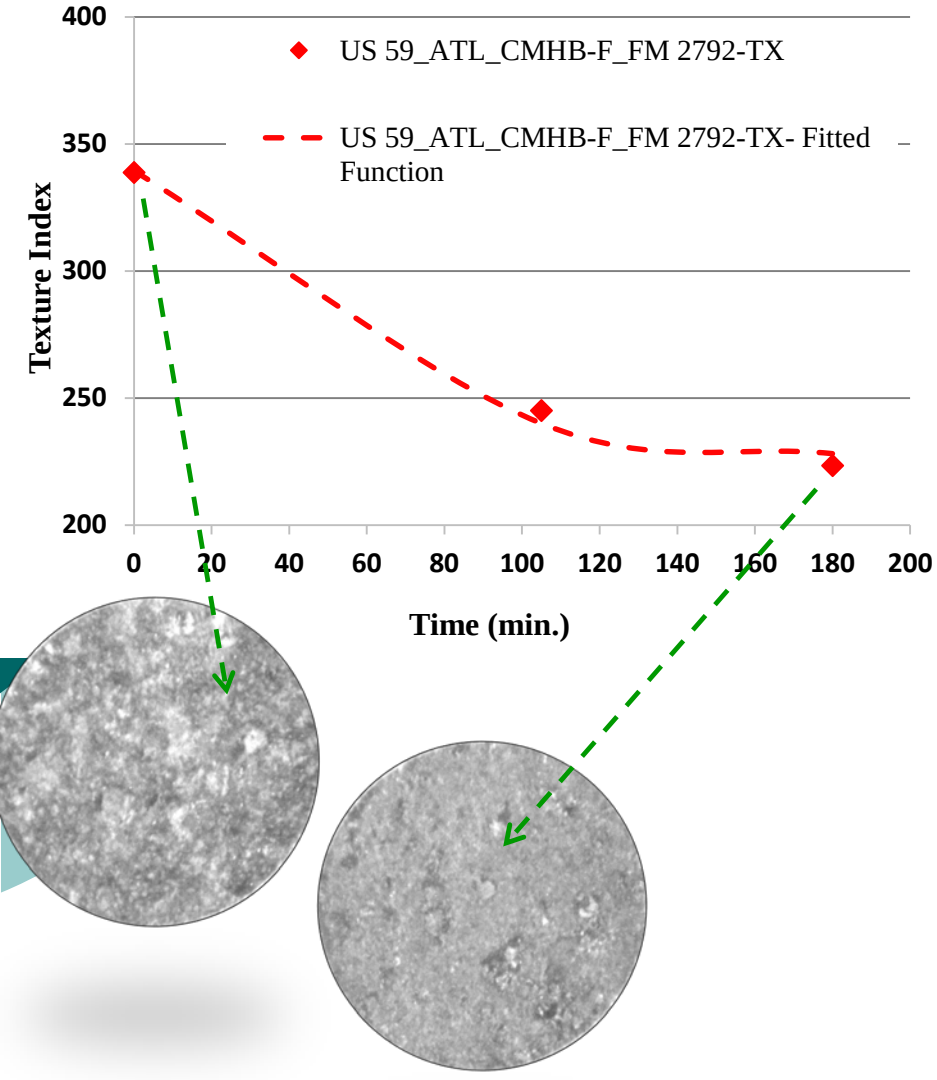
List of HMA Test Sections

- Locations: ATL, BMT, ODA, SAT, YKM, HOU, LRD, PHR, LFK
- Mix types: SMA-D, SMA-F, CMHB-F, Type C, Type D, TOM, PFC, CMHB-C, CAM
- Year of Construction: 2006 to 2013
- Aggregate Types: Limestone, Gravel, Granite, Sandstone, Dolomite, Rhyolite, Traprock, Quartzite

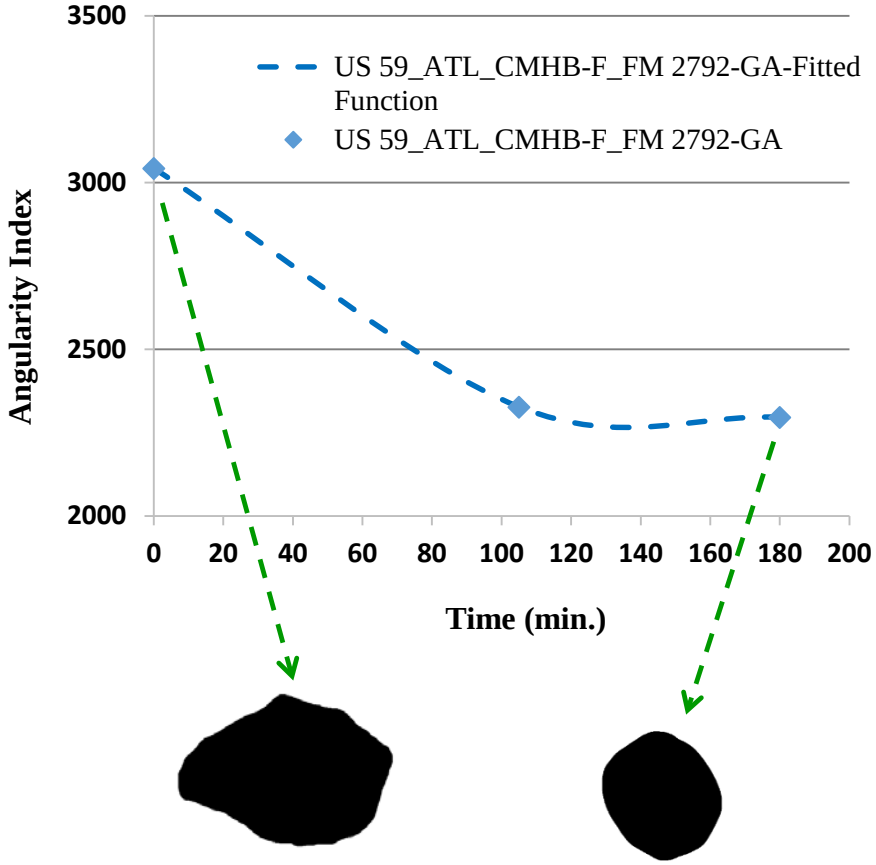
List of Seal Coat Test Sections

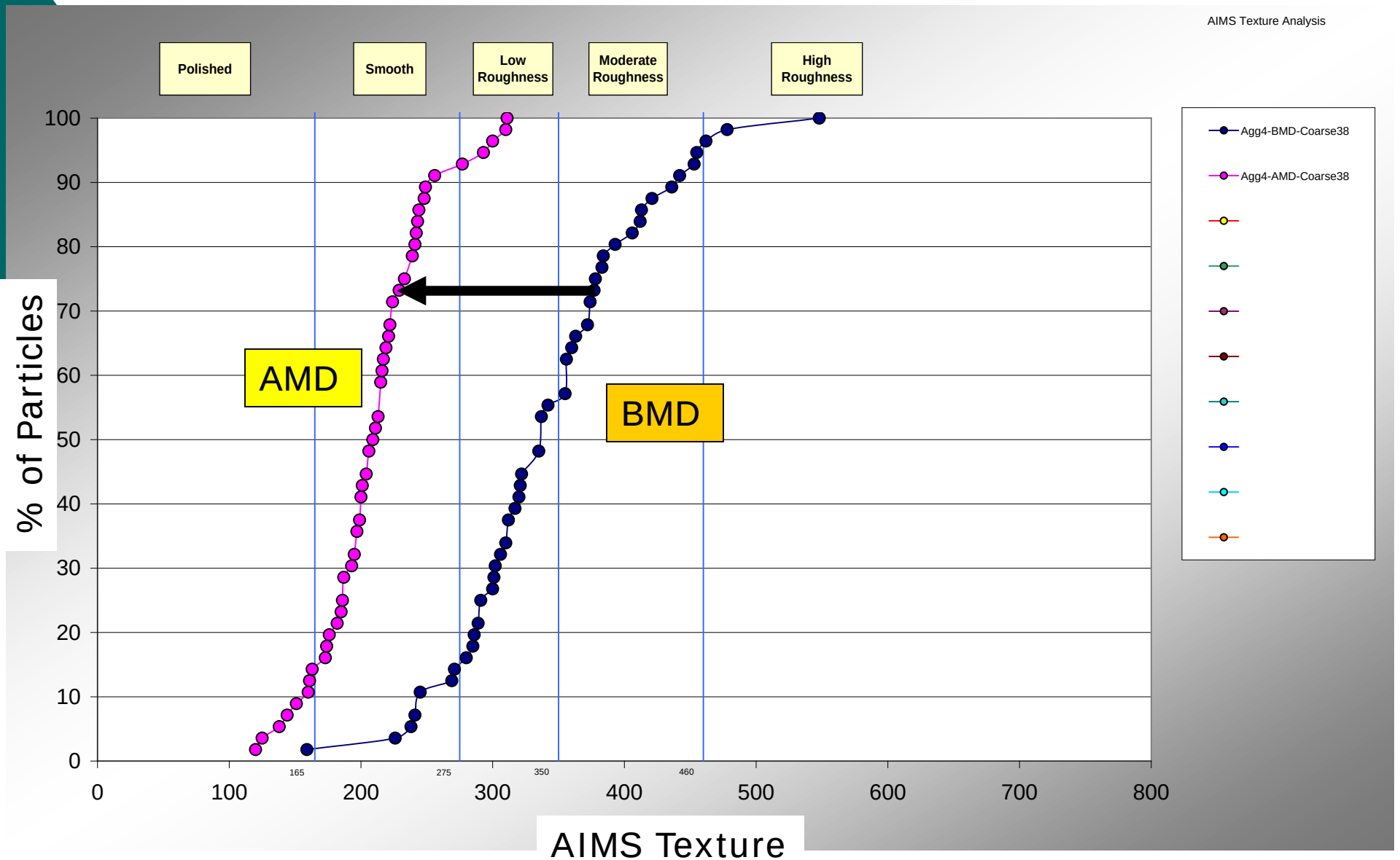
- Locations: ATL, BMT, ODA, SAT, YKM, LRD, PHR, LFK, BRY
- Grade: Grade 3, **Grade 4**, Grade 5
- Year of Construction: 2006 to 2013
- Aggregate Types: **Limestone**, Gravel, Traprock, Sandstone, Dolomite, Rhyolite, LRA, Lightweight
- Coating: **Pre-coated** and Virgin

TEXTURE

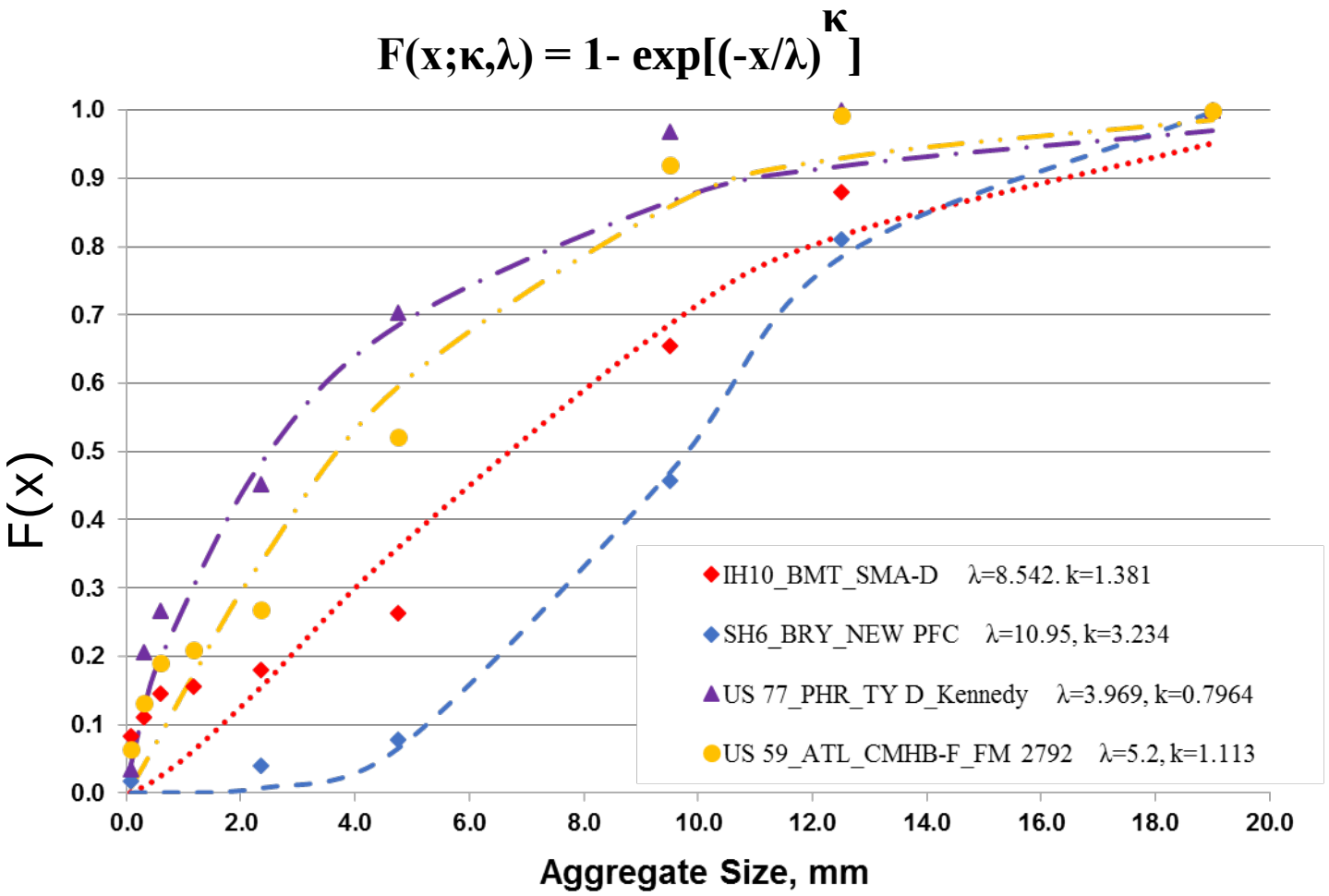


ANGULARITY



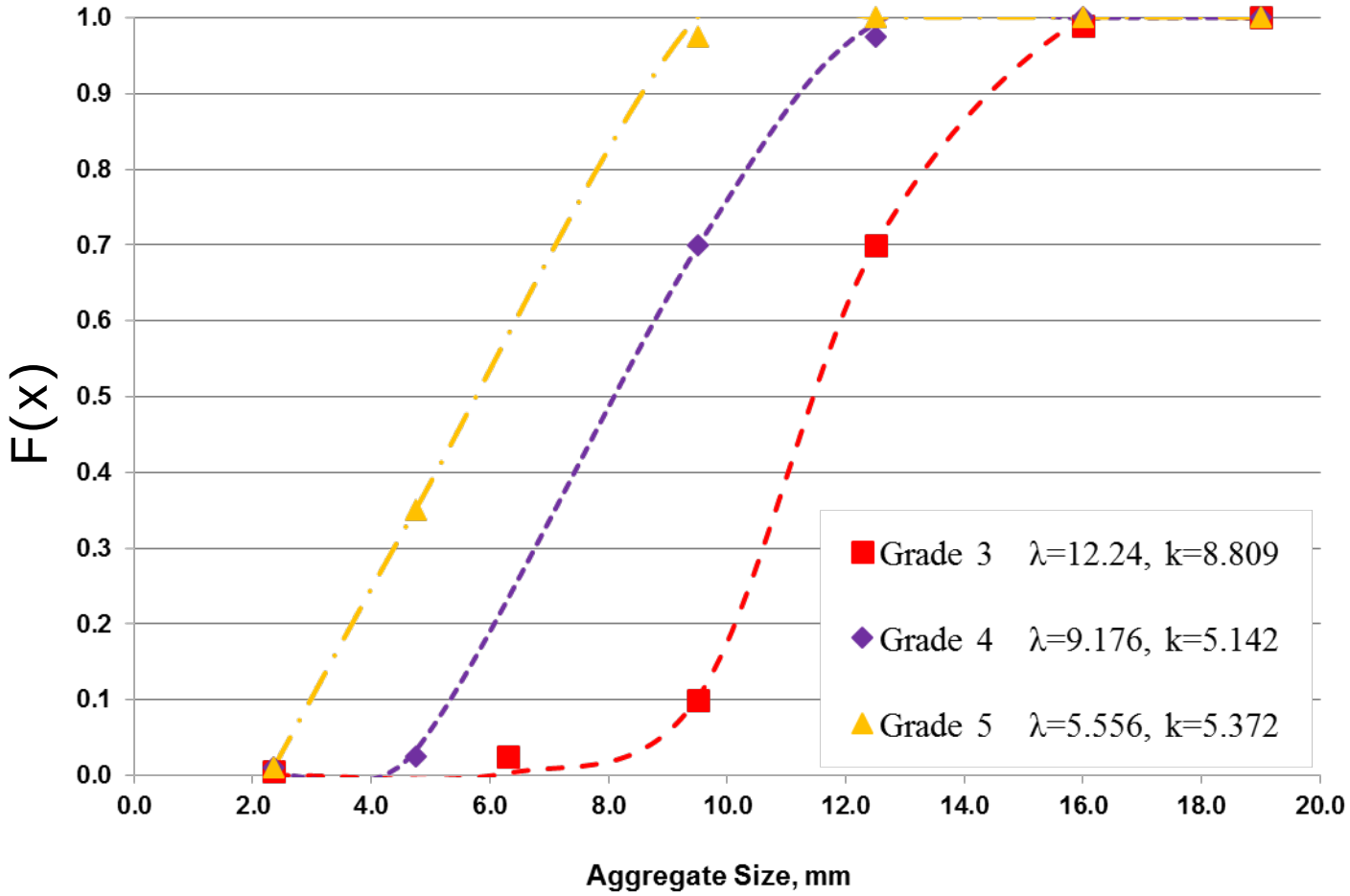

AIMS Texture Analysis
Polished
Smooth
Low Roughness
Moderate Roughness
High Roughness
AMD
BMD
Agg4-BMD-Coarse38
Agg4-AMD-Coarse38
% of Particles
AIMS Texture
0
10
20
30
40
50
60
70
80
90
100
0
100
200
300
400
500
600
700
800
165
275
350
460

Aggregate Gradation for HMA (Weibull Distribution Function)

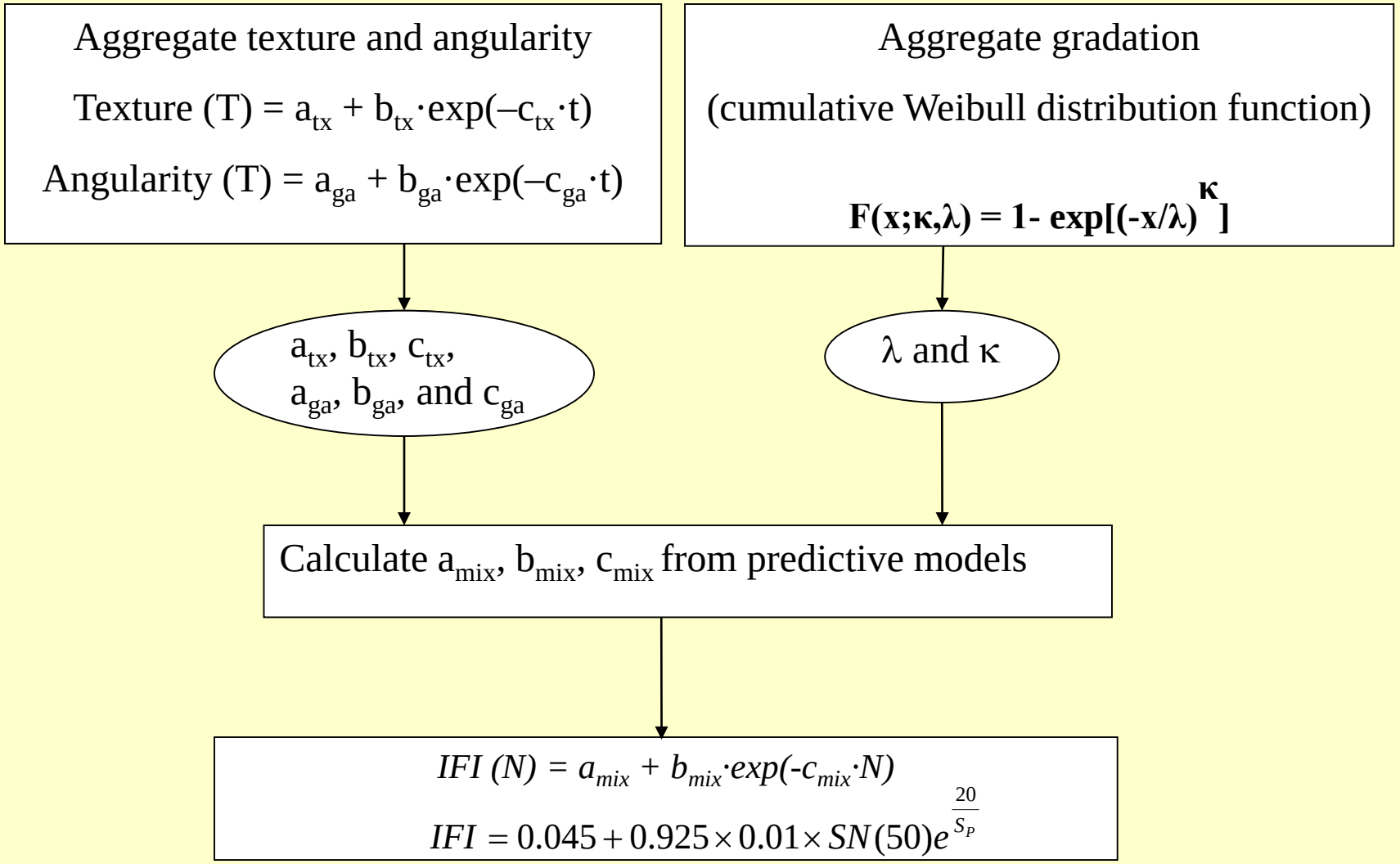


Aggregate Gradation for Sealcoat (Weibull Distribution Function)

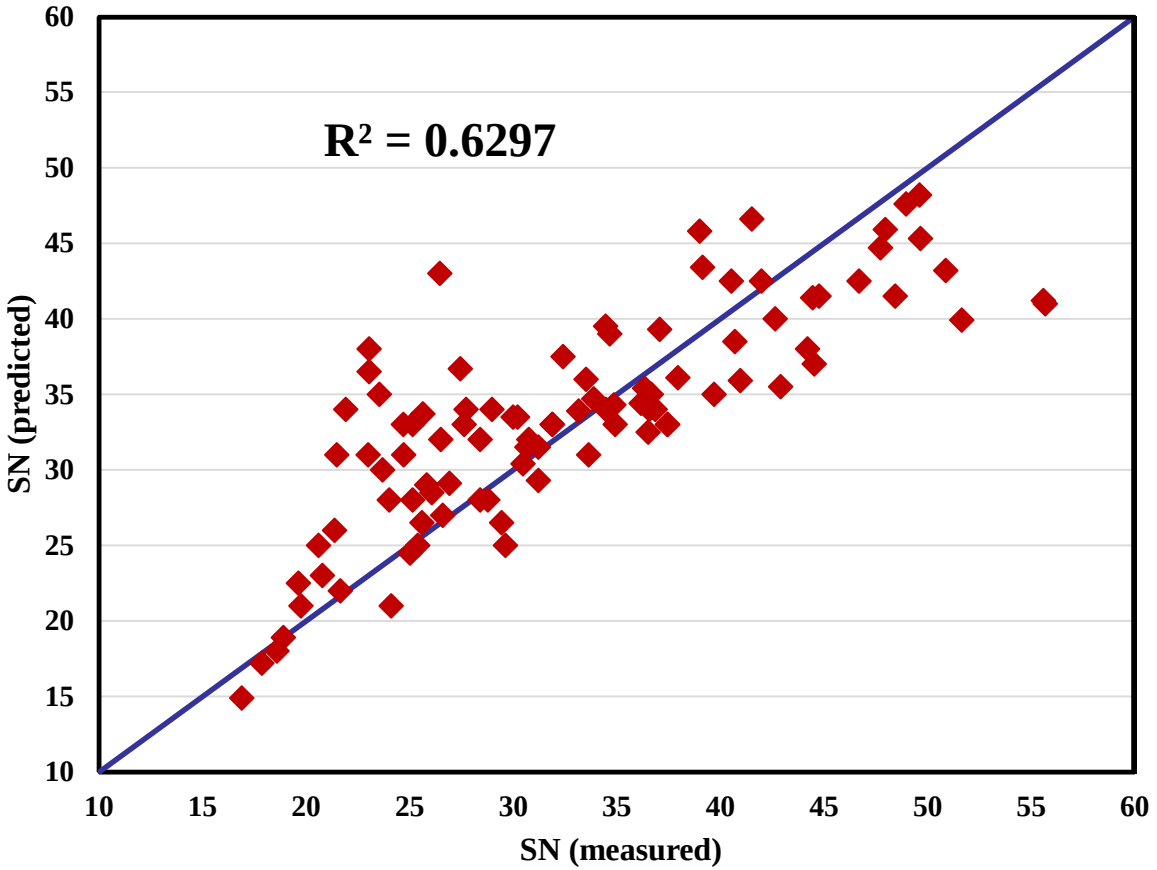
$$F(x;\kappa,\lambda) = 1 - \exp[(-x/\lambda)^{\kappa}]$$



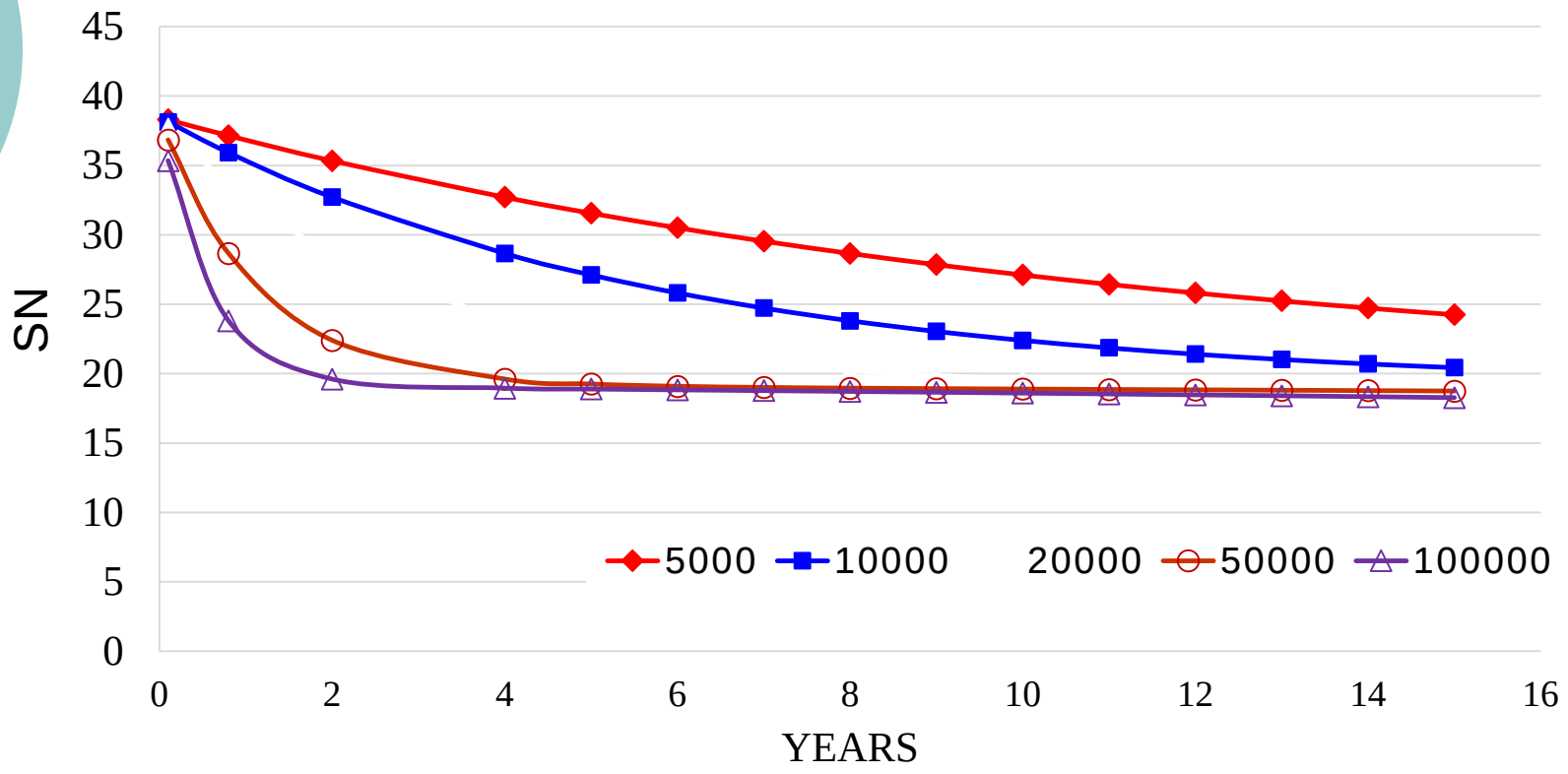
Friction Model



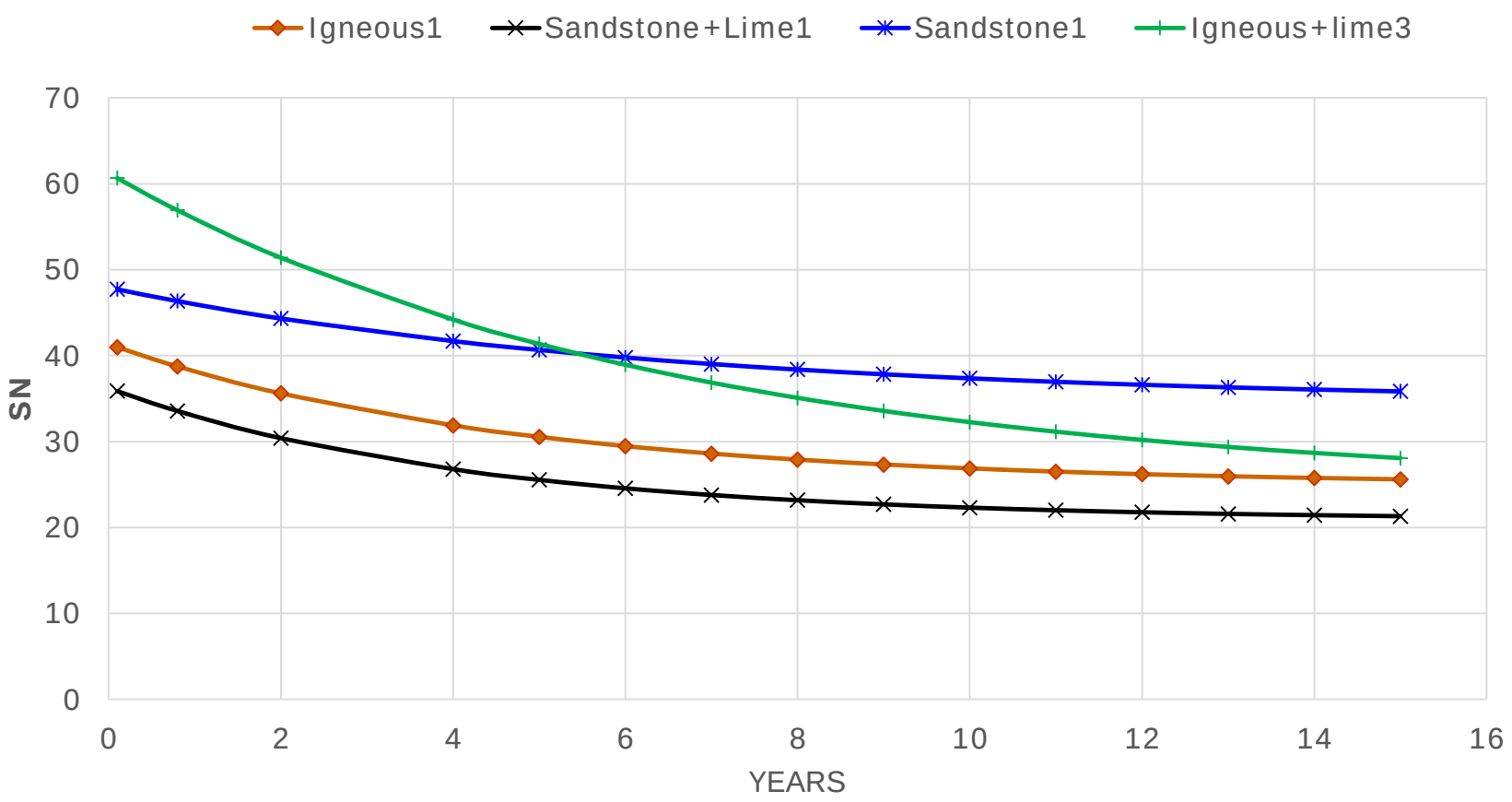
Skid Number for HMA



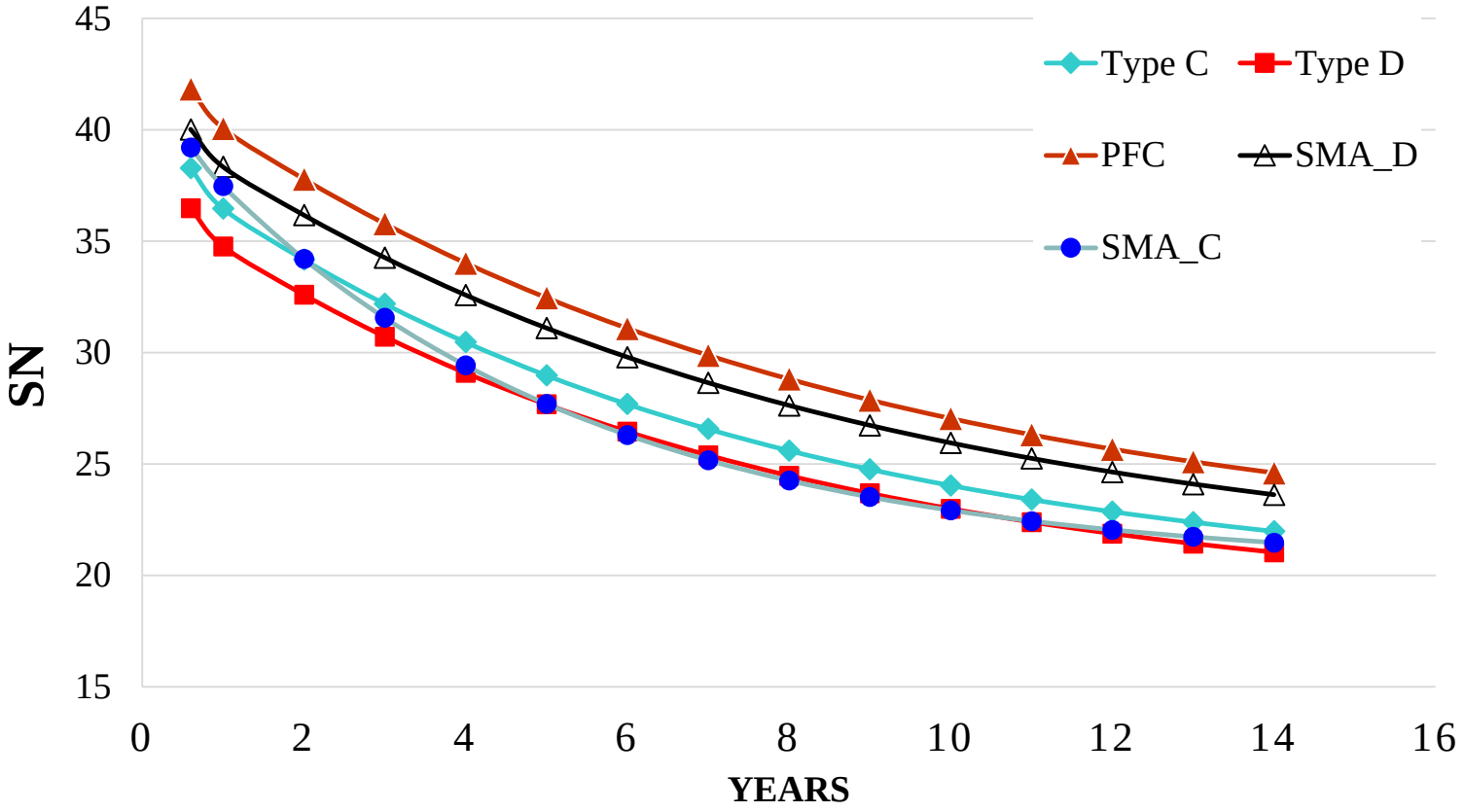
Effect of AADT on the Skid Number (SN)



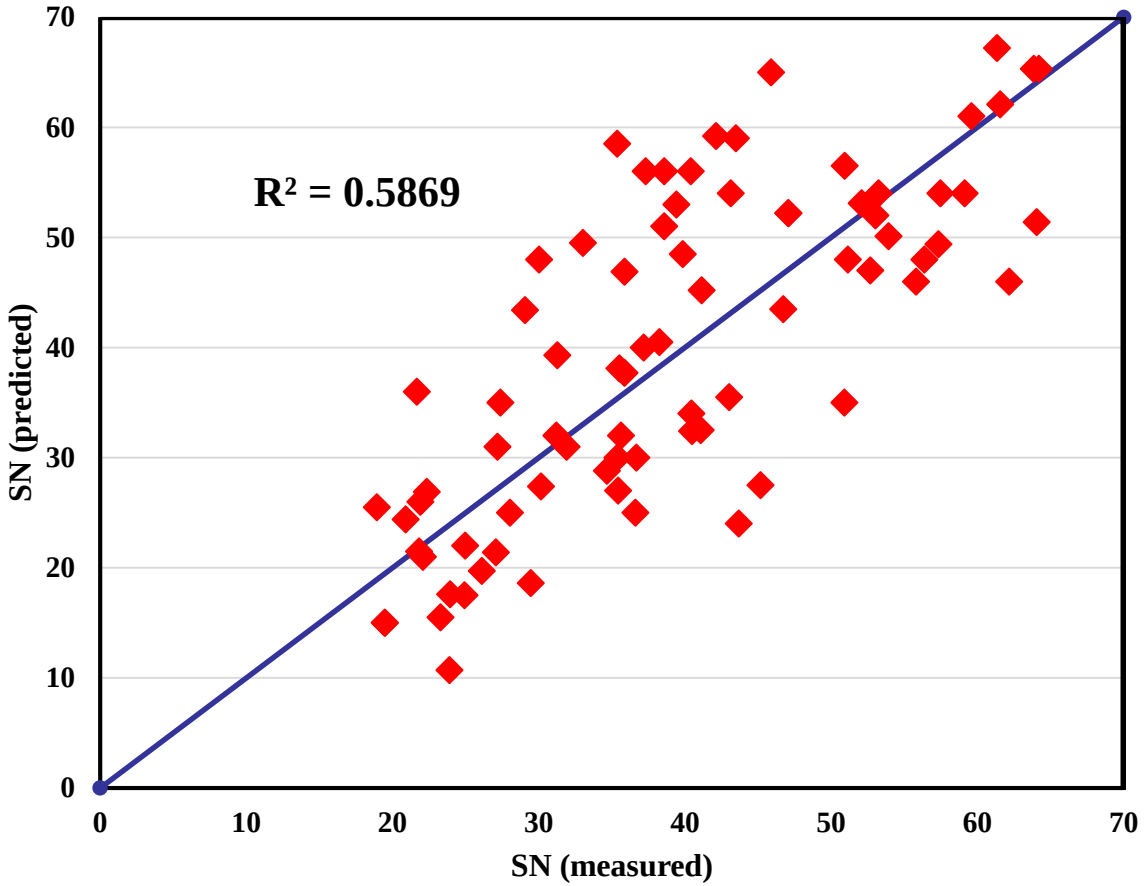
- **Effect of Aggregate Texture on the Skid Number (SN)**



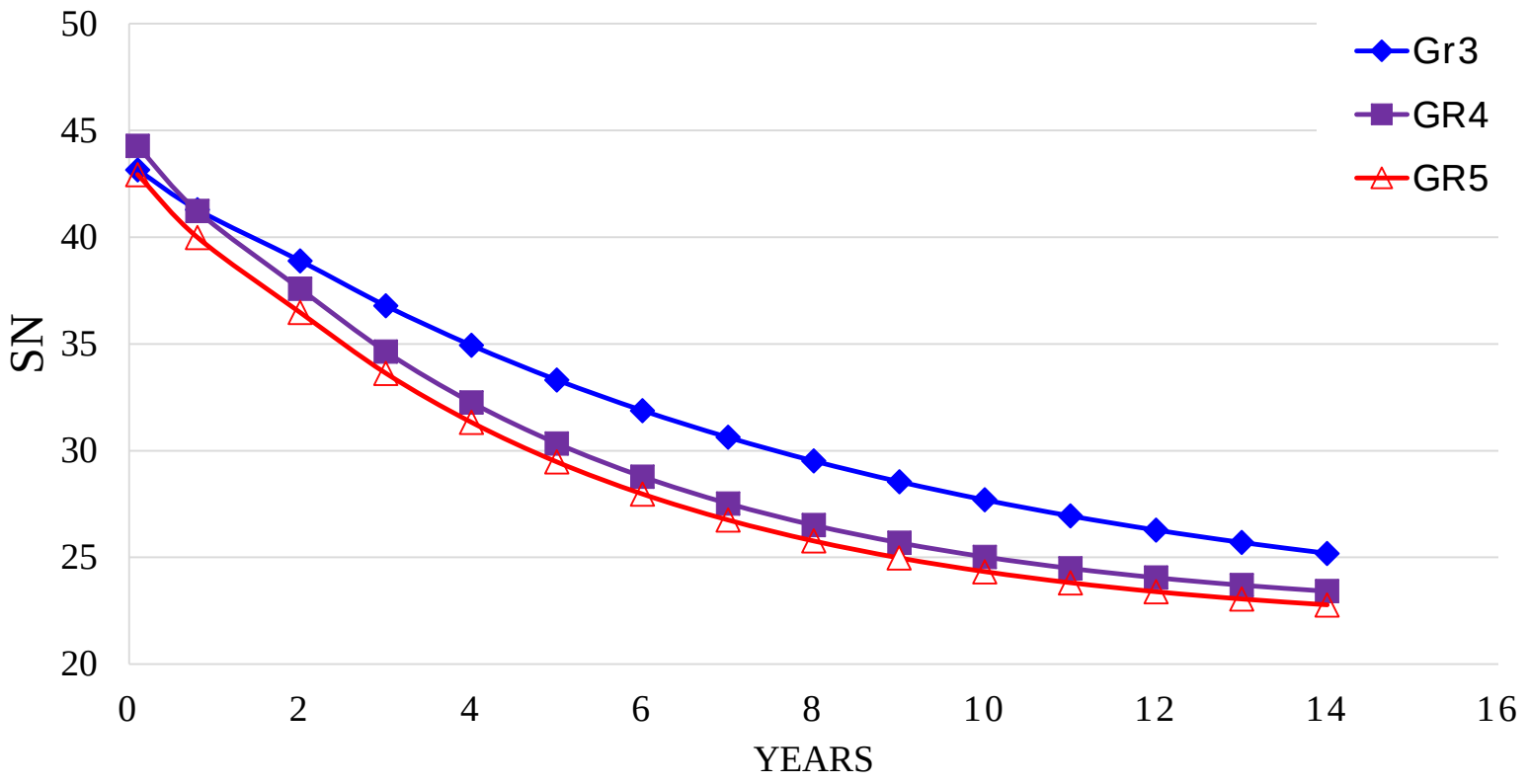
Effect of Mixture Gradation on the Skid Number (SN)



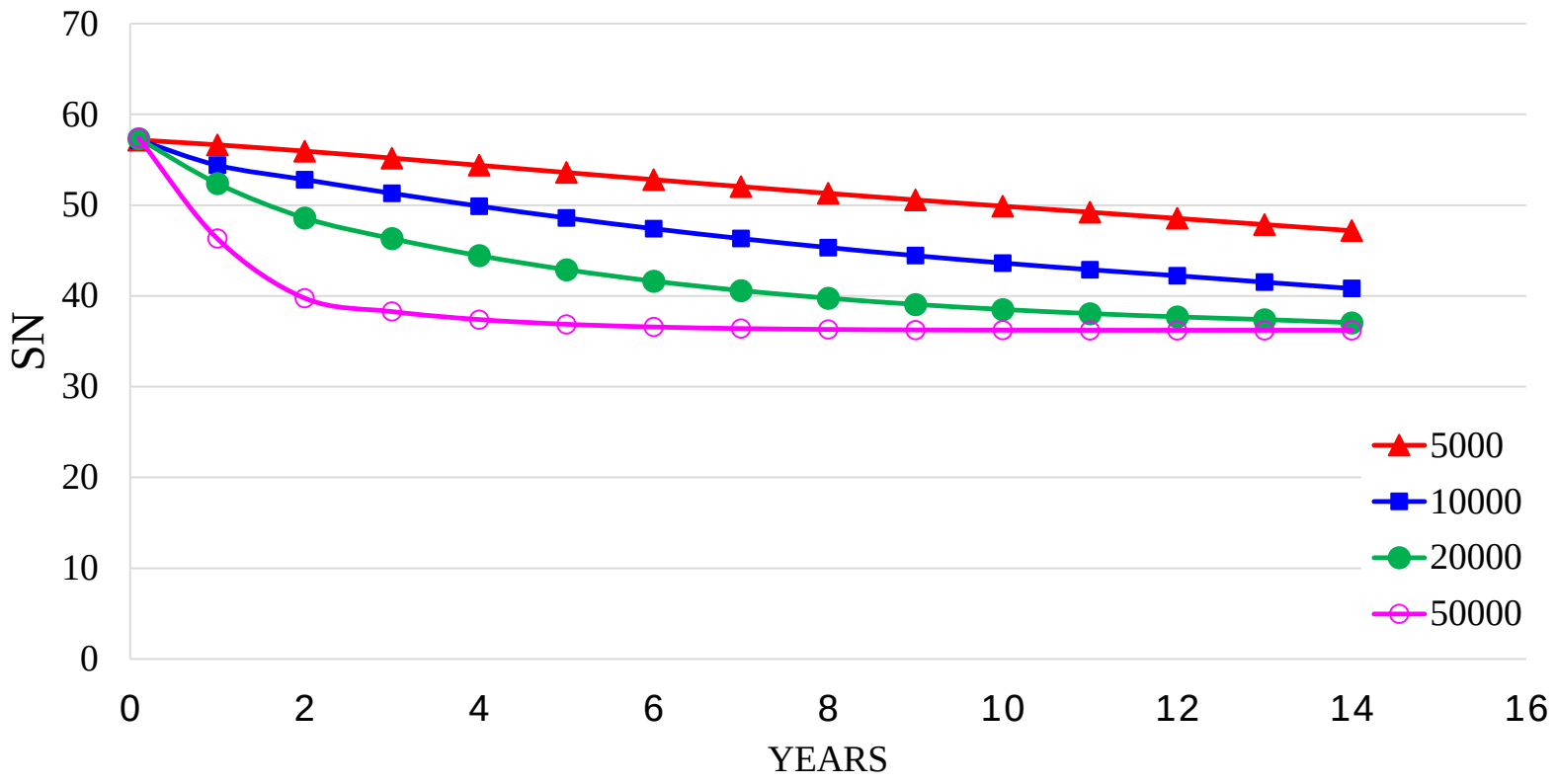
Skid Number for Seal coat



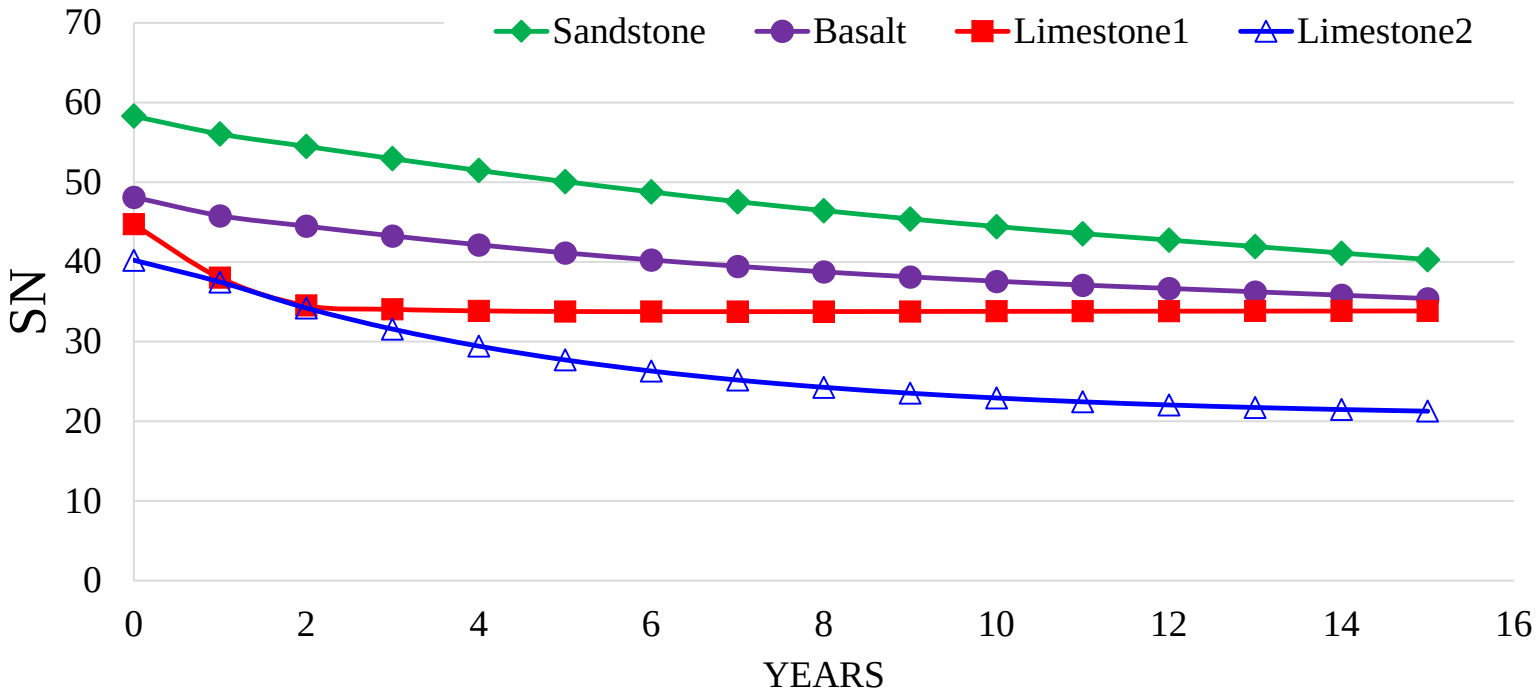
Effect of Seal Coat Gradation on the Skid Number (SN)



Effect of AADT on the Skid Number (SN)



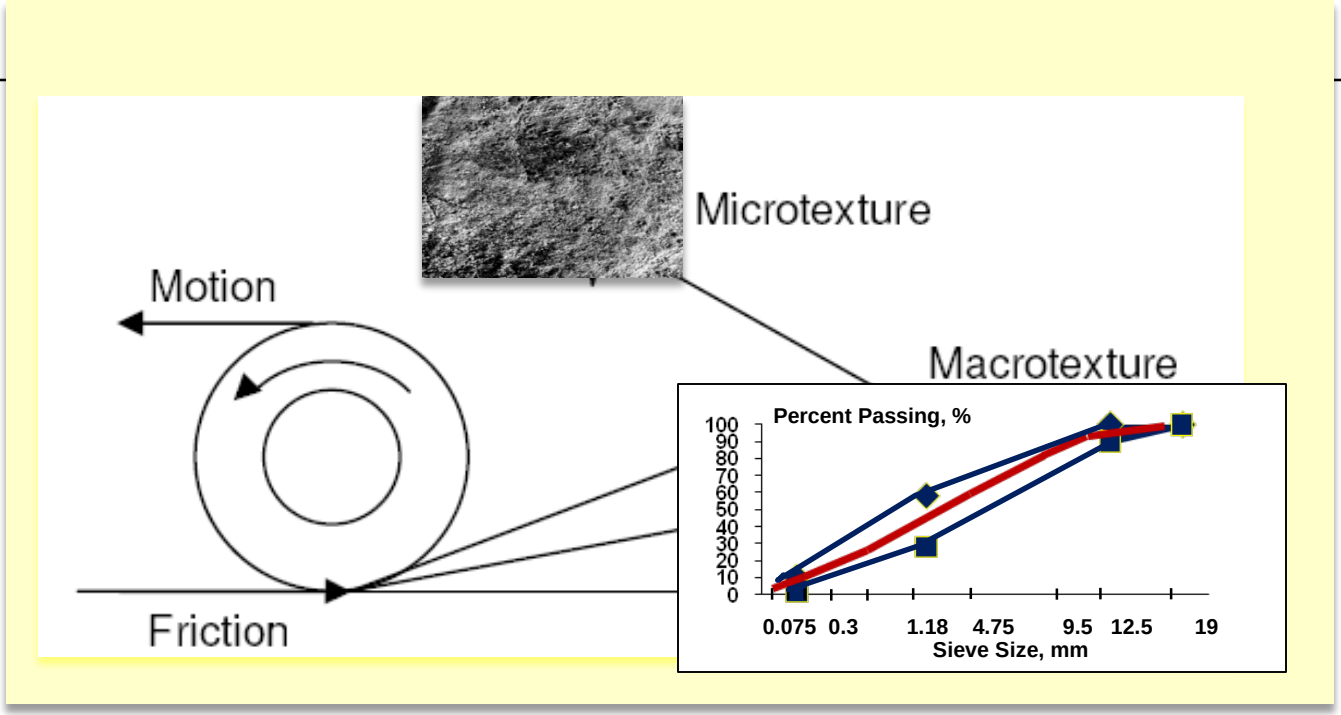
Effect of Aggregate Texture on the Skid Number (SN)

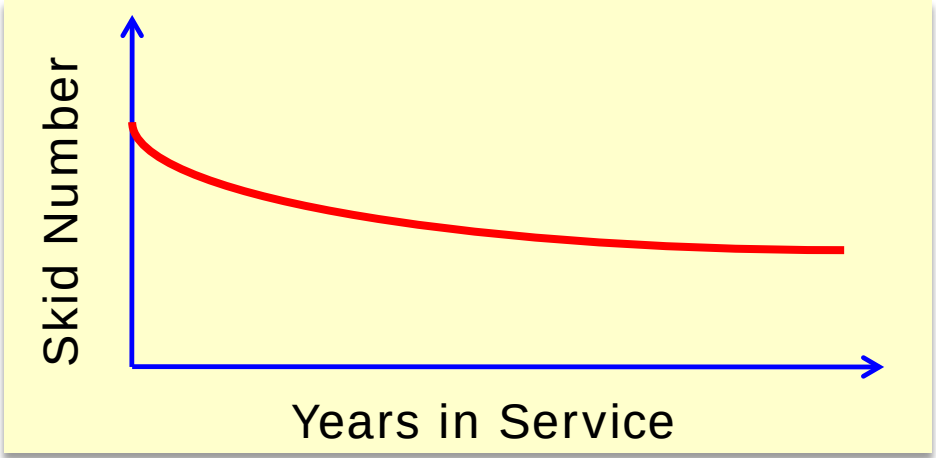


Example of Influence of Aggregate and Gradation on Skid Resistance

	Interstate		US Highway		State Highway	
AADT	64500	5700	34000	550	16800	150
Type C	21	29	23	31	26	31
Type D	12	15	12	15	12	15
PFC	29	47	34	51	40	51
SMA-D	29	54	36	60	45	60
SMA-C	29	57	37	63	47	63
CMHB-C	29	57	37	63	47	63
CMHB-F	7	11	7	11	7	11

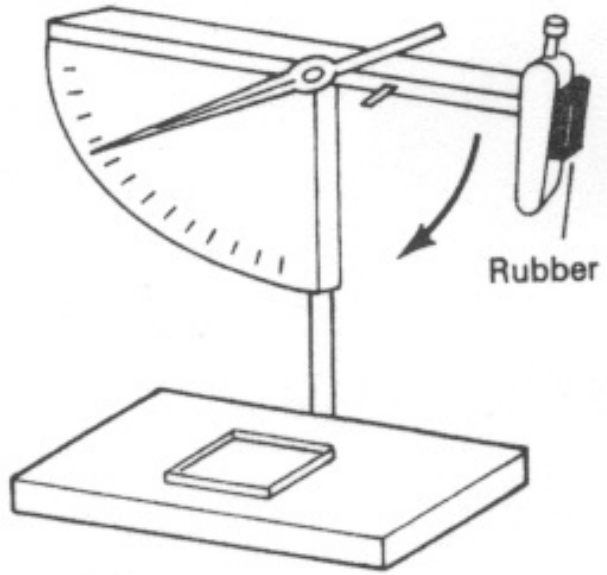
Benefits


Microtexture
Motion
Macrotexture
Friction
Percent Passing, %
100
90
80
70
60
50
40
30
20
10
0
0.075
0.3
1.18
4.75
9.5
12.5
19
Sieve Size, mm


Skid Number
Years in Service

Benefits

- Replace the current time consuming methods
  - Polishing of aggregate coupons for 9 hours.
  - Measure the friction value of the specimens using the British pendulum tester.



AIMS Draft AASHTO Test Procedures

Standard Method of Test for

Determining Aggregate Shape Properties by Means of Digital Image Analysis

AASHTO Designation TP81

1. SCOPE

1.1. This standard covers the measurement of aggregate shape properties using the Digital Image Analysis techniques.

1.2. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Standard Practice for

Determining Aggregate Source Shape Values from Digital Image Analysis Shape Properties

AASHTO Designation PP64

1. SCOPE

1.1. This standard covers the determination of aggregate source and source blend shape characteristics using gradation analysis and shape properties determined by means of digital image analysis.

AIMS Draft AASHTO Specifications

Determining Aggregate Shape Properties for Superpave Volumetric Mix Design

AASHTO Designation: MP zz-zz

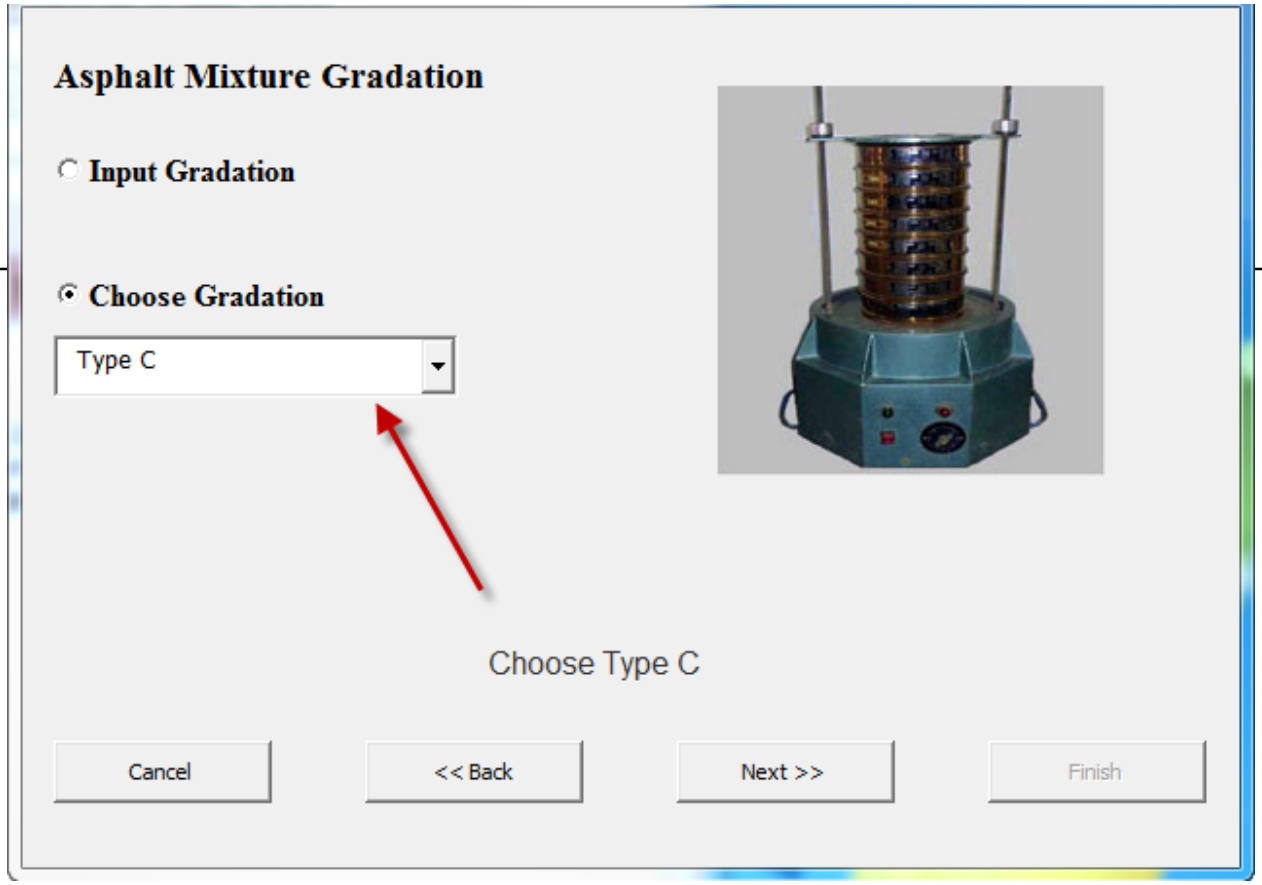
1. SCOPE

1.1. This specification for Superpave volumetric mix design uses aggregate and mixture properties to produce a hot mix asphalt (HMA) job mix formula.

1.2. This standard specifies minimum quality requirements for aggregate shape properties measured using the Aggregate Imaging System (AIMS).

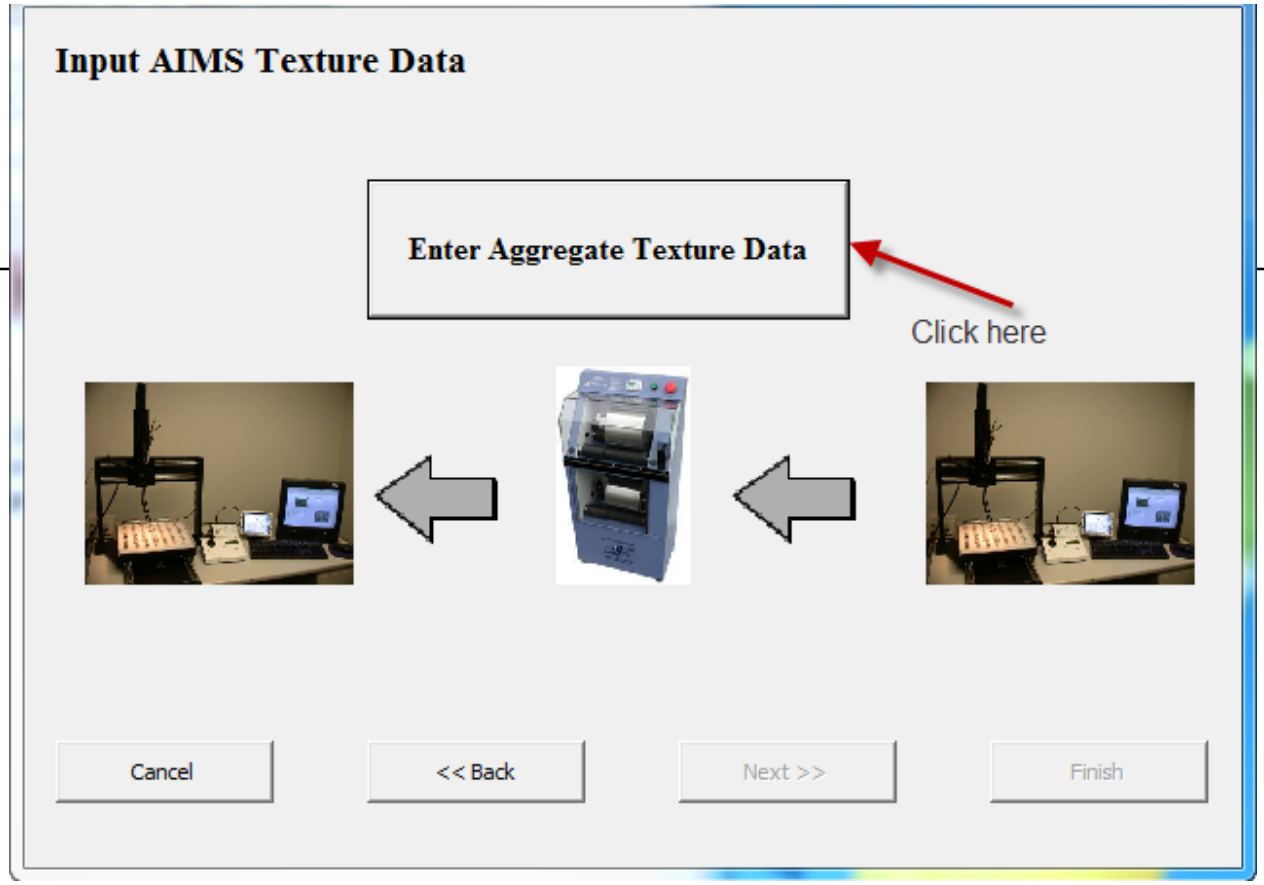
1.3. This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Thank You….



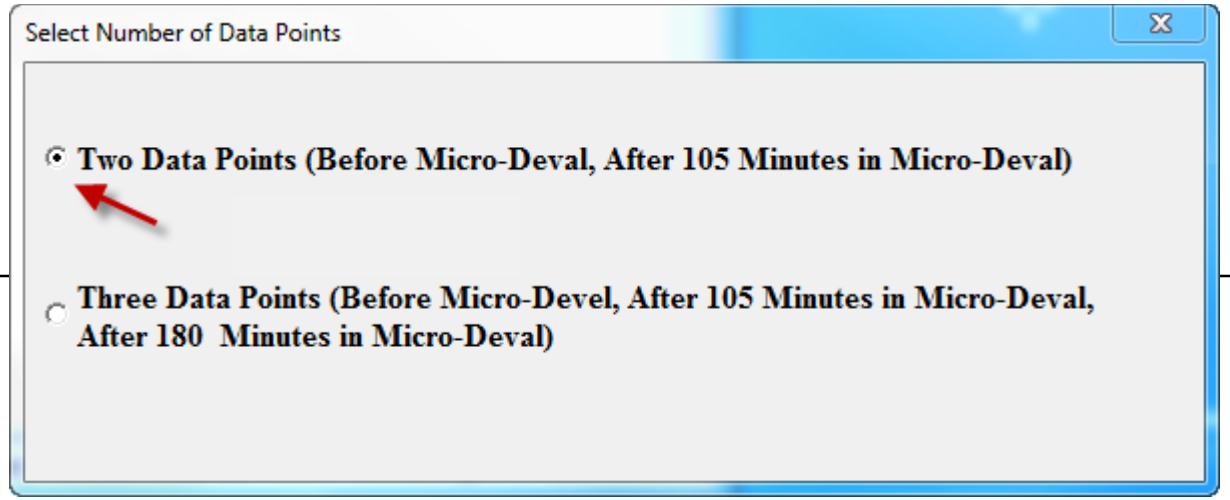
Step 1:

- Input gradation or choose standard TxDOT gradation.
- SAAP will calculate gradation parameters κ and λ.



Step 2:

- Click “Enter Aggregate Texture Data”

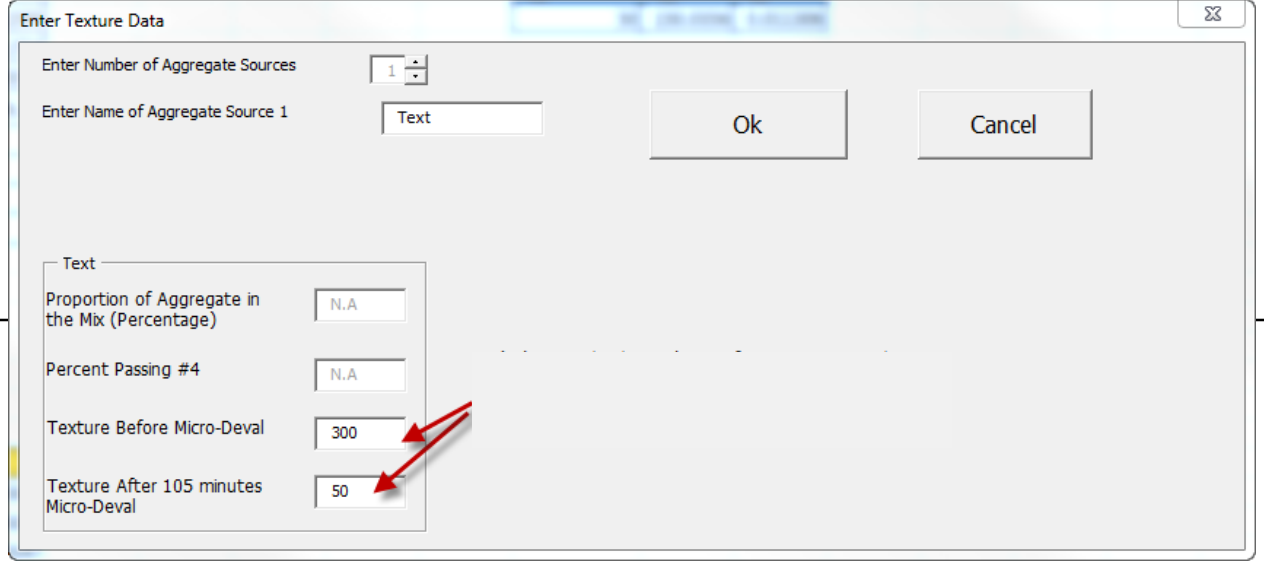


Step 3:

- Choose AIMS texture data at two points:
  - Before Micro-Deval Polishing.
  - After 105 minutes of Micro-Deval Polishing.

Or

- AIMS texture data at three points **(Note: more accurate than two points)**
  - Before Micro-Deval Polishing
  - After 105 minutes of Micro-Deval Polishing.
  - After 180 minutes of Micro-Deval Polishing.



Step 4:

- Choose number of aggregate sources used in preparing the mixture.
- Enter the proportion of each aggregate course in the mix.
- Percent Passing Sieve 4 for each source.
- Enter texture before and after Micro-Devel **(Note: typical texture is from 50 (low) to 600 (high)).**

Example:

Number of Aggregate Sources = 2.

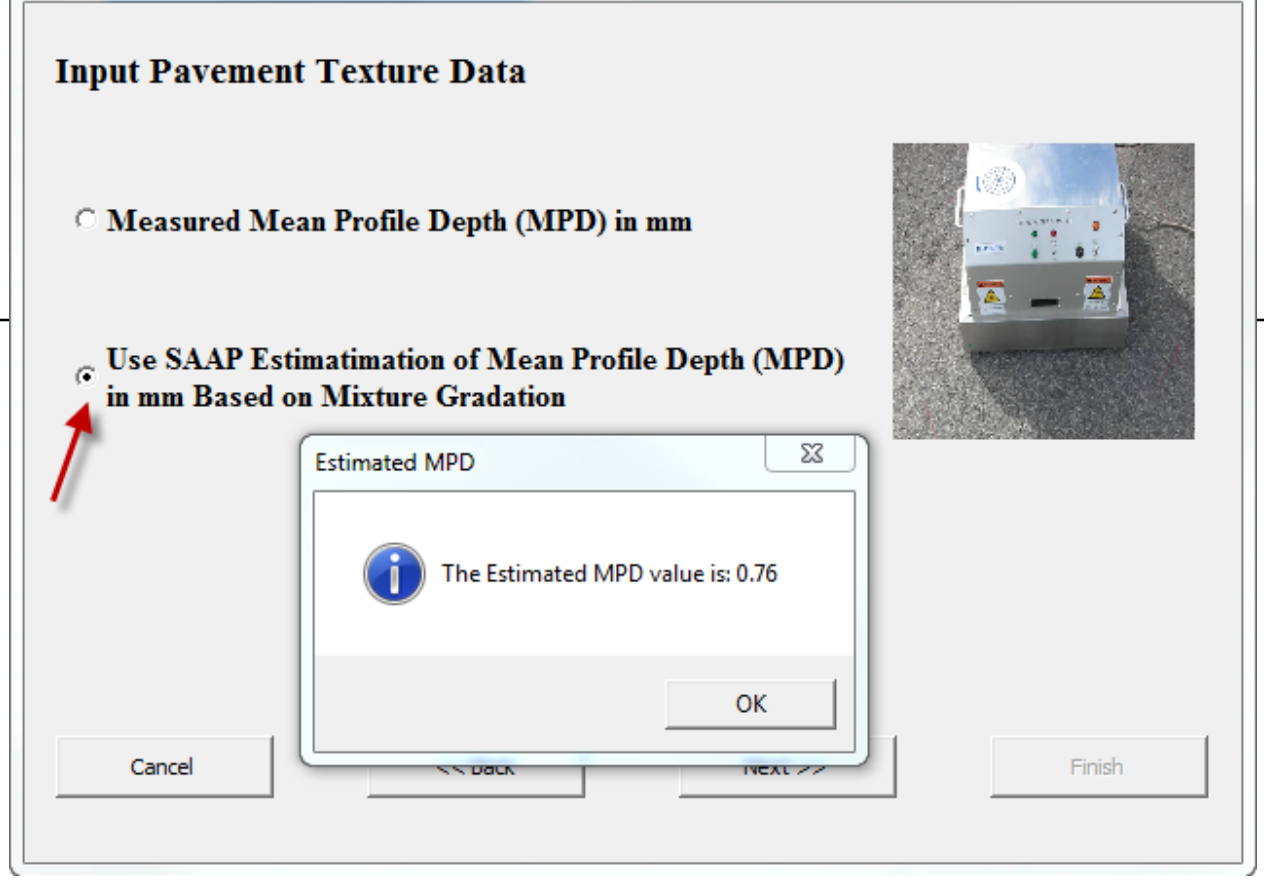
Proportion of Aggregate in the Mix (Aggregate 1) = 30%

Percent Passing Sieve 4 (Aggregate 1) = 90%

Proportion of Aggregate in the Mix (Aggregate 2) = 70%

Percent Passing Sieve 4 (Aggregate 1) = 100%

Material	Agg. #1		Agg. #2		Blend
% Used	30 %		70 %		
U.S. Sieve	% Passing	% Batch	% Passing	% Batch	
3/8 "	100	30	100	70	100
No. 4	90	27	100	70	97
No. 8	30	9	100	70	79
No. 16	7	2.1	88	61.6	63.7
No. 30	3	0.9	47	32.9	33.8
No. 50	1	0.3	32	22.4	22.7
No. 100	0	0	24	16.8	16.8
No. 200	0	0	10	7	7

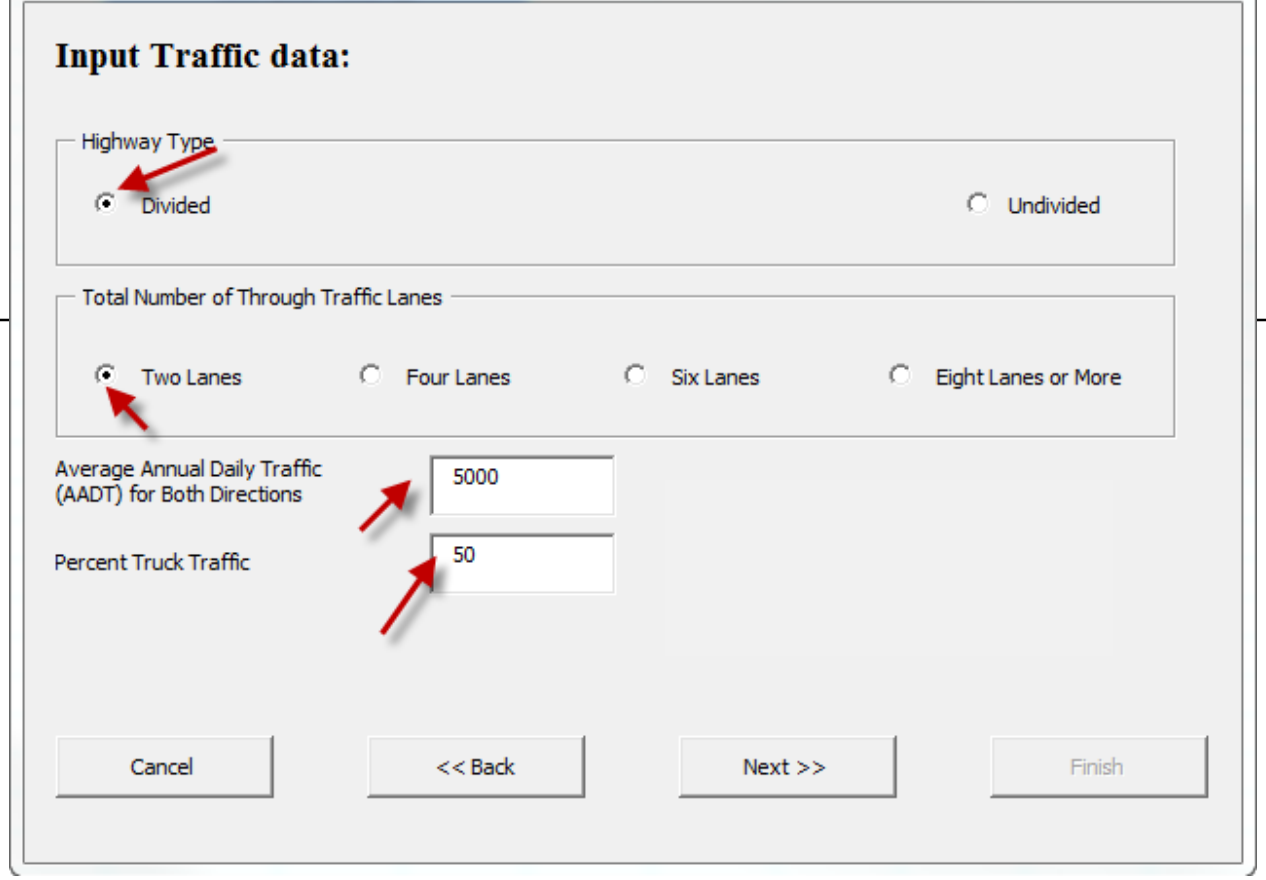


Step 5:

- Enter the MPD of a new road right after construction

Or

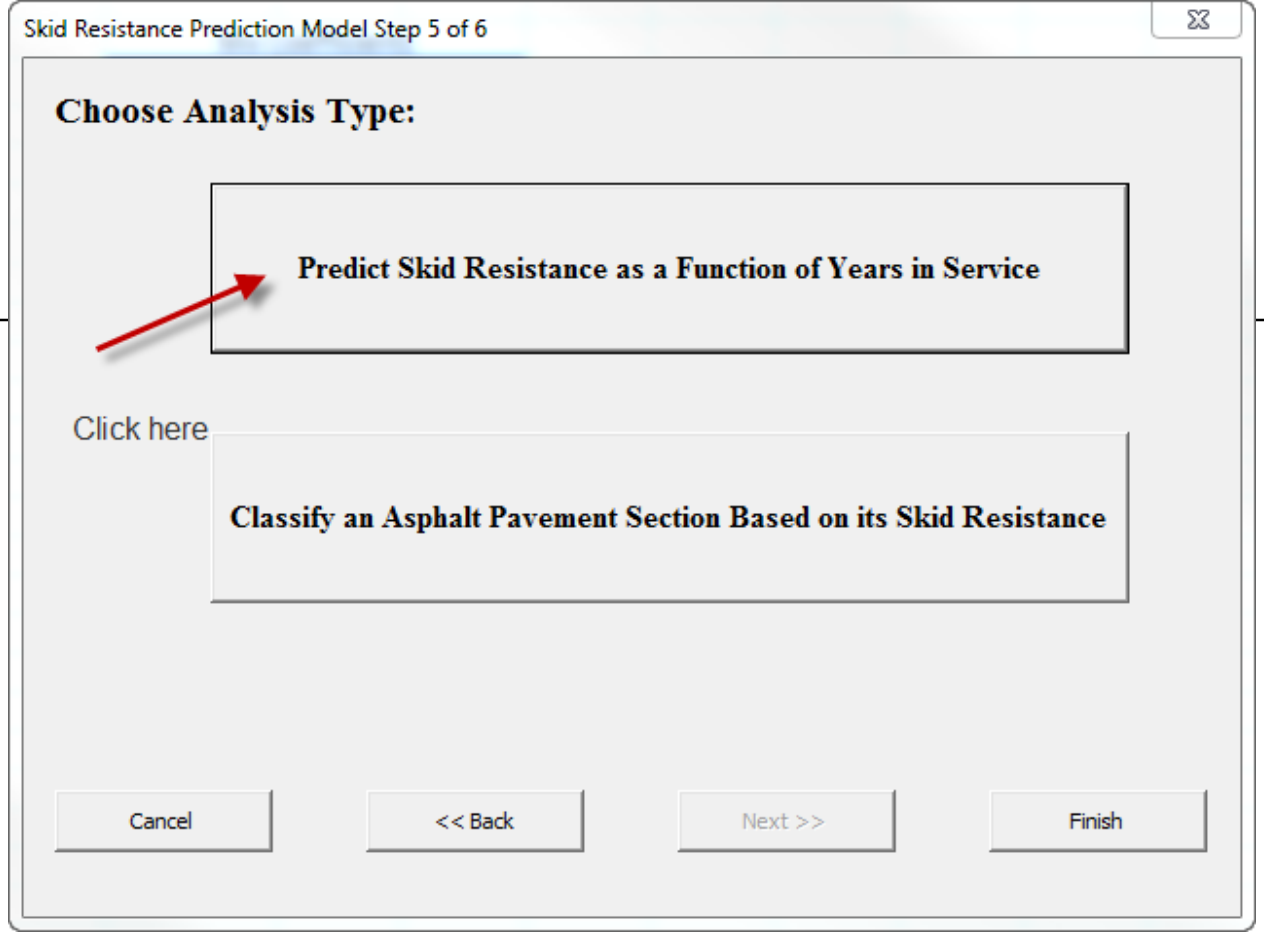
- Use SAAP to estimate MPD based on gradation.



Step 5:

- Enter road information and traffic data.
- SAAP will use this data to calculate Traffic Multiplication Factor (TMF).

$$TMF = \frac{AADT \times 365 \times Years\ in\ Service}{1000}$$

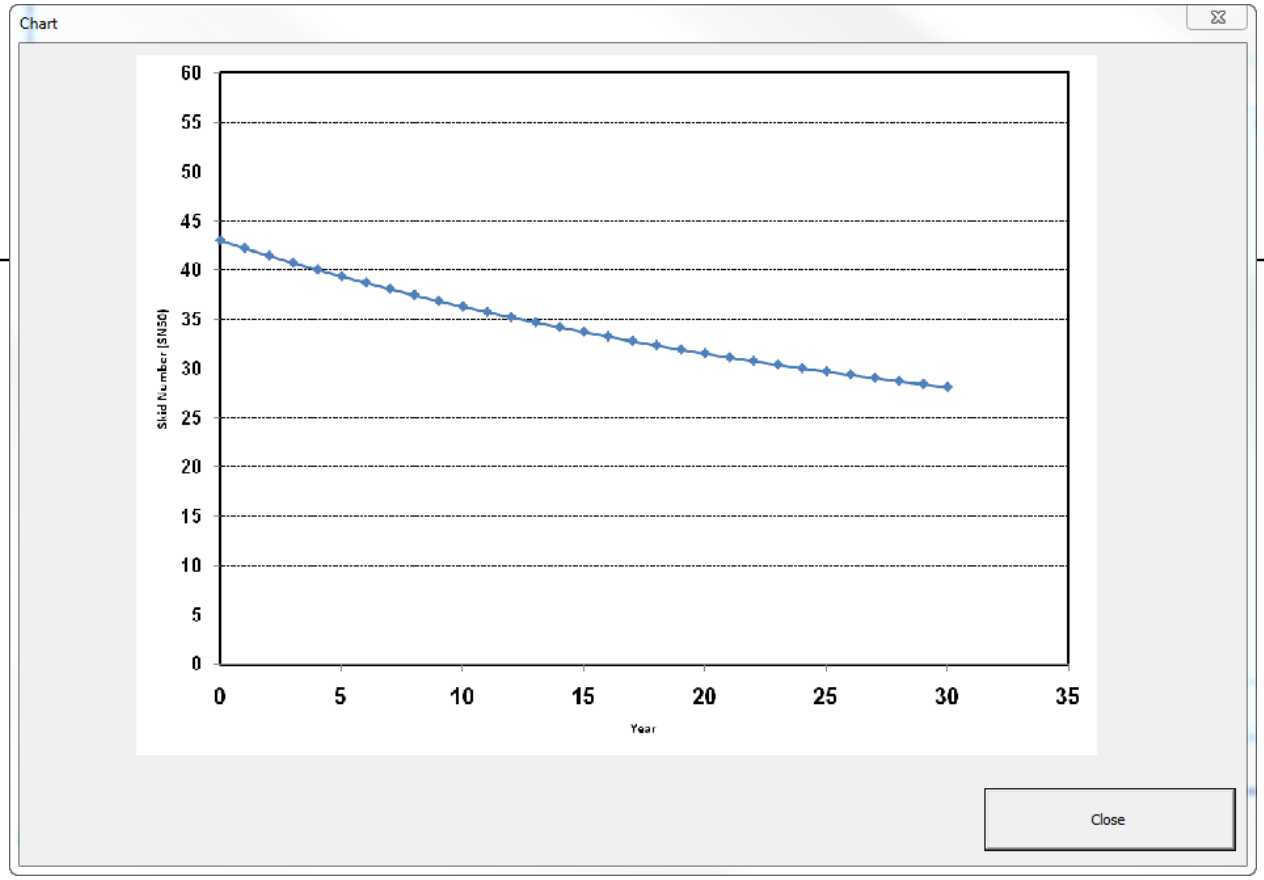


Step 6:

• In this step, you can choose to plot skid resistance (SN) as a function of years in service.

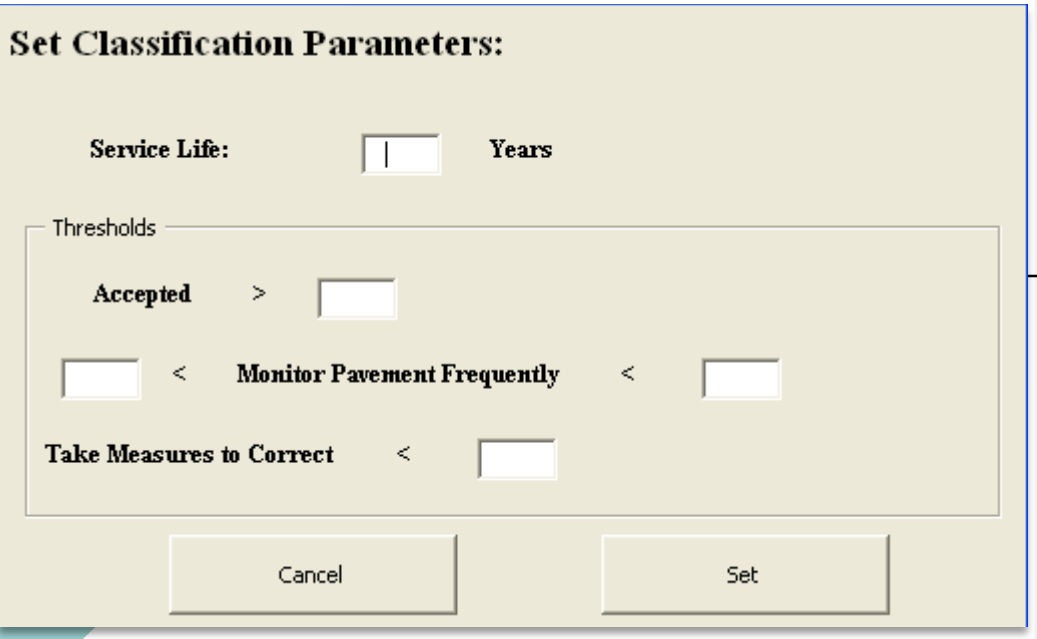
Or

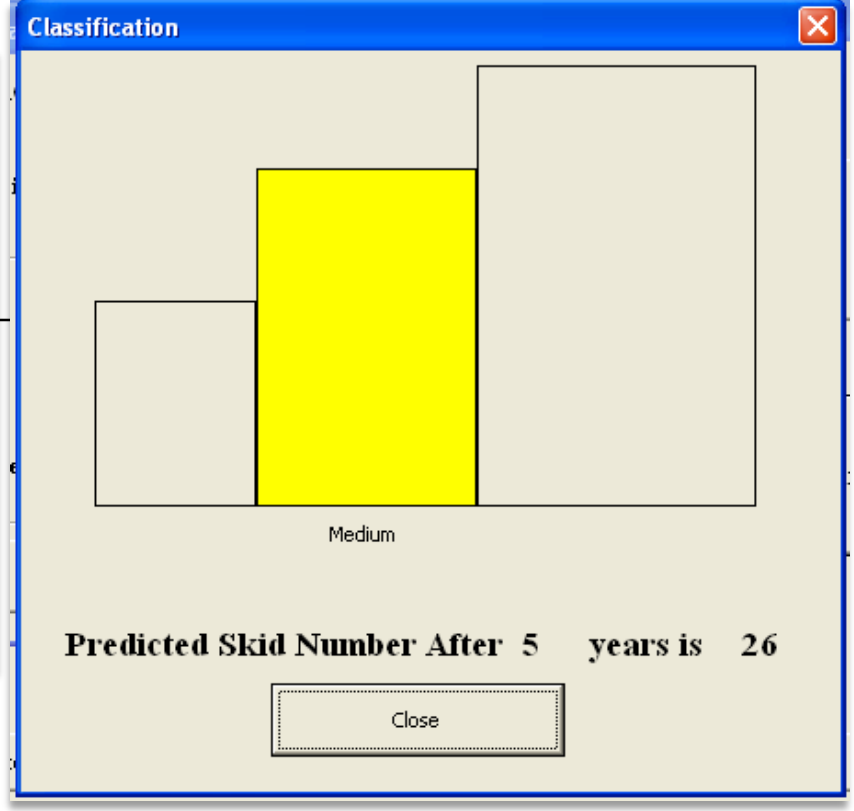
• You can choose to classify the pavement section based on the skid resistance after a certain number of years.



Step 7a:

- If you choose to predict skid resistance, the above chart will be plotted.





Step 7b:

- If you choose to classify asphalt pavement section, you need to enter:
  - Number of years at which the skid number is monitored.
  - Thresholds for skid number for accepted performance, moderate performance (section is monitored), and low performance (surface rehabilitation is required)
- The result of this analysis the is classification the pavement section after a certain number of years as shown in the screen on the right.