PAVEMENT TEXTURE AND FRICTION

Presentation to:

SWIFT

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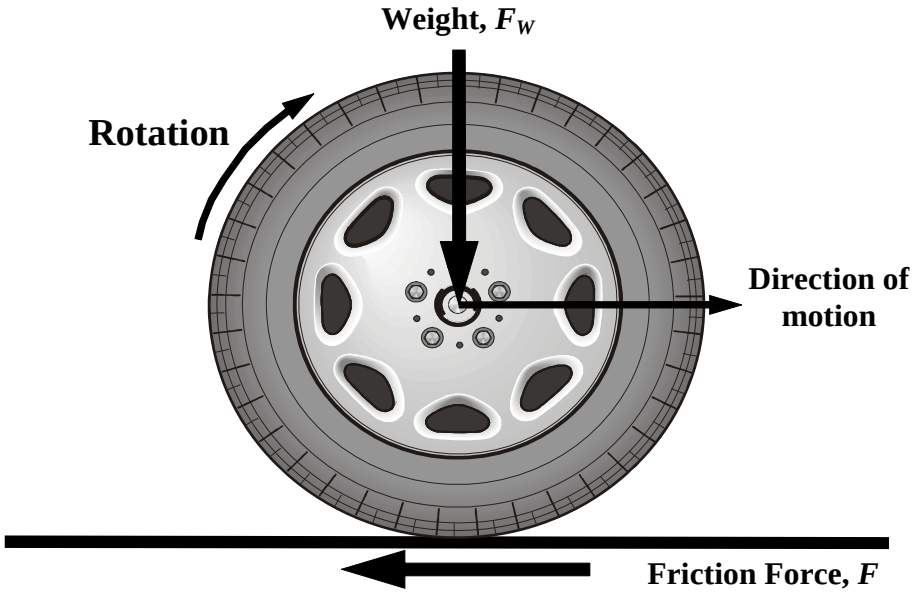
An Employee-Owned Company

Basics of Pavement Friction

Friction - force that resists the relative motion between a tire and pavement surface

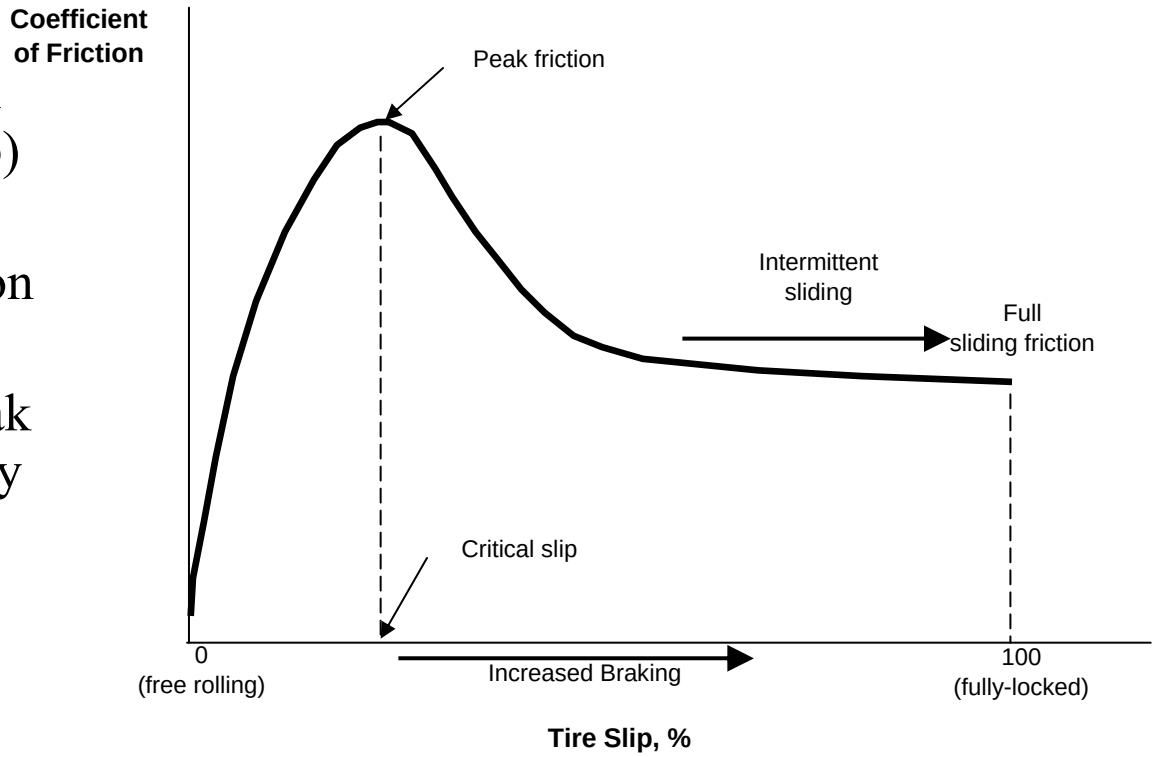


$$\mu = \frac{F}{F_W}$$

Pavement Friction versus Tire Slip

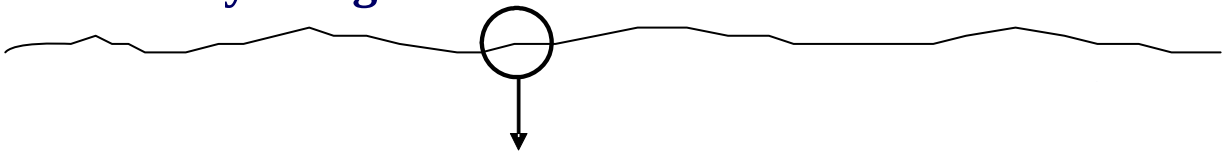
(Henry, 2000)

- Friction increases rapidly with increasing slip
- Peak value between 10 and 20 percent slip (critical slip)
- Friction decreases to coefficient of sliding friction at 100 percent slip
- Difference between the peak and sliding coefficients may equal 50 percent of sliding value
- This disparity is much greater on wet pavements
- Anti-locking brake system (ABS) uses this principle

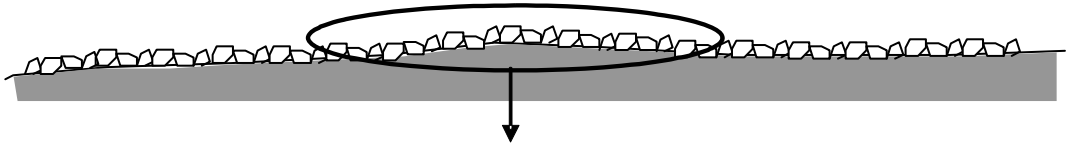


Levels of Surface Texture

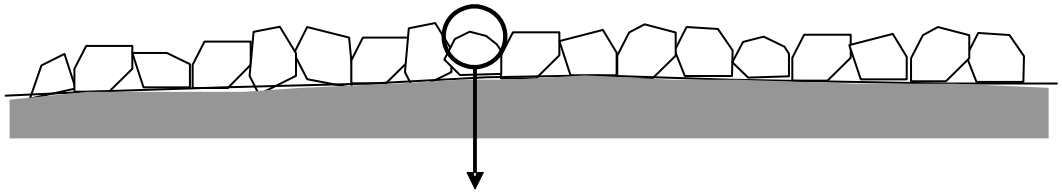
Runway Roughness — **λ > 20 in.**



Mega-texture — **λ = 2 to 20 in.; A = 0.005 to 2 in.**



Macro-texture — **λ = 0.02 in.; A = 0.04 to 20 mils**



Micro-texture

λ = Wave Length
A = Amplitude

Reference Length

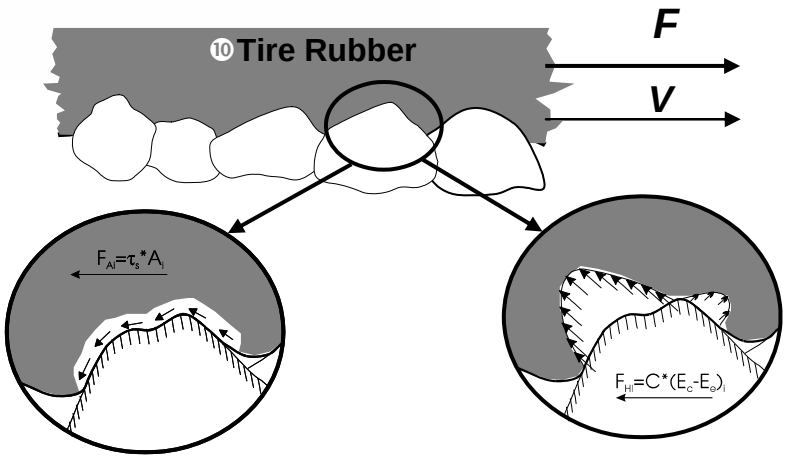
Short Stretch of Runway

Tire

Pavement – Tire Contact Area

Single Aggregate Particle

Components of Friction



Adhesion

Function of micro-texture

$$F_{Ai}=\tau_s * A_i$$

Hysteresis

Function of macro-texture

$$F_{Hi}=C*(E_c-E_e)_i$$

Total Braking Force, F, equals:

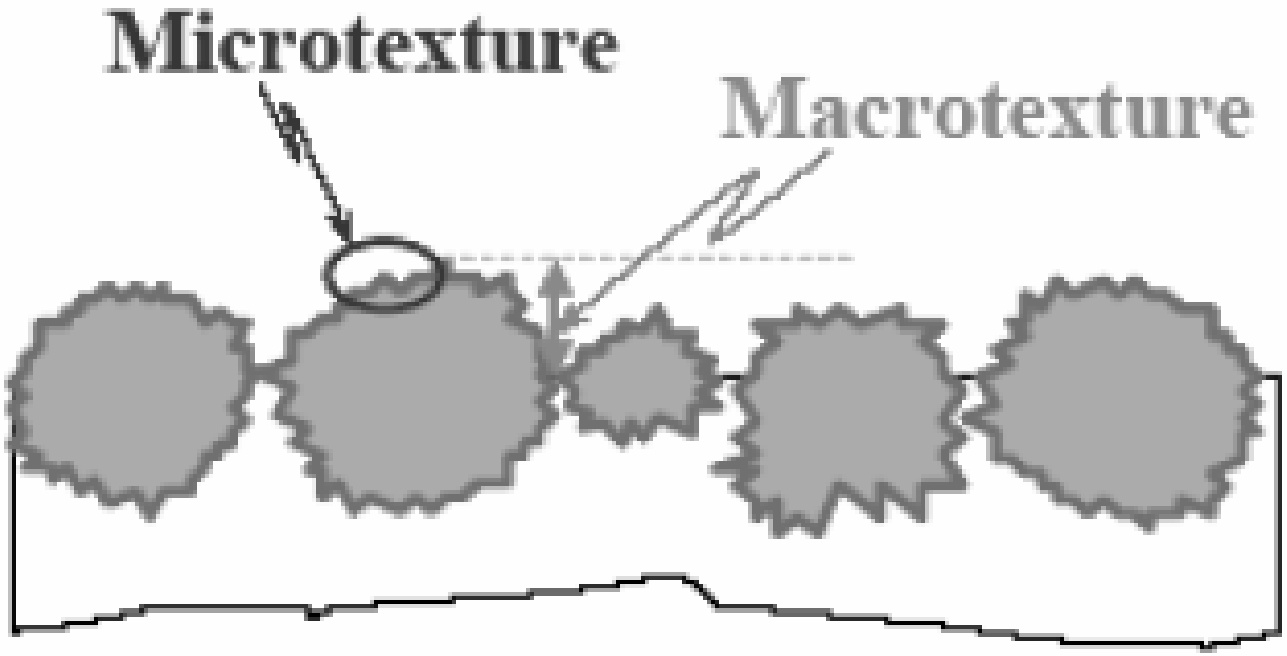
$$F = F_A + F_H$$

Components of Friction

- Hysteresis is:
  - force generated within the deflected, visco-elastic tire tread
  - a function of speed
  - mainly related to macro-texture
- Adhesion is related to micro-texture
- For wet pavements
  - adhesion drops off with increased speed
  - hysteresis increases with speed
  - above 56 mi/hr (90 km/hr) macro-texture accounts for over 90 percent of friction
- Winter friction on snow and ice is function of contaminant

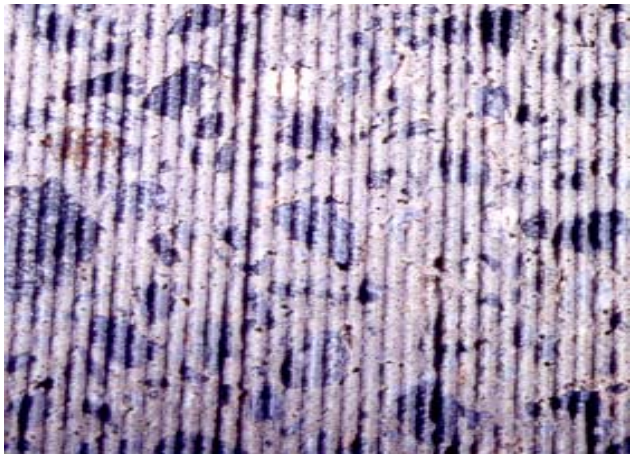
Micro and Macro Textures

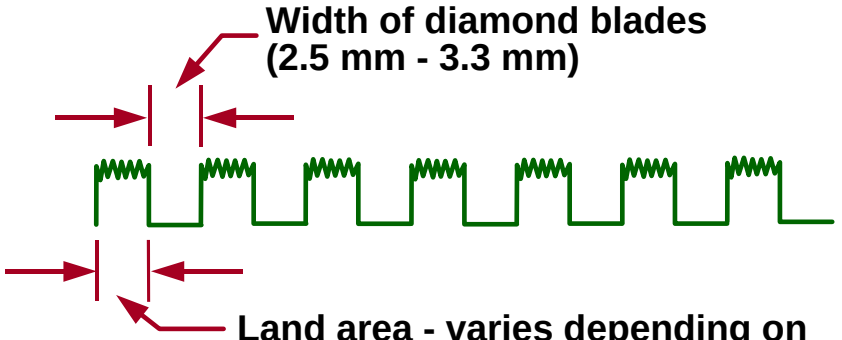
- Micro-texture provides pavement friction at low speeds
- Macro-texture:
  - reduces potential for hydroplaning
  - provides friction by hysteresis at high speeds



Surface Texturing (PCC pavements)

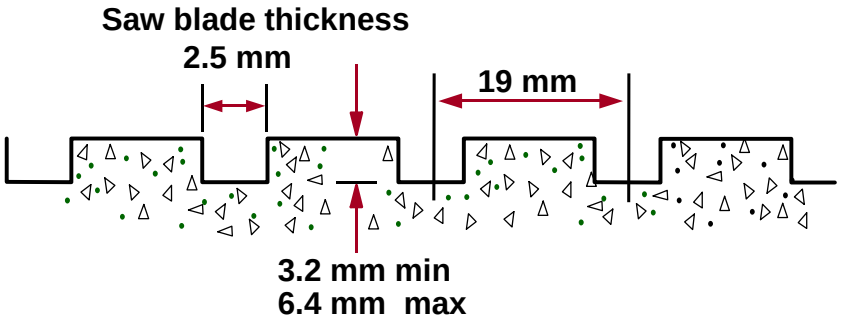
- Grinding





➔ 2.0 mm typical for hard aggregate
➔ 2.8 mm in typical for soft aggregate

- Grooving



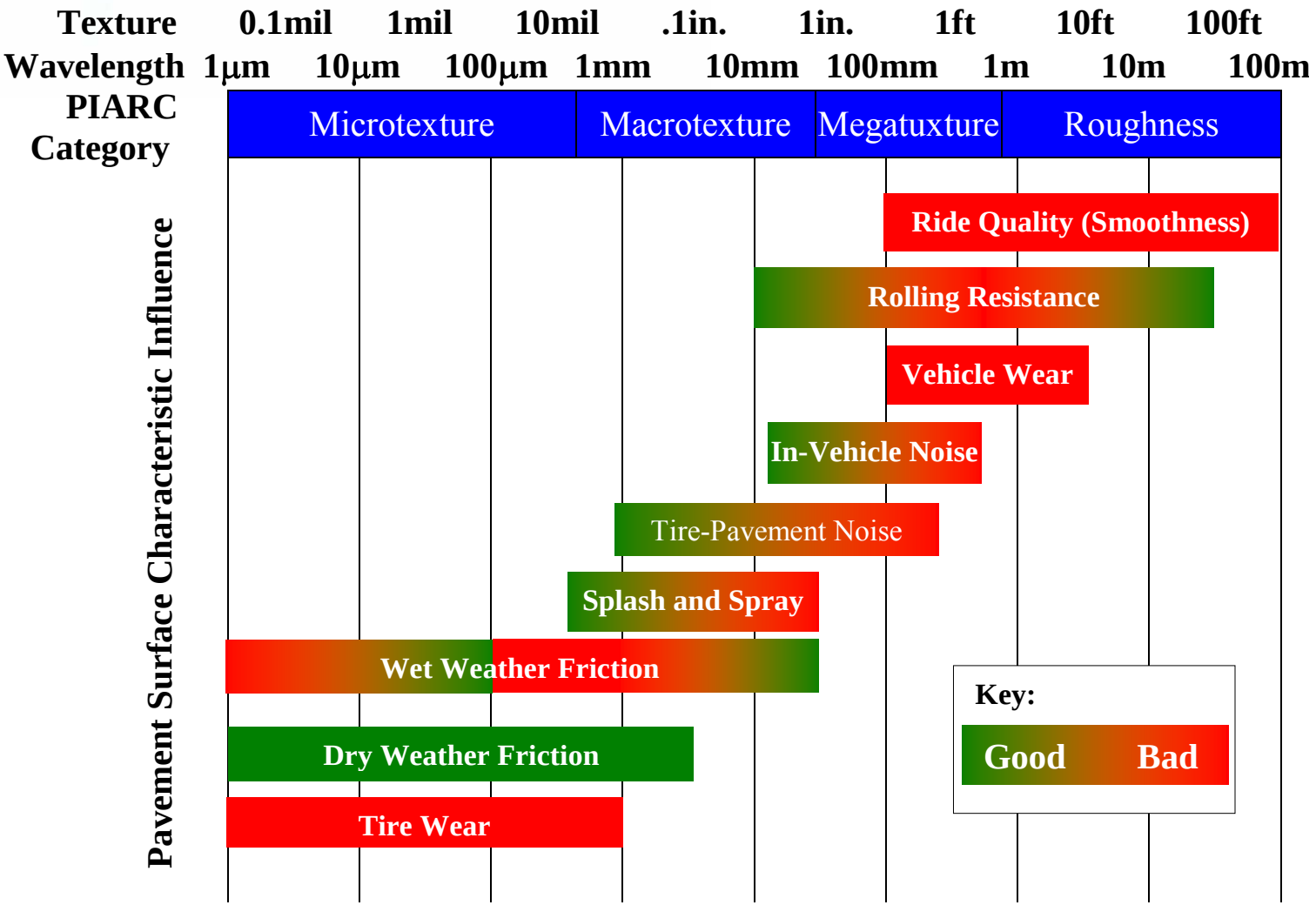
Surface Texturing (AC pavements)

- Grooved AC

- Porous Friction

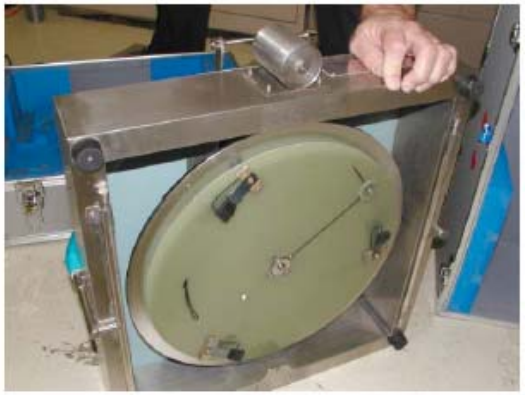
- SMA

PIARC Texture Classification



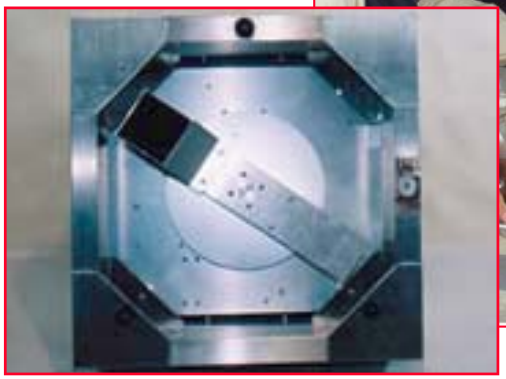
Measurement of Texture and Friction (highways)

- Micro-texture
  - ASTM E 274 Locked Wheel
  - ASTM E 524 (smooth tire)
  - ASTM E 501 (ribbed tire)
  - Smooth tire recommended for friction measurement
  - Spot measurements are made on highways since tire wear would be a problem for continuous runs
  - ASTM E 1911 (Dynamic Friction Tester)
  - ASTM E 303 (British Pendulum Tester)



Measurement of Texture and Friction
(highways)

- Macro-Texture
  - ASTM E 2157 Circular Texture Meter
  - ASTM E 965 Sand Patch
  - ASTM E 2389 Outflow Meter



Measurement of Texture and Friction

- Macro-Texture
  - High-speed laser based devices

FHWA ROSANv

High-Speed Inertial Profilers

Measurement of Texture and Friction (Runways)

- Microtexture (friction)
  - ASTM E 274 Fixed slip (GripTester, Mu-Meter)
  - ASTM E 1859 Variable slip (French IMAG; Norwegian Norsemeter RUNAR)
  - Runways tested with continuous measurements since tire wear is not a problem for one or two miles

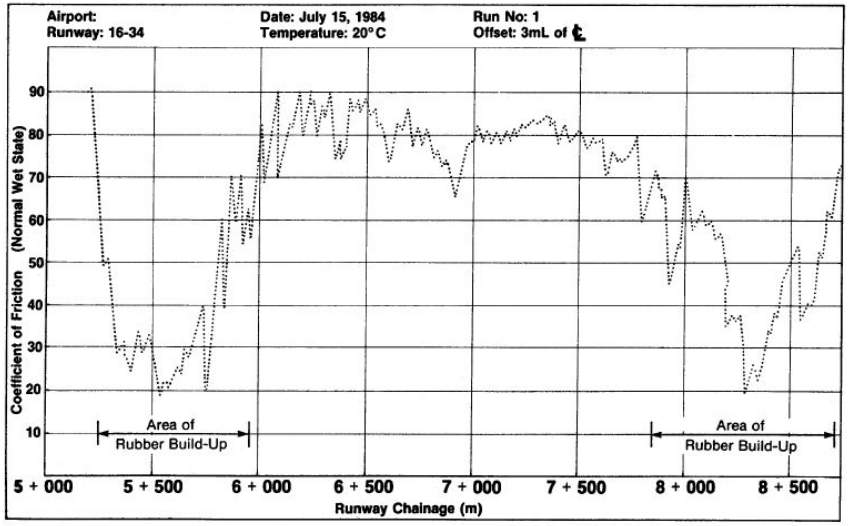
- Macro-texture
  - ASTM E 2157 (Circular Texture Meter)
  - ASTM E 965 (Sand Patch)

Department of National Defence Friction Testing

- Friction measurements with Grip Tester
- Continuous measurements for length of runway
- Measurements at 65 km/hr (40 mph) with water depth of 0.25 mm

Transport Canada Friction Testing

- Continuous Friction Measuring Equipment (CFME)
  - Surface Friction Tester (SFT)
  - Benchmark for standard runway coefficient of friction
- Spot Measuring Devices (Decelerometers)
  - deceleration rate of vehicle braked to four wheel lock up
  - friction values available to pilots
  - surface conditions of snow, ice or compacted snow made available to pilots as CRFI (Canadian Runway Friction Index)



Runway Coefficient of Friction Profile Trace

International Friction Index (IFI)

- Developed by PIARC
- Based on ASTM E 1960

$$F(S) = F(60) \times e^{\left(\frac{60-S}{S_P}\right)}$$

$$S_P = 89.7 * MPD + 14.2$$

$F(S)$	= adjusted value of friction for a slip speed of S
$F(60)$	= measured friction value at slip speed of 60 km/hr
S_P	= speed number, km/hr
S	= measurement speed, km/hr
MPD	= mean profile depth (macro-texture), mm

- Sp from CT Meter or high-speed profilers (MPD) or relationships between MPD and MTD from Sand Patch or Outflow Meter
- F(S) is friction value from tests at slip speed S

Guide for Pavement Friction (for highways)

- NCHRP Project 1-43
  - The "Guide for Pavement Friction" developed for adoption by AASHTO
  - Outlines a friction management and design program for highway pavement surfaces
- Guide provides
  - information on aggregates and mixture types for long-lasting, high-quality friction surfaces
  - information on friction-testing methods, equipment, and indices
  - methods for establishing investigatory and intervention friction levels

NCHRP 1-43

Guide for Pavement Friction (for highways)

- Pavement Friction Basics
  - Importance of Pavement Friction
  - Pavement Friction Principles
- Pavement Friction Management
  - Developing Pavement Friction Management Policies
  - Establishing the Pavement Friction Management Program
- Pavement Friction Design
  - Developing Friction Design Policies
  - Project-level Design Guidelines

NCHRP 1-43

Friction Management (for highways)

Systematic approach to measuring/monitoring friction and crash rates, identifying surfaces in need of remediation, and planning/budgeting for treatments and reconstruction

- Key Components
  - Network definition
  - Network-level data collection
  - Network-level data analysis
  - Adequate monitoring of friction and crashes
  - Detailed site investigation
  - Selection and prioritization of short and long term restoration treatments

NCHRP 1-43

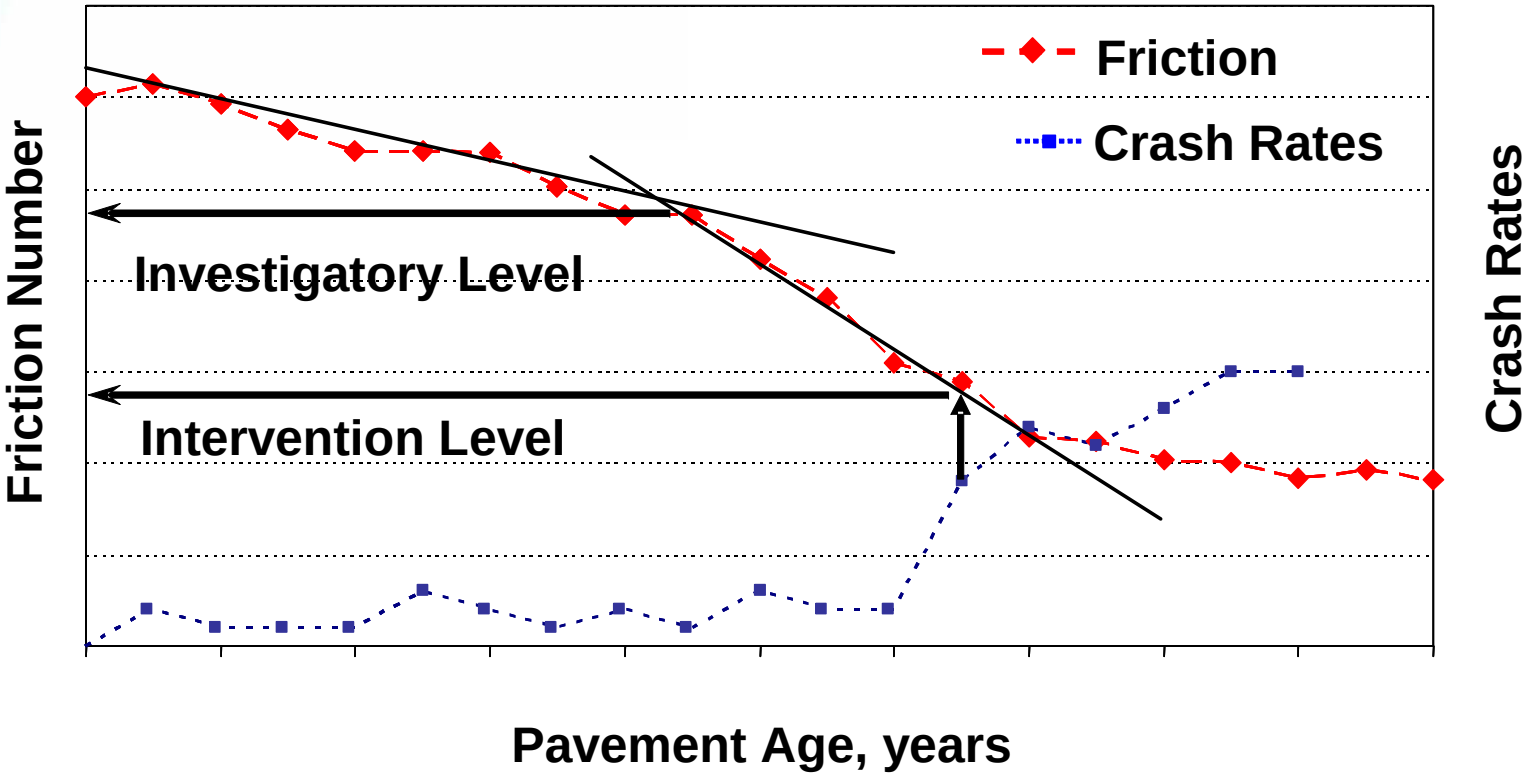
Friction Management (for highways)

- Two threshold levels of friction:
  - ***Investigatory*** – calls for detailed site investigation to determine need for remedial action; actions are:
    - Erect warning signs
    - More frequent testing
    - Further analysis of friction and crash data
    - Short-term restoration treatment
  - ***Intervention*** – Remedial action required; actions are:
    - Immediate restoration treatment
    - Erect warning signs
    - Program treatment in maintenance or construction work plan

NCHRP 1-43

Defining Levels

NCHRP 1-43



- Plot friction deterioration curve (for a specific friction demand category)
- Plot corresponding crash rates curve
- Set intervention level at significant increase in crash rates

Network-Level Friction Design

- Aggregate testing
  - Recommended tests that help characterize aggregate frictional (micro-texture) properties
  - Basic test criteria for discerning friction quality of aggregates
- Asphalt mix types and concrete texturing methods
  - Typical macro-texture depths
- Friction design categories
  - Matching aggregate sources and mix type/texturing techniques

NCHRP 1-43

Aggregate Properties

- Coarse aggregate controls the friction properties of asphalt mixes
- Fine aggregate controls the frictional properties of concrete mixes
- Mineralogical and Petrographic Properties
  - Aggregate composition/structure and mineral hardness
- Physical and Geometrical properties
  - Angularity, shape, and texture
- Mechanical Properties
  - Abrasion/wear resistance
  - Polish characteristics
  - Durability Properties
  - Soundness

NCHRP 1-43

Aggregate Mineralogy

- Hard, strongly bonded, interlocking mineral crystals (coarse grains) embedded in a matrix of softer minerals
- Differences in grain size and hardness constantly renew abrasive surface because of differential wear rates
- Mohs scratch hardness test for determining mineral hardness
  - Mohs hardness > 6 - resists wear
  - Mohs hardness of 3 to 6 - resists polishing but wears quickly

Project Level Friction Design

- Project level design guidelines
  - Step 1 – Determine design friction level
  - Step 2 – Select aggregates (micro-texture)
  - Step 3 – Establish surface mix types and/or texturing techniques (macro-texture)
    - Use IFI equation to identify combination(s) of aggregate and mix type/texturing technique that satisfy design friction level
  - Step 4 – Develop construction specifications
  - Step 5 – Formulate design strategies

NCHRP 1-43

Transport Canada - Runway Friction Standards

Corrective Action	Runway Average COF less than
Shall Be Planned (Investigatory)	0.60
Shall Be Taken (Intervention)	0.50
Corrective Action	**Runway 100 Metre Section Avg. COF less than**
Shall Be Planned (Investigatory)	0.40
Shall Be Taken (Intervention)	0.30

Department of National Defence -
Runway Friction Standards

GripTester Friction Value	Action
< 0.41 to < 0.60	Remedial work scheduled (Investigatory)
< 0.40	Remedial work required (Intervention)

Recommended Textures for Friction

- PCC Surfaces
  1. Transverse grooved (with quality aggregate)
  2. Transverse or skewed tining
  3. Diamond grinding
  4. Longitudinal tining

- AC Surfaces
  1. Aggregate type dictates texture/friction
  2. Open-textured friction course (PFC)
  3. Gap-graded mixes (SMA, NovaChip)
  4. Grooving for Macrotexture

For more information:

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