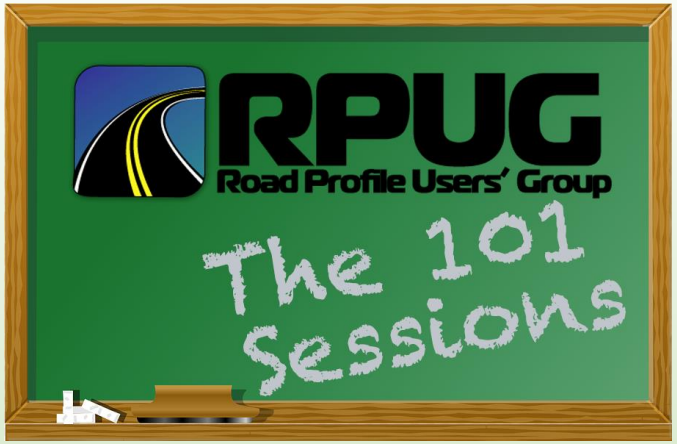


2020

WEBINAR SERIES

RPUG
Road Profile Users' Group

Tire/Pavement Friction & Grip 101

Brian L. Schleppi, OH DOT

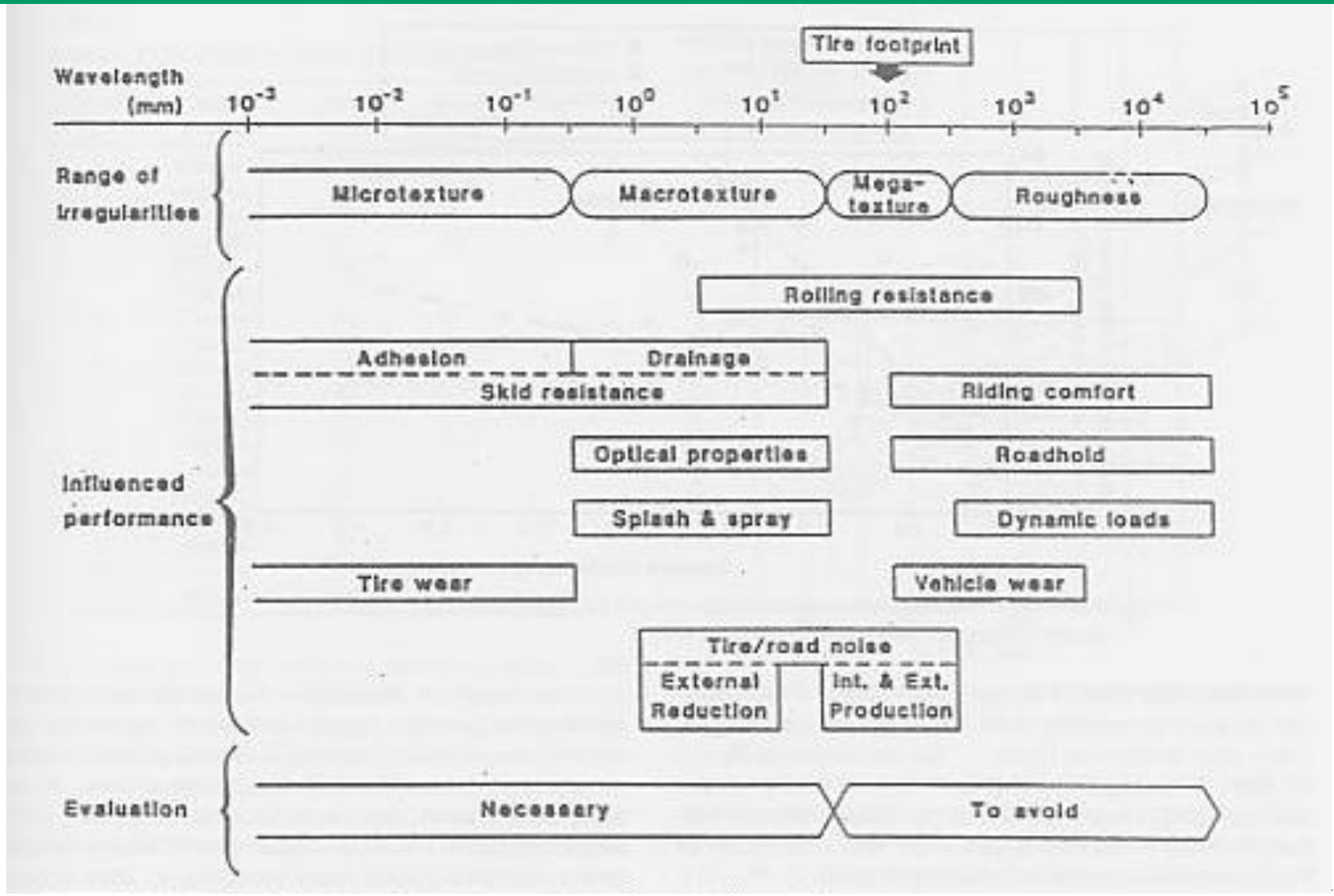
OVERVIEW PART 1

- Where and How does friction fit in with respect to the other highway surface characteristics?
- Science & Theory of Tire Pavement Friction
- What does the highway surface contribute to friction?

BACKGROUND – FRICTION AND OTHER SURFACE CHARACTERISTICS

- Surface Smoothness – Rideability (International Roughness Index [IRI])
- Tire/Pavement Noise
- Friction/Tire Grip (emphasis on wet friction or grip)
- Vehicle Rolling Resistance
- Splash and Spray & Surface Drainage

BACKGROUND – FRICTION AND OTHER SURFACE CHARACTERISTICS



Ayton, 1991
Influence of Surface Characteristics on Vehicle Performance

BACKGROUND – FRICTION AND OTHER SURFACE CHARACTERISTICS

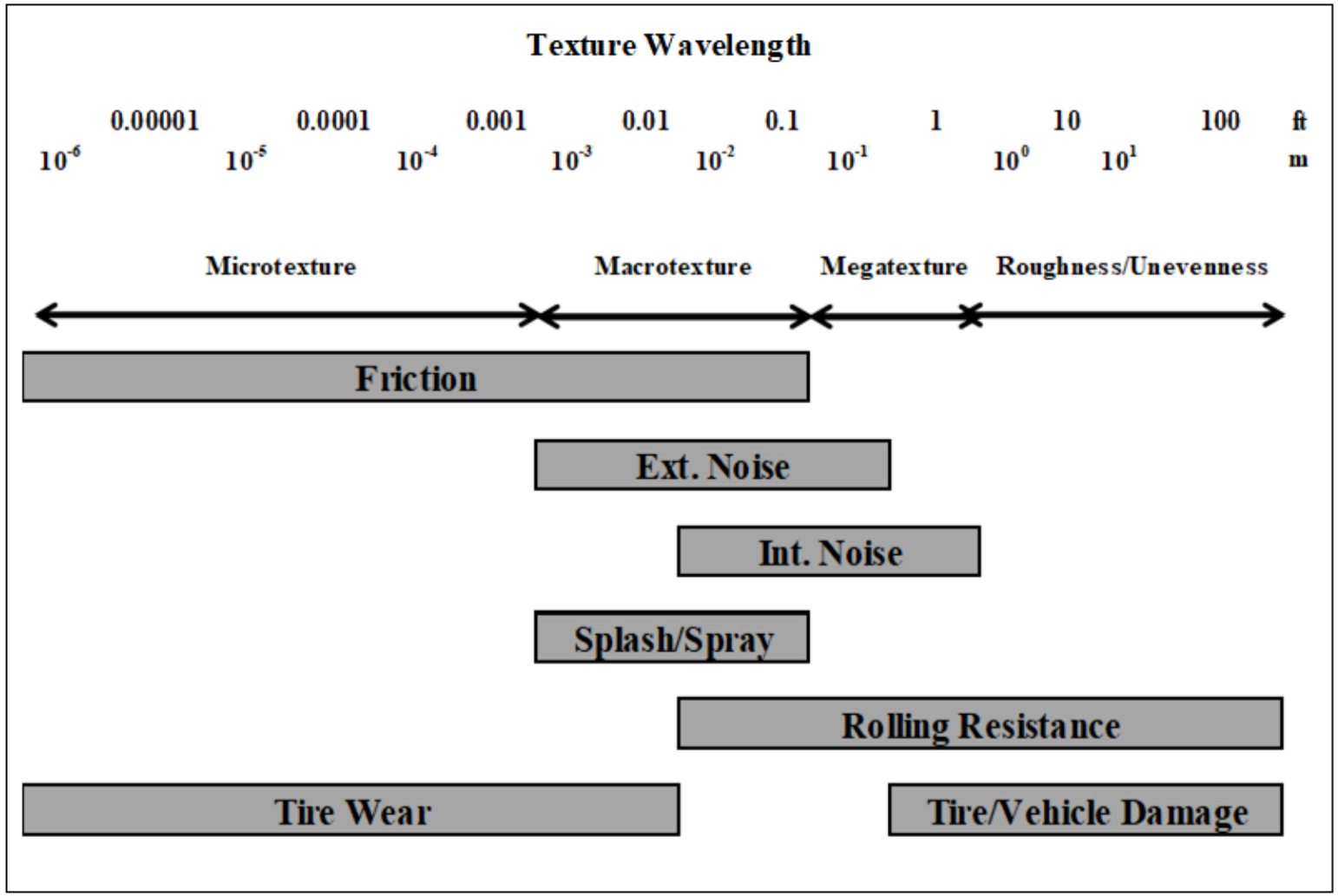
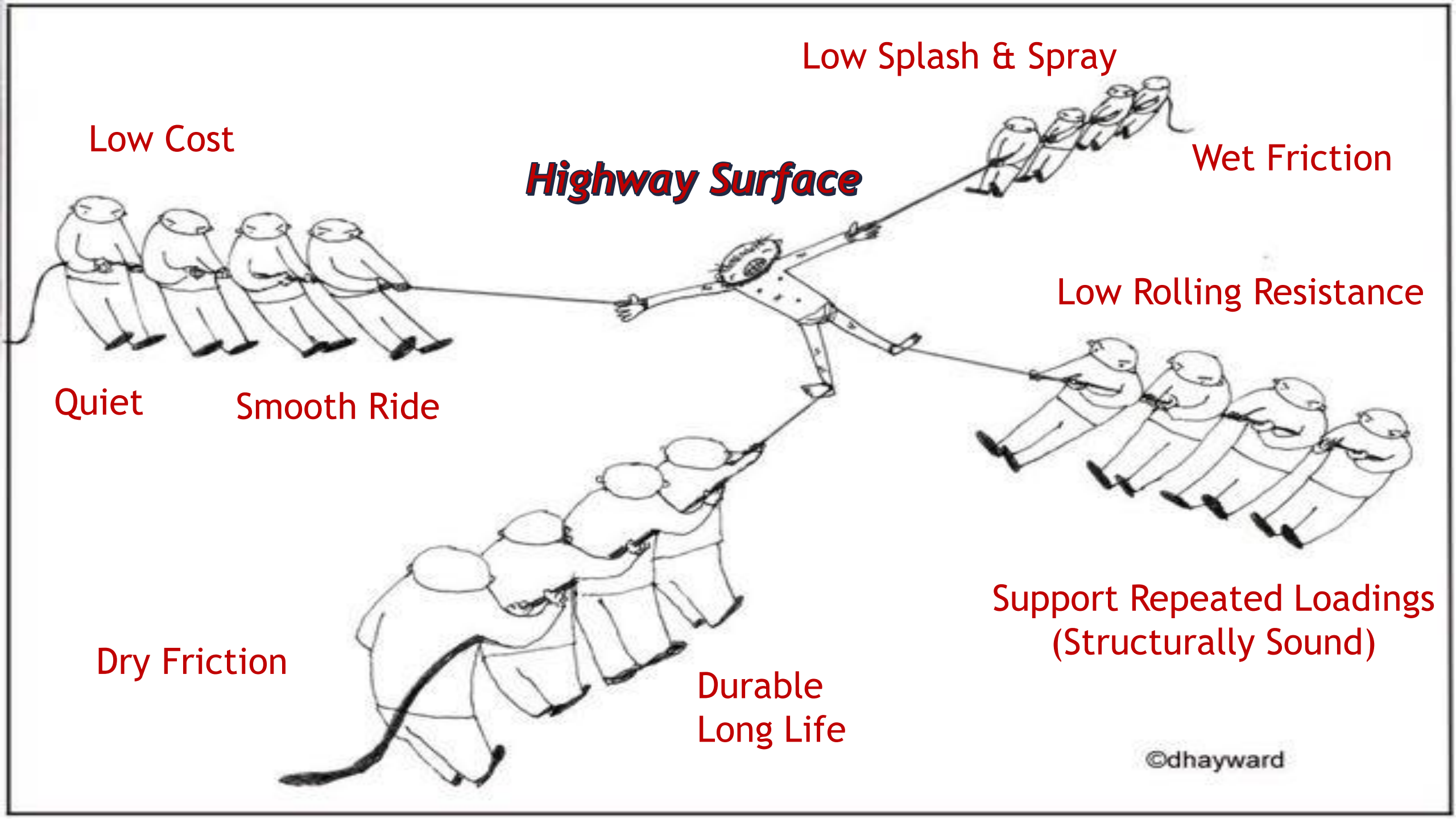
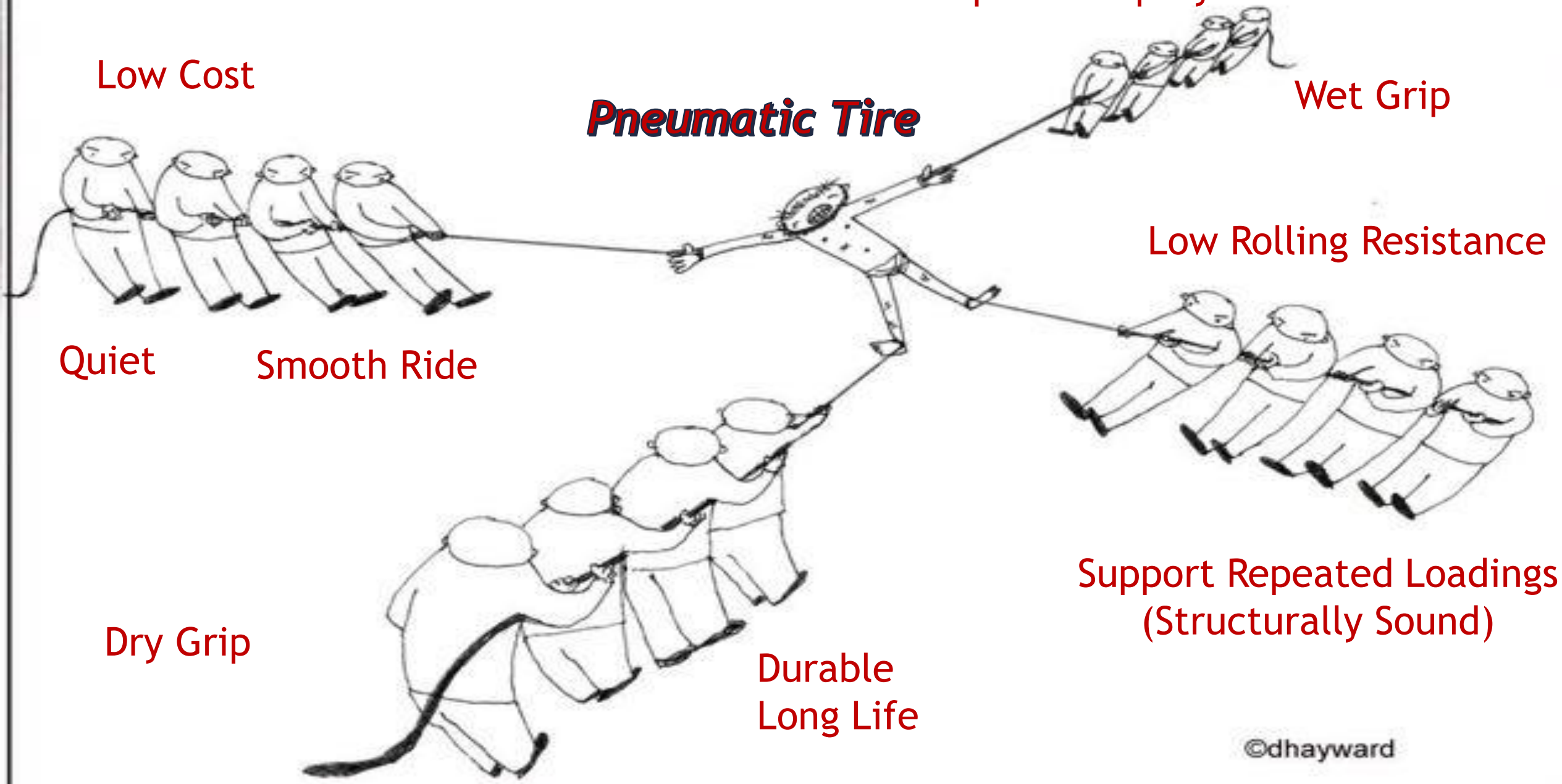


Figure 2 Influence of texture wavelength on tire pavement interaction (after Henry, 2000)

Flintsch, Mcghee, Izeppi, Najafi 2012
The Little Book of Tire Pavement Friction


Low Splash & Spray
Low Cost
Wet Friction
Highway Surface
Low Rolling Resistance
Quiet
Smooth Ride
Support Repeated Loadings
(Structurally Sound)
Dry Friction
Durable
Long Life
©dhayward

Pneumatic Tire

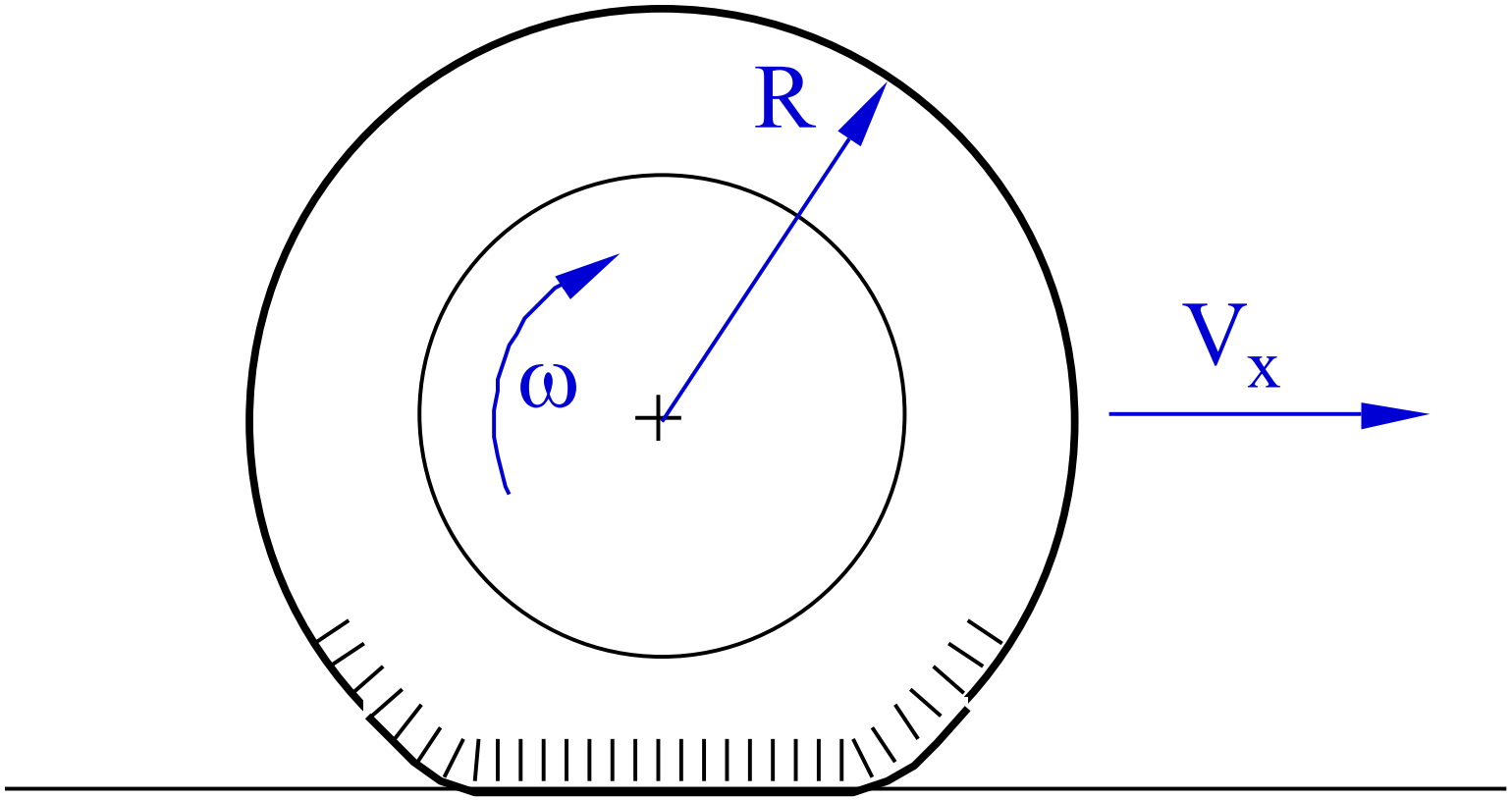


SCIENCE & THEORY OF TIRE PAVEMENT FRICTION

- What is Friction?
  - One object in contact with another object in which one is moving at the area of contact with respect to the other. One object moving across another.
- Is there friction between a tire at rest on the surface (ex. a parked car) ?
- Is there friction between a tire and the surface in which the angular velocity of the tire equals the longitudinal velocity of the vehicle?

SCIENCE & THEORY OF TIRE PAVEMENT FRICTION

Tire in contact with the surface



Source: Steve Karamihas
UMTRI

SCIENCE & THEORY OF TIRE PAVEMENT FRICTION

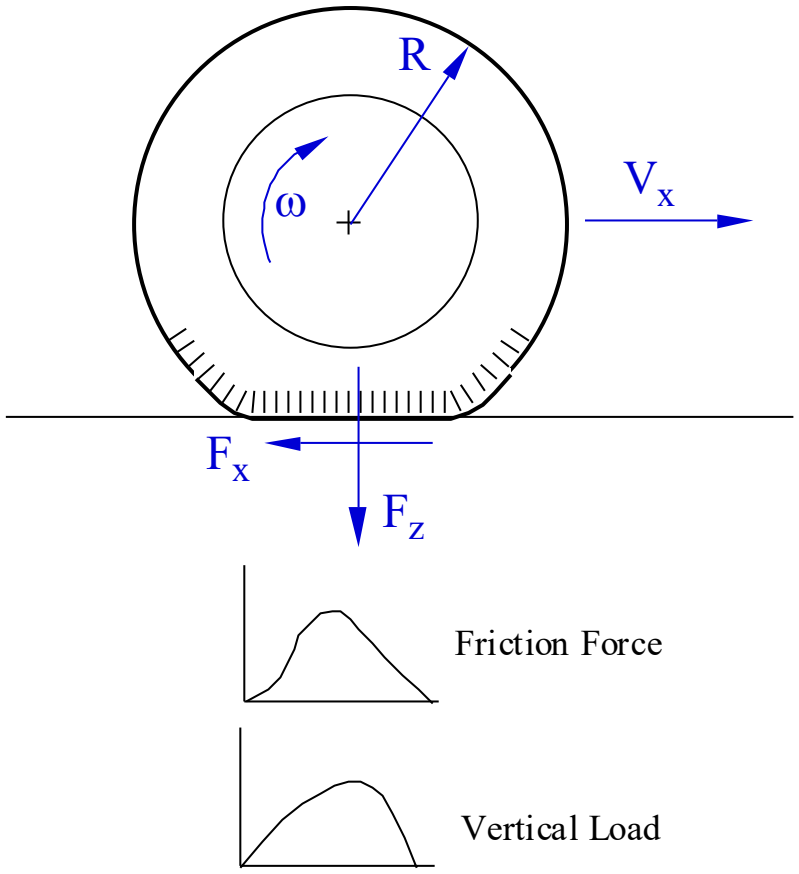
Longitudinal Slip, Traction (vehicle acceleration)

$$\text{Slip} = \frac{V_x - R \bullet \omega}{R \bullet \omega} \bullet 100$$

Source: Steve Karamihas
UMTRI

SCIENCE & THEORY OF TIRE PAVEMENT FRICTION

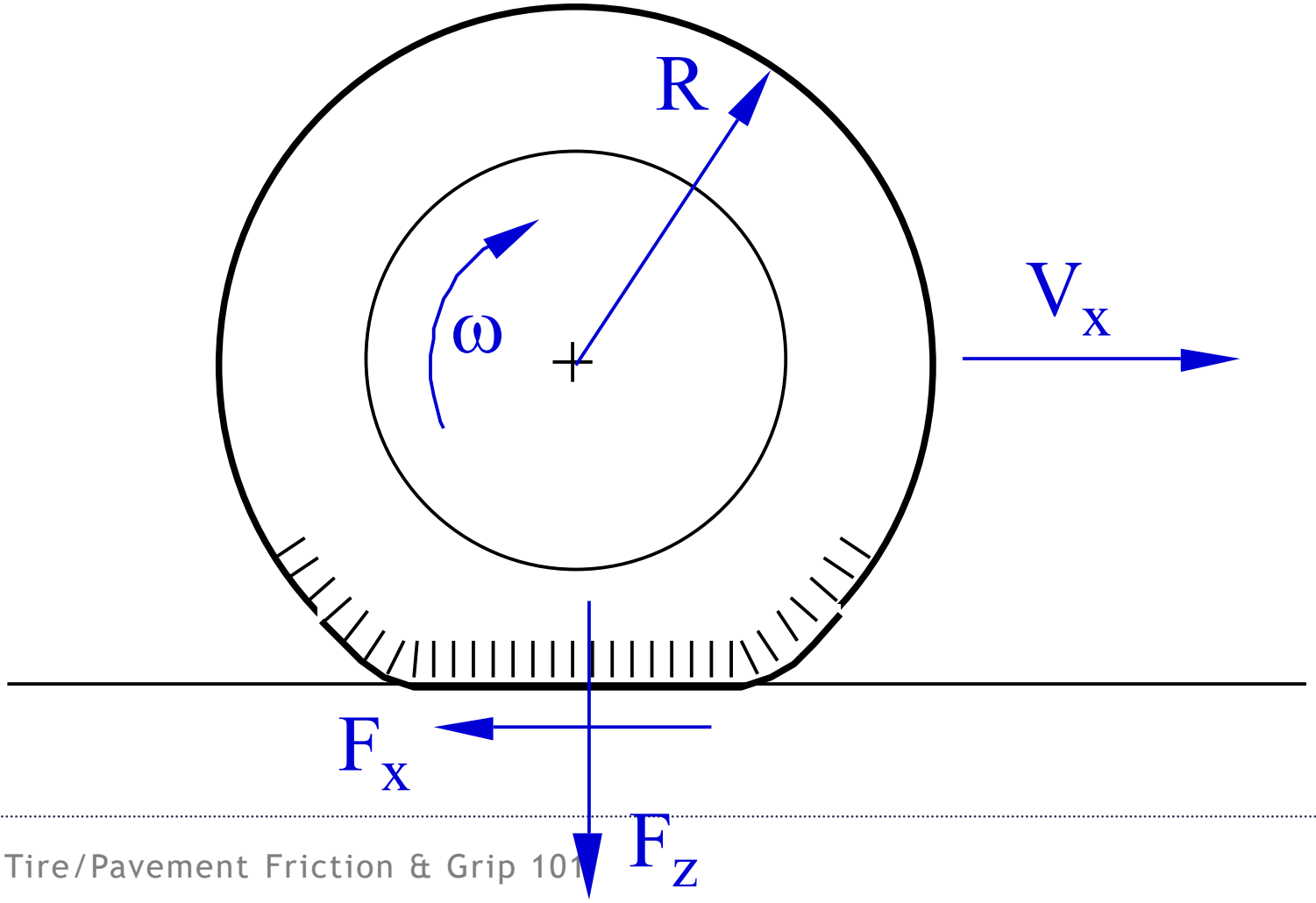
Braking Tire



Source: Steve Karamihas
UMTRI

SCIENCE & THEORY OF TIRE PAVEMENT FRICTION

Braking Tire



Source: Steve Karamihas
UMTRI

SCIENCE & THEORY OF TIRE PAVEMENT FRICTION

Longitudinal Slip, Braking (vehicle deceleration)

$$\text{Slip} = \frac{V_x - R \bullet \omega}{V_x} \bullet 100$$

Source: Steve Karamihas
UMTRI

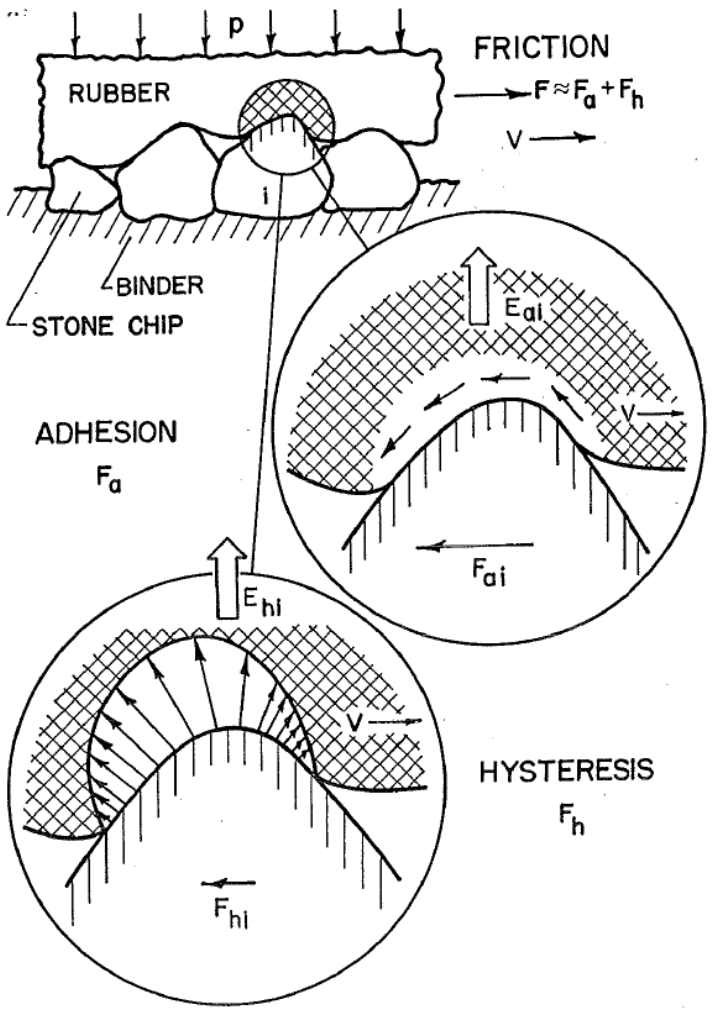
SCIENCE & THEORY OF TIRE PAVEMENT FRICTION

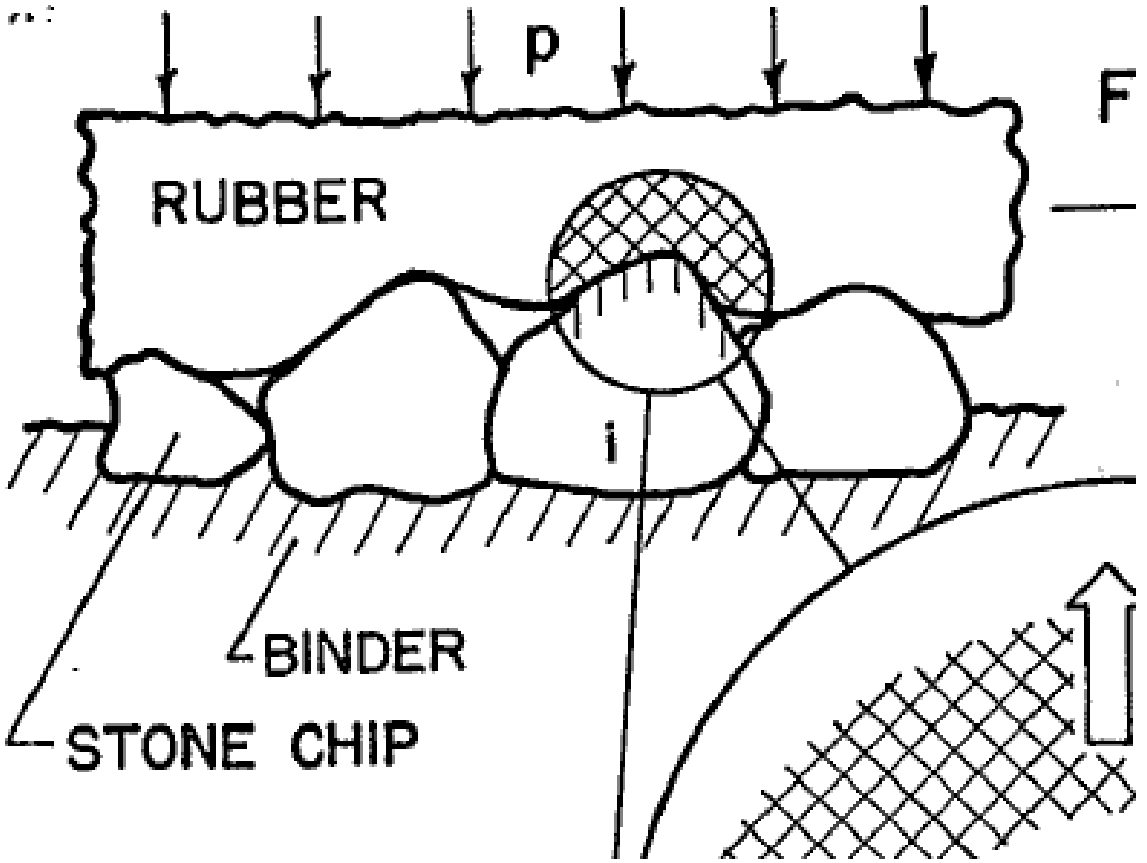
- Traditional Highway Community thinking
  - Friction from Adhesion
    - the rubber “adheres” to the road (microtexture)
    - chemical bonding at the molecular level (interface)
  - Friction from Hysteresis
    - energy (heat) generated from rubber deformation
    - internal friction generated from the rubber changing shape

SCIENCE & THEORY OF TIRE PAVEMENT FRICTION

- Current Tire/Vehicle Community thinking
  - It's all Hysteresis
    - bulk hysteresis of the sidewall and tire patch deforming (macrotexture)
    - micro-hysteresis from deformation of the tread block surface (microtexture)
    - too short of time for chemical bonding to occur
  - More and more of the highway community is coming to this was of thinking

SCIENCE & THEORY OF TIRE PAVEMENT FRICTION





Source: Hartwig Kummer, 1966 ERB 94 PSU
Unified Theory of Rubber And Tire Friction

BACKGROUND – FRICTION AND OTHER SURFACE CHARACTERISTICS

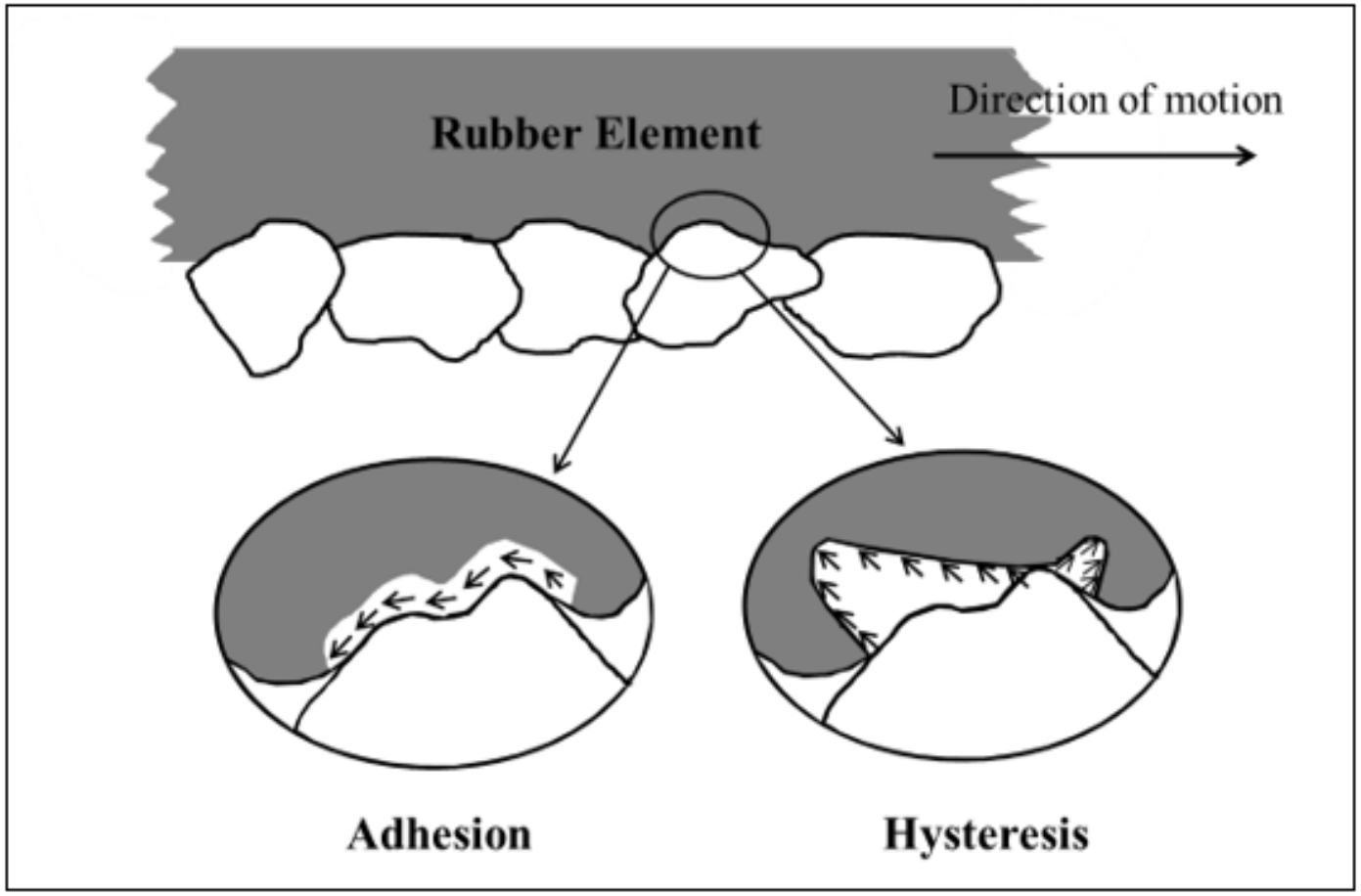
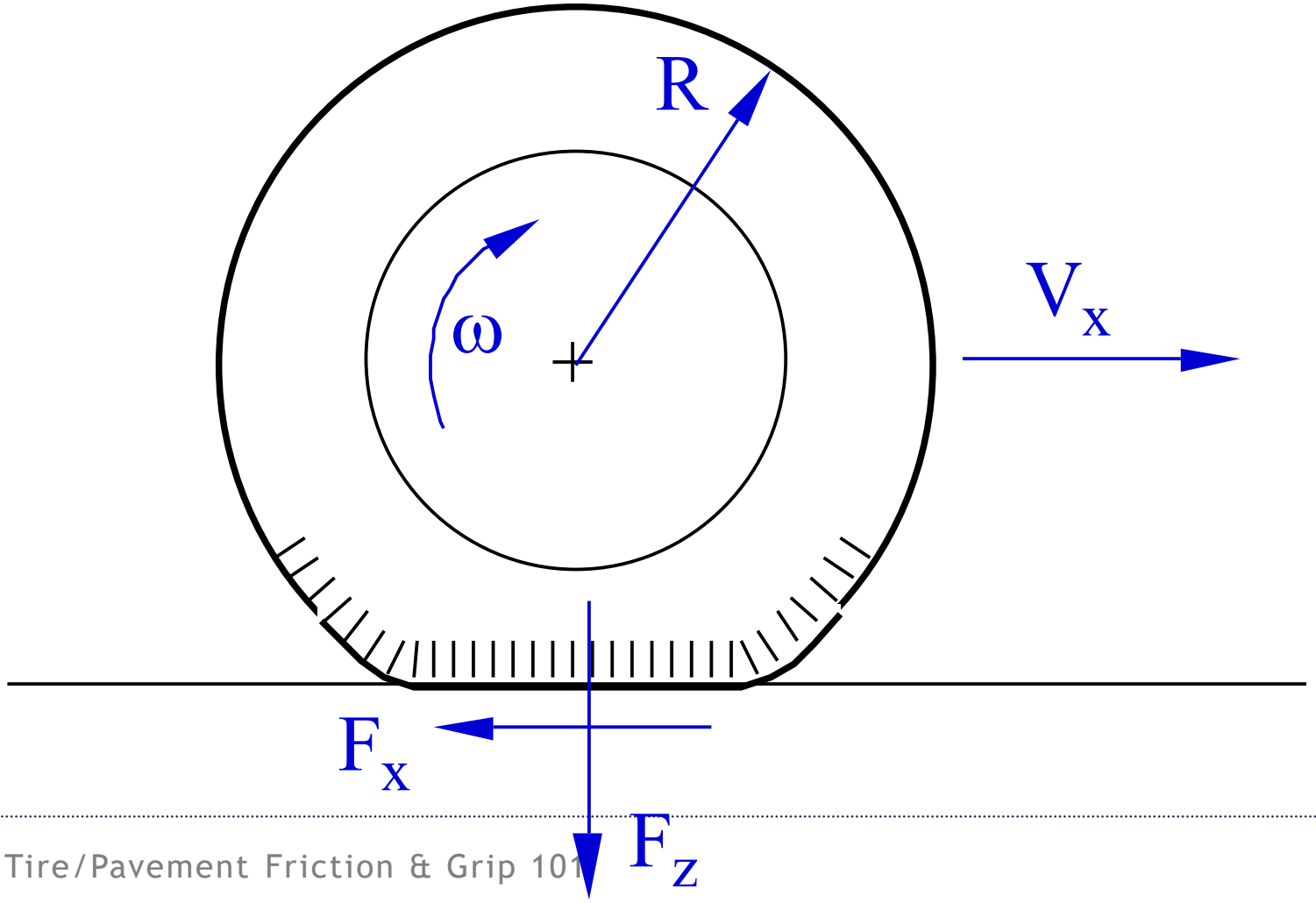


Figure 4 Key components of tire pavement friction (after Hall et al. 2009)

Flintsch, Mcghee, Izeppi, Najafi 2012
The Little Book of Tire Pavement Friction

SCIENCE & THEORY OF TIRE PAVEMENT FRICTION

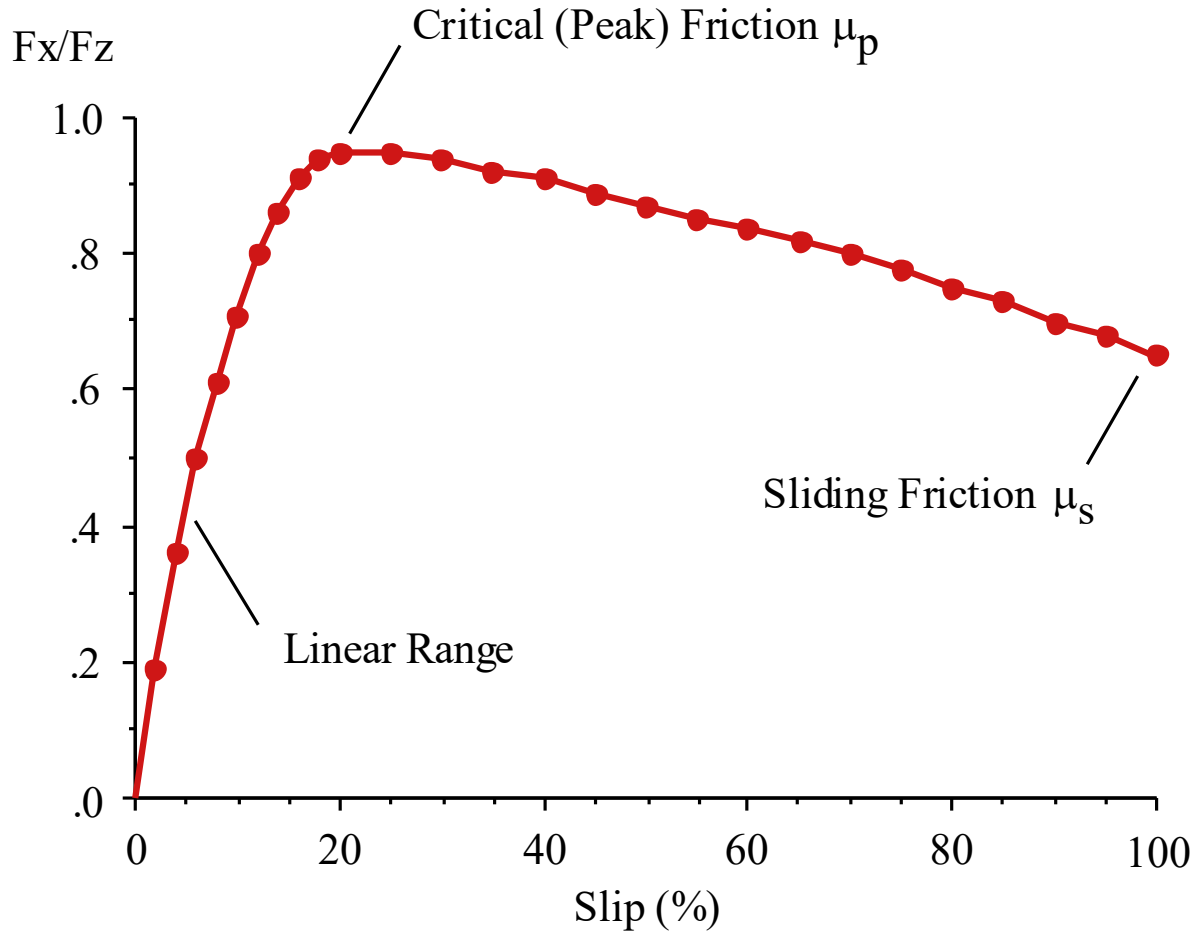
Braking Tire



Source: Steve Karamihas
UMTRI

SCIENCE & THEORY OF TIRE PAVEMENT FRICTION

Tire Pavement Friction



Source: Steve Karamihas
UMTRI

SCIENCE & THEORY OF TIRE PAVEMENT FRICTION

- What happens when we add water?
  - In simple terms, “lubrication”
  - Enough water and enough speed = dynamic hydroplaning

    (Separating the tire from the surface on a film of water)

    deterrent = increase the macrotexture
  - Bulk water is pushed out of the way but a viscous film remains that the surface does not penetrate = viscous hydroplaning

    deterrent = polish resistant aggregates / high microtexture

BACKGROUND – FRICTION AND OTHER SURFACE CHARACTERISTICS

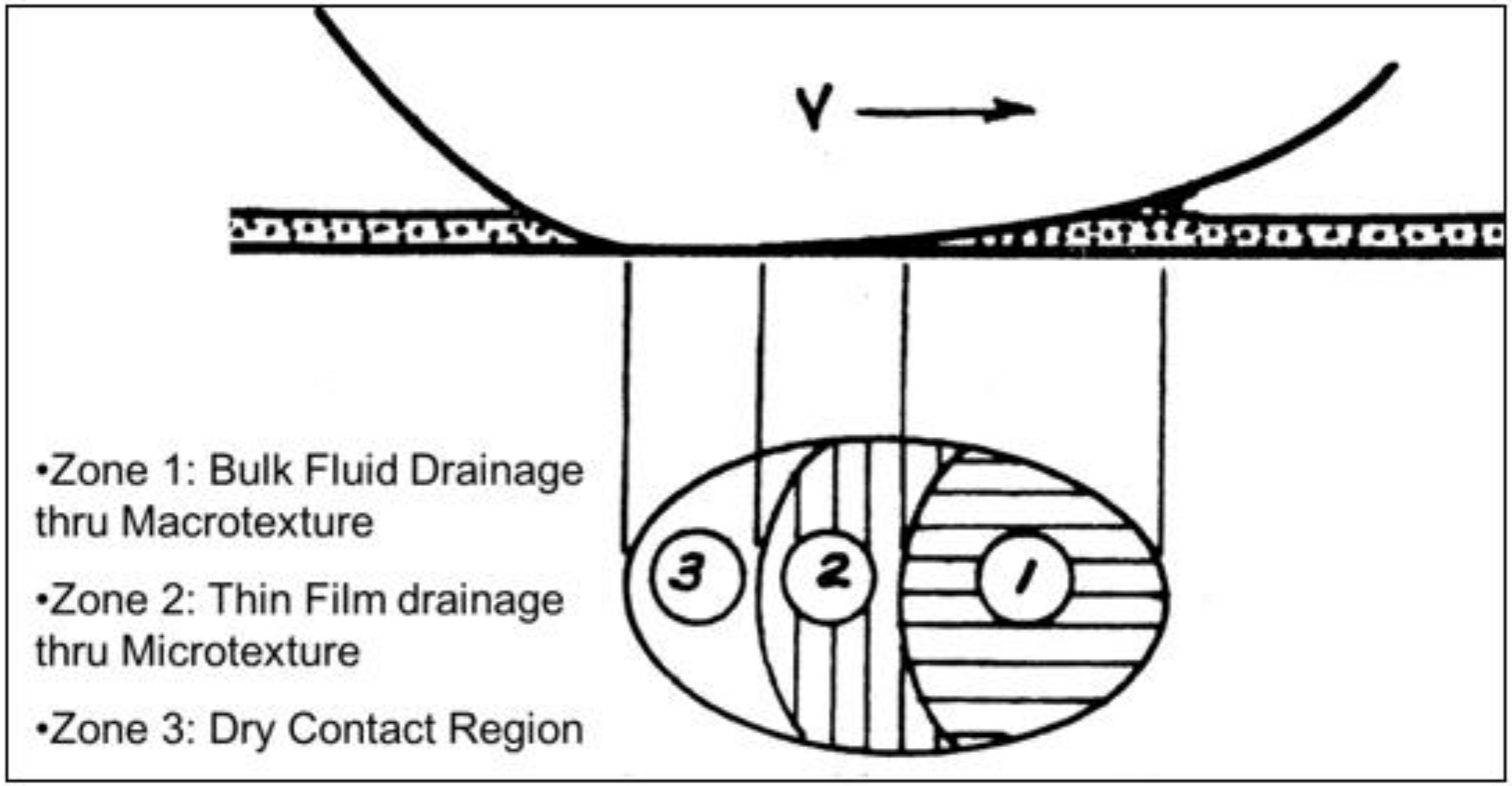


Figure 3 Texture Three Zone Concept of a wet surface (after Moore, 1966)

Flintsch, Mcghee, Izeppi, Najafi 2012
The Little Book of Tire Pavement Friction

HIGHWAY SURFACE CONTRIBUTION TO FRICTION

"If there are no impediments to surface drainage then the highway's contribution to friction is exclusively a function of its microtexture and macrotexture."

- Schleppi, 2009

HIGHWAY SURFACE CONTRIBUTION TO FRICTION

- What do we mean by impediments?
  - Rutting or corrugations, vertical lips
  - Blocked or obstructed drains/improper drainage systems
  - Insufficient geometrics (cross slope, super elevations)
  - Ponding
  - Anything that prevents sheet flow

HIGHWAY SURFACE CONTRIBUTION TO FRICTION

- Macrotexture
  - Texture you can easily see
  - Space or voids between aggregate particles
  - Can be positive or negative
  - Tining or grooving of PCC surfaces
  - Greater macrotexture deters dynamic hydroplaning
  - Greater speeds require greater macrotexture
  - Friction from hysteresis

HIGHWAY SURFACE CONTRIBUTION TO FRICTION

- Microtexture
  - You really can't see it but you can feel it. Surface may look shiny/reflective if it is polished (loss of micro)
  - Comes from the surface of the aggregates and their crystallinity
  - Some aggregates maintain their microtexture longer than others (are harder and less prone to polish)
  - Greater microtexture deters viscous hydroplaning
  - Friction from adhesion or micro-hysteresis
  - Necessary everywhere on our highway network

REVIEW PART 1

- Where and How does friction fit in with respect to the other highway surface characteristics?
- Science & Theory of Tire Pavement Friction
- What does the highway surface contribute to friction?

OVERVIEW PART 2

- Concepts of Friction Demand
- How we Measure Highway Surface Friction
- Combining Friction Demand with Measurement to Determine whether we have a problem
- Measurement must relate to micro and macro texture of the surface
- Basic treatment options and considerations

FRICTION DEMAND

- Does the surface provide sufficient available wet (and dry) friction to meet reasonable demand and expectations of the motoring public?
- It's not one size fits all, some locations require more while others require less.
- Two sided: Highway side & User side

Goal of a Highway Friction Management Program

We strive for sufficient available friction everywhere on our highway network through the service life of the highway surface.

FRICTION DEMAND – USER SIDE

- Operator Alertness & Awareness
- Operator Reaction Time
- Vehicle Weight
- Design and Condition of Brakes
- Vehicle Suspension System
- Tires

FRICTION DEMAND – USER SIDE: TIRES

- Age and Tread Depth
- Tread Pattern
- Hardness/Softness of Rubber
- Inflation Pressure
- Type and Design

FRICTION DEMAND – HIGHWAY SIDE

- Traffic Speeds
- Traffic Volumes
- Truck Volumes
- Congestion
- Geometry Curves vs. Flat/Straight
- Vertical Curves

FRICTION DEMAND – HIGHWAY SIDE

- Sight Distances
- Propensity to Change Lanes
- Mainline vs. Ramps
- Intersections
- Ingress & Egress Opportunities

FRICTION DEMAND

- Can Friction Demand change through time?
- If so, how or why?

FRICTION SUPPLY – HIGHWAY SIDE

- Drainage, Rutting, Ponding
- Raveling
- Bleeding/Flushing
- Cracking
- Kneading
- Aggregate rounding and polishing

FRICTION SUPPLY

- Can Friction Supply change through time?
- If so, how or why?

FRICTION MEASUREMENT

- Proven
- Standardized
- Formal
- Repeatable
- Expensive
- Objective
- Scientific
- At speed (no MOT)
- Very few service providers
- Scheduling hurdles

- Subjective
- Informal
- Imprecise
- Very Inexpensive
- Requires some skill/experience
- Quickly and Easily Learned
- Requires MOT (dodging traffic)
- Spend some time at a given location
- Easily scheduled and performed

FRICTION MEASUREMENT

Stationary / Laboratory

- Circular Texture Meter
- Dynamic Friction Tester
- Stationary 3-D texture measurement systems
- Sand Patch
- British Pendulum
- Grease Smear
- Etc.

Vehicle Mounted / Travel Speed

- Locked Wheel Friction Testers
  - Fixed Slip devices
- Side Force Skew Angle devices
  - Drag Sled
- Spot Laser macrotexture sensor systems
- Line laser macrotexture systems

FRICTION MEASUREMENT SYSTEMS

Does it make sense to use any of these systems to evaluate friction?

- Testing principals employed?
- Test tires used?
- Etc?

FRICTION MEASUREMENT – SUBJECTIVE

"Yukon Cornelius" Method

FRICTION MEASUREMENT – SUBJECTIVE

Based on Optical and Contact Sensors

- Eyeballs, Fingertips, Foot and Shoe Sole

Examine and compare the Wheel Tracks, Outside the Wheel Tracks, and the Shoulder

- Close careful visual inspection
  - Shiny vs. dull, tight vs. open
- How do the 3 areas feel to the fingertips?
- How do they feel to the sole of the shoe?

FRICTION MEASUREMENT & FRICTION DEMAND

"I have insufficient available friction on a particular segment of a highway." – How was this determined?

Possible Friction Evaluation Triggers:

- Frequently Replaced/Repaired Barrier or perhaps Chevron Signs
- Maintenance Supervisor/Engineer or Highway Worker has told us
- J. Q. Public has told us
- Law Enforcement Officers have told us
- ITS cameras gave visual footage
- Crash Analysis: Crash Rate; Wet vs. Total Crash Rate; Fixed Object Crashes
- Suspicion: bleeding, flushing, lots of crack sealer, spill/contaminant, etc.
- Routine Friction Measurement

FRICTION MEASUREMENT & FRICTION DEMAND

"I have insufficient available friction on a particular segment of a highway." – How was this determined?

Friction Evaluation Performed then compared to demand.

SO WE HAVE A PROBLEM, WHAT IS IT?

And the problem is Friction but…

- Is it Microtexture?
- Is it Macrotexture?
- Is it both?

WHAT ARE MY FRICTION TREATMENT OPTIONS?

Mechanically Change the Surface (scuff it up)

- Carbide Milling
  - Micro Milling
  - Fine Milling
  - Conventional Coarse Milling
- Diamond Grinding
- Diamond Grooving
- Shot Blasting

Cover Up the Surface

- Micro Surfacing
- HMA Overlay
  - Traditional Mill & Fill or Straight Overlay
  - Fine Graded Polymer Overlay
  - Open Graded Friction Course
- Chip Seal
- High Friction Surface Treatment (Epoxy Binder with Calcined Bauxite Chips)

THINGS TO CONSIDER WHEN PROPOSING A FIX

- From evaluation, what's the problem: micro, macrotexture, or both?
- What aggregates do I have in the mix? What's the surface mix makeup?
- How is my binder? Bleeding, flushing, tighter in the wheel-tracks?
- Is the surface contaminated? Crack sealer, tar, or perhaps a spill?
- What is my traffic like? Speeds, vehicle mix, congestion?

THINGS TO CONSIDER WHEN PROPOSING A FIX

- How much life do I want or need to get out of the fix? When is it programmed for a surface treatment? Can I bump it ahead in the que?
- How old is the surface?
- Will weather prevent or delay an immediate fix?
- How much $ do I have to correct the problem?
- How severe is my problem? Do I need to do a cheap/short term fix now to get by until $, and/or time, and/or weather allows for a long term fix?

REVIEW PART 2

- Concepts of Friction Demand
- How we Measure Highway Surface Friction
- Combining Friction Demand with Measurement to Determine whether we have a problem
- Measurement must relate to micro and macro texture of the surface
- Basic treatment options and considerations

Questions and Discussion

CONTACT INFORMATION

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