Development of a Prediction Model for Skid Resistance of Asphalt Pavements

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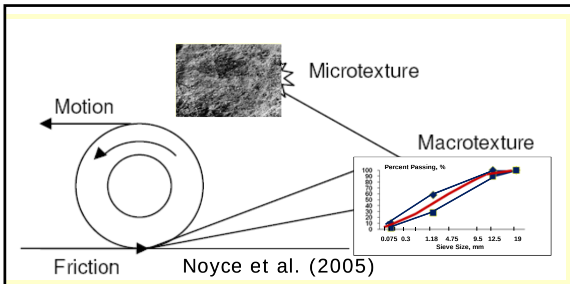


Microtexture is dependent on aggregate petrography and shape characteristics.

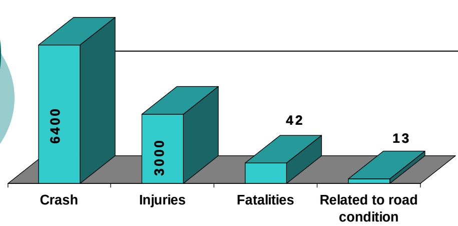
Macrotexture is dependent on aggregate gradation.

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]

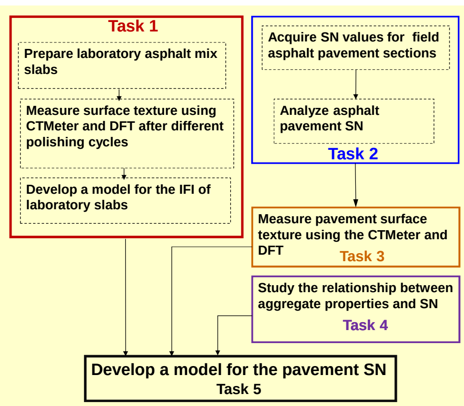
Objectives

- Develop a model for the IFI and SN of asphalt pavements as functions of traffic level, aggregate characteristics, and aggregate gradation.
- Use the models to classify road sections based on their skid resistance.



National Crash Statistics between 1993 and 2003 (thousands)

The cost of crashes is about $231 billion



International Friction Index

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

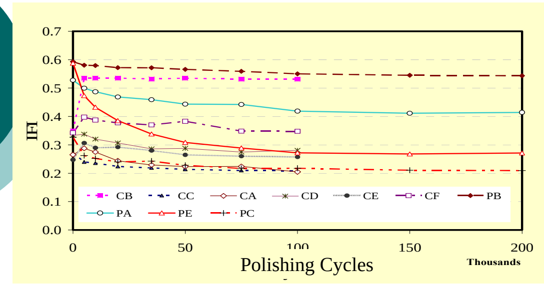
$$S_P = 14.2 + 89.7 MPD$$

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

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

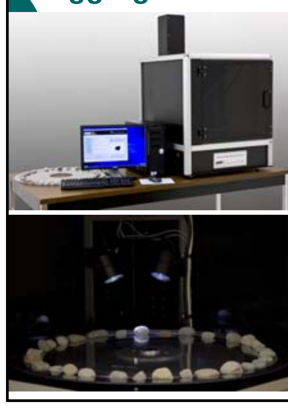
$a_{mix} + b_{mix}$: Initial IFI

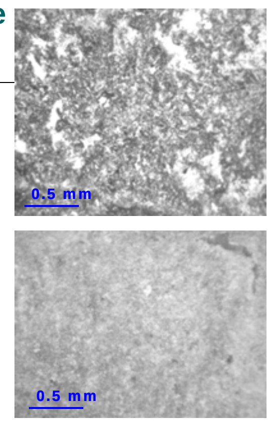
c_{mix}: Rate of IFI Change

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

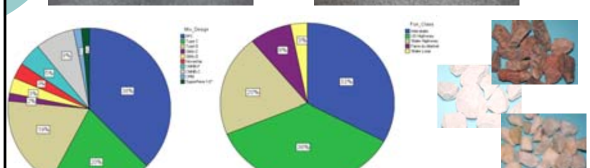
Laboratory Experiments

Aggregate Texture



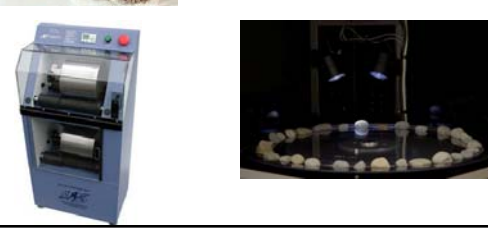


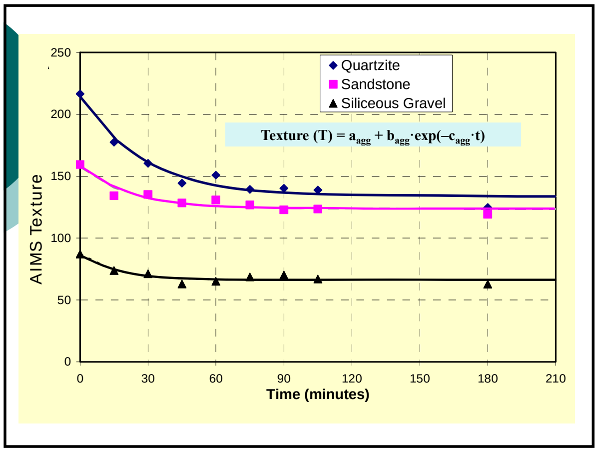
Field Experiments

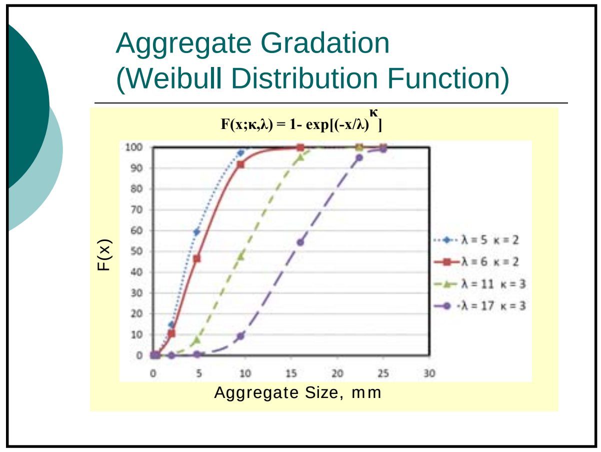


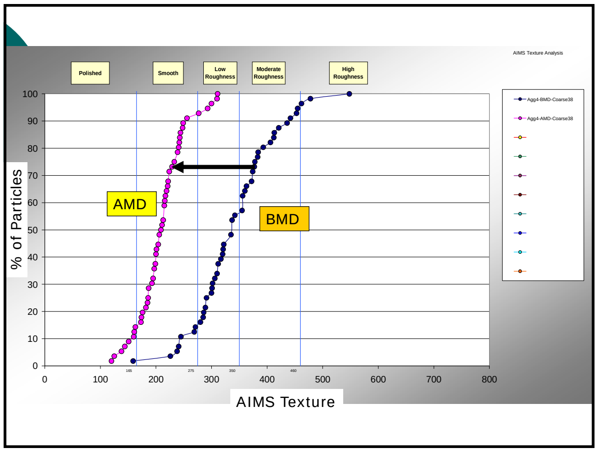
Mix Designs Traffic Levels Aggregate Sources

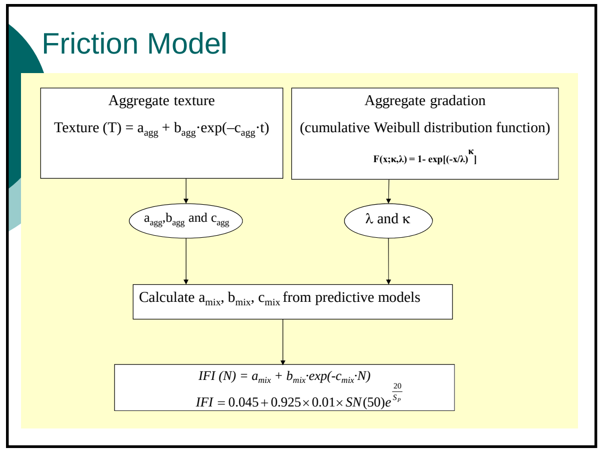
Measure Texture Before and After Micro-Deval Polishing

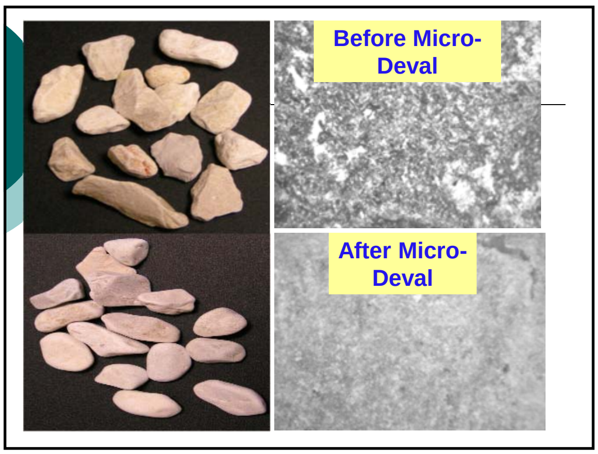


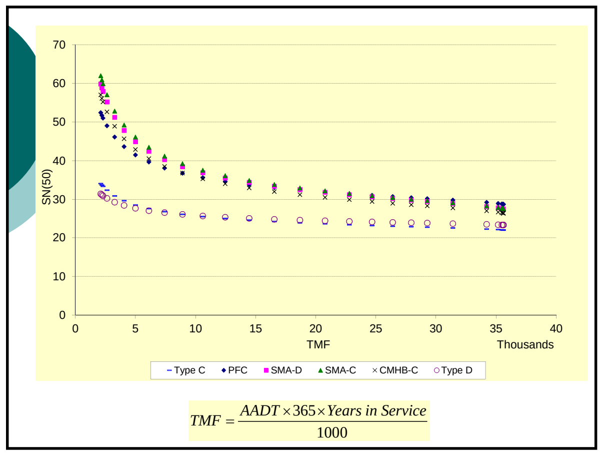

Quartzite
Sandstone
Siliceous Gravel
Texture (T) = $a_{agg} + b_{agg} \cdot exp(-c_{agg} \cdot t)$
AIMS Texture
Time (minutes)


Aggregate Gradation
(Weibull Distribution Function)
$F(x;\kappa,\lambda) = 1 - exp[(-x/\lambda)^{\kappa}]$
F(x)
Aggregate Size, mm
λ = 5 κ = 2
λ = 6 κ = 2
λ = 11 κ = 3
λ = 17 κ = 3


Polished
Smooth
Low Roughness
Moderate Roughness
High Roughness
AMD
BMD
% of Particles
AIMS Texture


Friction Model
Aggregate texture
Texture (T) = $a_{agg} + b_{agg} \cdot exp(-c_{agg} \cdot t)$
Aggregate gradation
(cumulative Weibull distribution function)
$F(x;\kappa,\lambda) = 1 - exp[(-x/\lambda)^{\kappa}]$
a_{agg}, b_{agg} and c_{agg}
λ and κ
Calculate a_{mix}, b_{mix}, c_{mix} from predictive models
$IFI\ (N) = a_{mix} + b_{mix} \cdot exp(-c_{mix} \cdot N)$
$IFI = 0.045 + 0.925 \times 0.01 \times SN(50) e^{\frac{20}{S_P}}$


Before Micro-Deval
After Micro-Deval

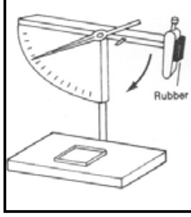

SN(50)
TMF
Thousands
Type C
PFC
SMA-D
SMA-C
CMHB-C
Type D
$TMF = \frac{AADT \times 365 \times Years\ in\ Service}{1000}$

Skid Analysis of Asphalt Pavements (SAAP ©)

- An Excel® based software was developed for prediction of field pavement skid resistance and aggregate classification

Benefits

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



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

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

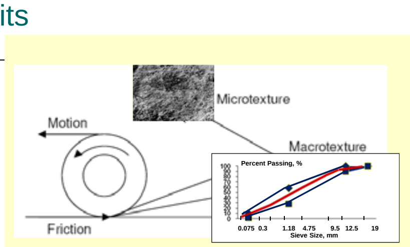
Determining Aggregate Source Shape Values from Digital Image Analysis Shape Properties

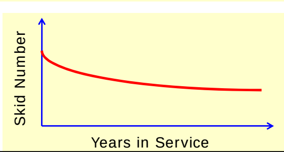
AASHTO Designation PP64

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.

Benefits





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.

Resources

- Masad, E., Rezaei, A., Chowdhury, A., and Freeman, T. (2010). *Field Evaluation of Asphalt Mixture Skid Resistance and Its Relationship to Aggregate Characteristics*, Report Number 0-5627-2, Texas Transportation Institute, Texas A&M University, College Station, TX.
- Masad, E., Freeman, T., Rezaei, A., and Chowdhury, A. (2010). *Aggregate Resistance to Polishing and Its Relationship to Skid Resistance*, Report Number 0-5627-S, Texas Transportation Institute, Texas A&M University, College Station, TX.
- Masad, E., Rezaei, A., Chowdhury, A., and Harris, J. P. (2010). *Predicting Asphalt Mixture Skid Resistance based on Aggregate Characteristics*, Report Number 0-5627-1, Texas Transportation Institute, Texas A&M University, College Station, TX.

http://tti.tamu.edu/publications/

Step 3:
- Choose AIMS texture data at two points:
  - Before Micro-Deval Polishing.
  - After 105 minutes of Micro-Deval Polishing.

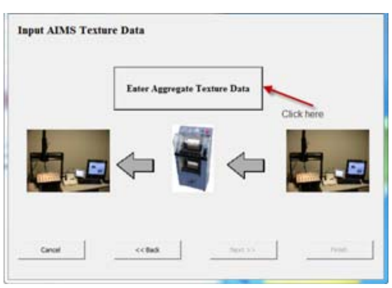
Or
- AIMS texture data at three points **(Note: more accurate than two points)**
  - Before Micro-Deval Polishing
  - After 105 minutes of Micro-Deval Polishing.
  - After 180 minutes of Micro-Deval Polishing.

Step 1:
- Input gradation or choose standard TxDOT gradation.
- SAAP will calculate gradation parameters κ and λ.

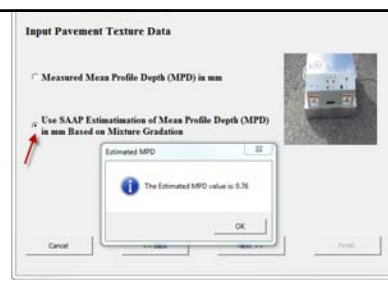
Step 4:
- Choose number of aggregate sources used in preparing the mixture.
- Enter the proportion of each aggregate course in the mix.
- Percent Passing Sieve 4 for each source.
- Enter texture before and after Micro-Devel **(Note: typical texture is from 50 (low) to 600 (high)).**

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 2:
- Click "Enter Aggregate Texture Data"



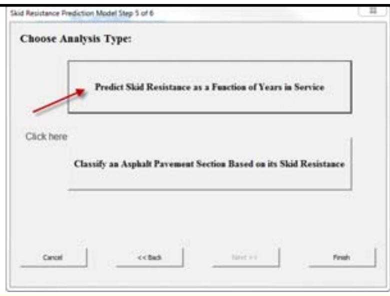
Step 5:
- Enter the MPD of a new road right after construction

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).

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

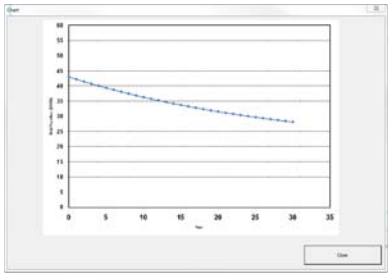


Step 6:

- 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.