Lecture L6

Pavement Skid Resistance Evaluation & Management

T. F. Fwa

Center for Transportation Research
Department of Civil Engineering
National University of Singapore

2007

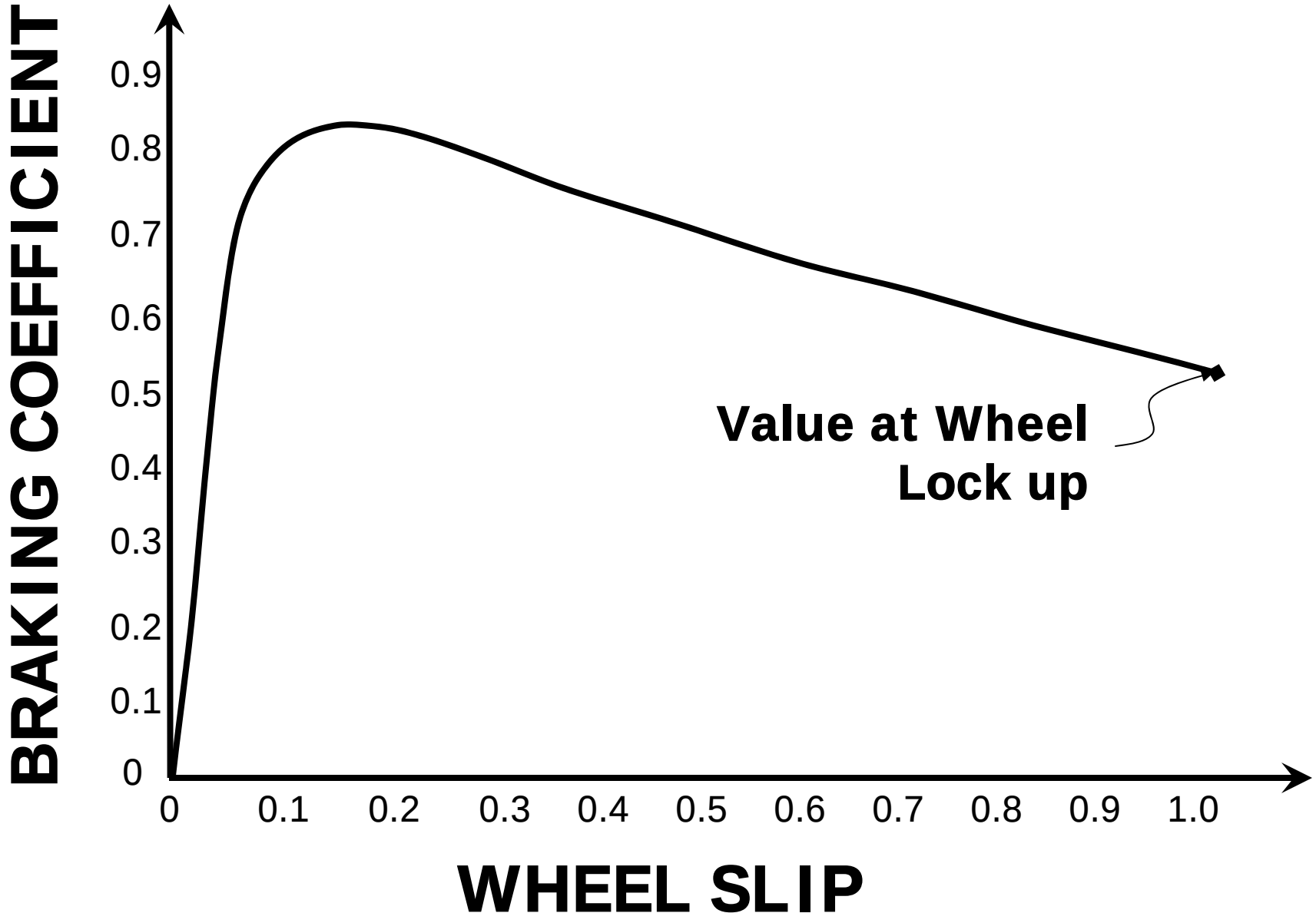
Pavement Skid Resistance Evaluation & Management

Importance of Tyre-Pavement Friction

- Low friction would not allow a vehicle to come to a stop within a safe distance braking
- In emergency braking, skidding occurs when the applied braking force exceeds the maximum shear force that can be developed at the tyre-pavement interface. Skidding during braking is dangerous because the driver is unable to retain steering (directional) control of the vehicle.

Skid Resistance in Braking

- A free-rolling wheel (i.e. tyre slip S = 0) offers no braking force, the aircraft cannot be brought to a stop.
- The aircraft can be brought to a stop by applying brake, thus causing some slip.
- The maximum braking force does not occur at 100% slip (i.e. locked wheel condition).
- The maximum braking force occurs at about 100% slip, known as the ***critical slip***.

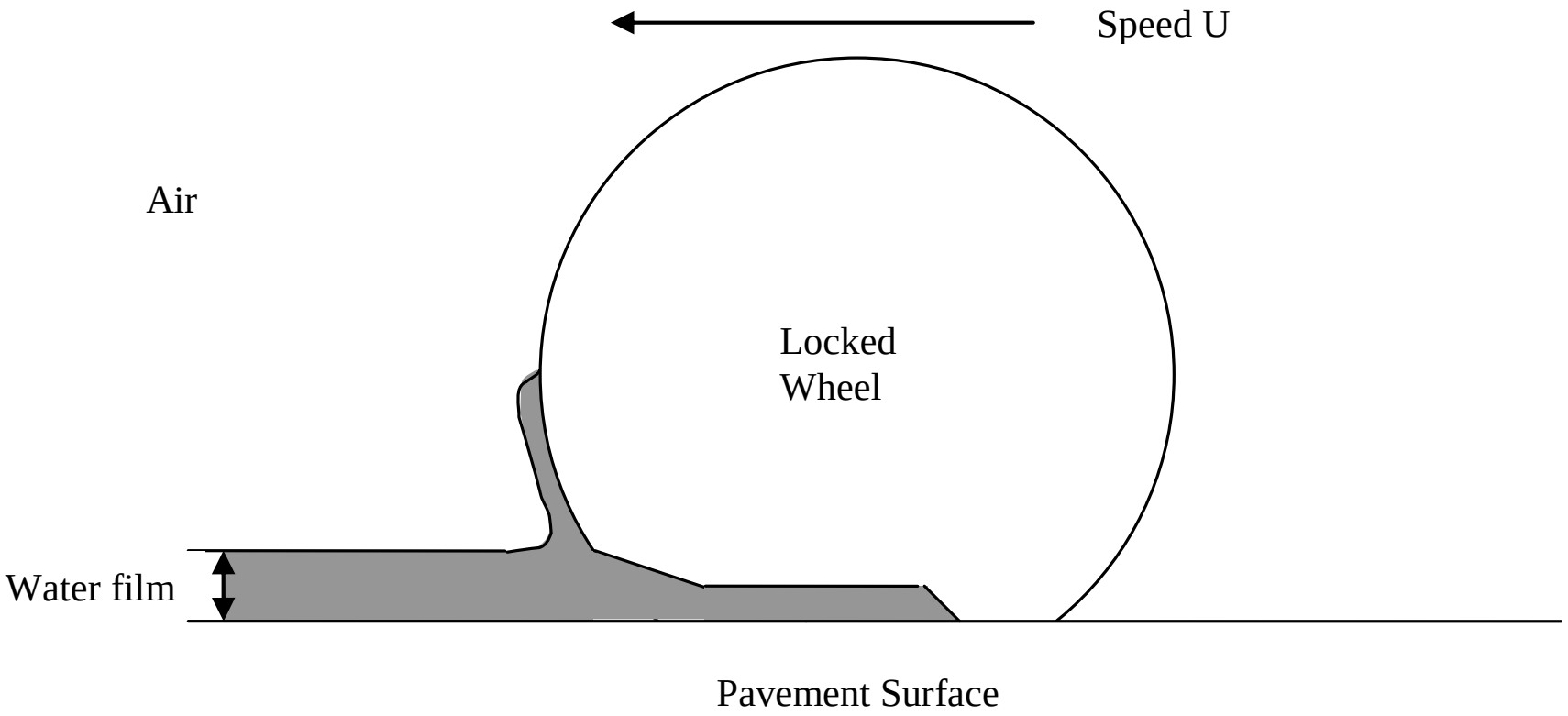

BRAKING COEFFICIENT
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
WHEEL SLIP
Value at Wheel
Lock up

Pavement Skid Resistance Evaluation & Management

Wet vs. Dry Skid Resistance

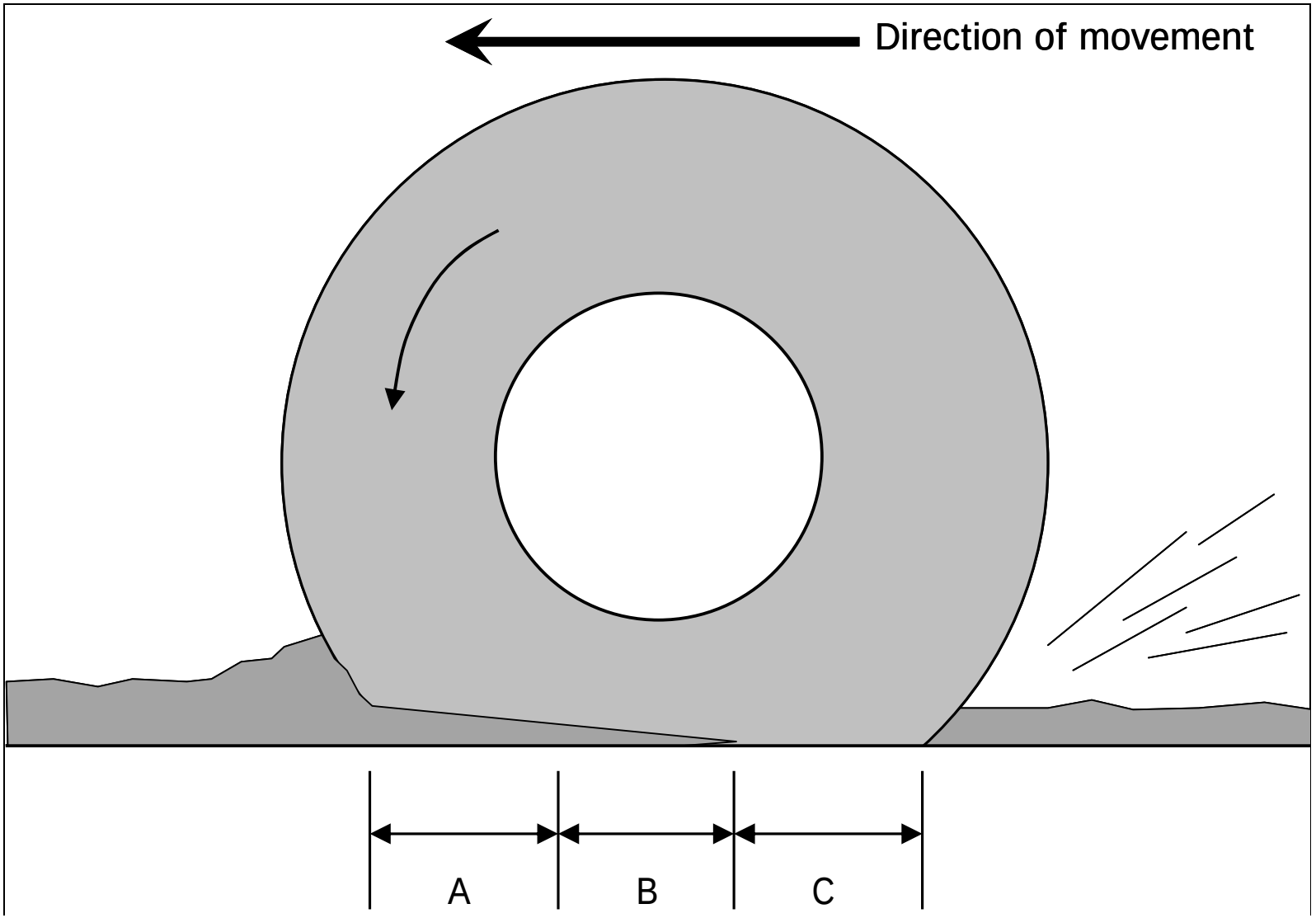
- Under dry condition, the tyre-pavement friction is more than adequate to accommodate vehicle braking force demand without skidding.
- There is a substantial drop in skid resistance when the pavement is wet.
- **Hence, pavement skid resistance management and performance evaluation has to be based on wet-pavement condition.**

Mechanism of Wet Pavement Skid Resistance

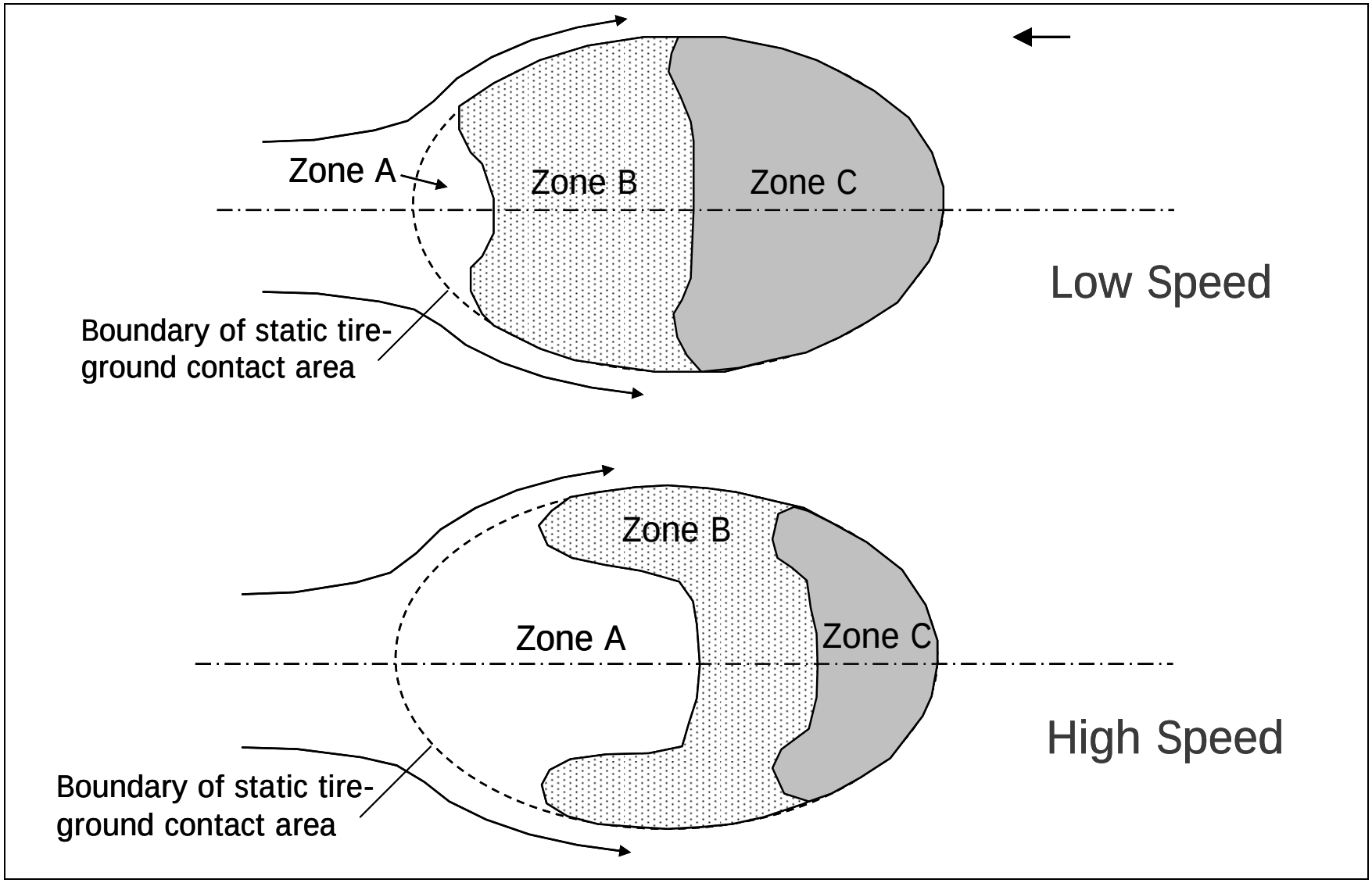


Locked wheel traveling on pavement in stationary observer's reference frame

3-Zone Model for Wet Pavement Skid Resistance



3-Zone Model for Wet Pavement Skid Resistance



Pavement Skid Resistance Evaluation & Management

Elements of Skid Resistance Management

A. Measurement and evaluation of pavement skid resistance
B. Inspection and monitoring of skid resistance
C. Skid resistance maintenance
D. Skid resistance enhancement and treatment

(A) Measurement and Evaluation of Skid Resistance

- Basic method is to measure the force required to slide a tyre over the wetted test pavement at specified % slip and slip angle.
- In accordance with ICAO procedures, the maximum friction at the optimal slip is measured and reported instead of the locked-wheel skidding friction.

(A) Measurement and Evaluation of Skid Resistance

- Different devices respond differently to such variables as speed, water-film thickness, method of wetting, temperature and tyre design.
- Each device measures a different aspect of skid resistance. Good correlation between measurements by different devices is not expected.

(A) Measurement and Evaluation of Skid Resistance

Continuous Friction Measuring Equipment (CDME) :

- The first CFMEs were developed mainly for testing in winter conditions
- It is as important to measure runway friction in summer as in winter
- In rain, a pavement with poor texture can be just as slippery as a runway contaminated with ice and snow

(A) Measurement and Evaluation of Skid Resistance

Operational vs. Maintenance Testing :

- **Operational testing** is carried out in natural conditions, e.g. in winter, in order to make immediate ***operational decisions*.**
- **Maintenance testing** is carried out in carefully controlled conditions, which include an exact amount of water put down in front of the measuring wheel, in order to make ***engineering management decisions*.**

(A) Measurement and Evaluation of Skid Resistance

Operational vs. Maintenance Testing :

- Engineering management decisions must not be made on the basis of operational testing
- Natural conditions are much too variable to provide a proper basis for engineering management decisions
- CFME offers a consistent basis for maintenance friction testing, regardless of the test location

(A) Measurement and Evaluation of Skid Resistance

Types of Measuring Devices :

CFME	Body Type	Friction Measured	Test Speed
SCRIM	Vehicle	Side	50 km/h
GRIPTESTER	Trailer	Longitudinal	50 km/h (30 -130 km/h)
Mu-Meter	Trailer	Side	65 km/h
ICC Friction Tester	Trailer	Longitudinal	65 km/h
Surface Friction Tester	Vehicle /Trailer	Longitudinal	65 km/h or selected speed

(B) Inspection and Monitoring of Pavement Skid Resistance

Two key aspects of inspection :

1) **Identify areas that require immediate correction and repair**
2) **Identify areas that present potential skid resistance risk and calls for either monitoring or corrective measures to be scheduled**

(B) Inspection and Monitoring of Pavement Skid Resistance

Needs for Monitoring :

1) Monitor areas with potential skid resistance risk
2) Periodic scheduled skid resistance measurements to
   a) Identify areas where deterioration of skid resistance is approaching warning level
   b) Assess the overall skid resistance performance of pavements

(B) Inspection and Monitoring of Pavement Skid Resistance

Areas with potential skid resistance risk :

- **Insufficient texture depth**
- **Pavement depressions**
- **Rutted areas**
- **Signs of asphalt bleeding**
- **Rubber deposited areas**
- **Clogged drains**

(B) Inspection and Monitoring of Pavement Skid Resistance

EFFECT OF PAVEMENT SURFACE TEXTURE

A pavement surface contains **microtexture** and **macrotexture**

Microtexture – texture of the surface of individual aggregate, not readily discernible to the eye but apparent to the touch

Macrotexture – coarse texture or visible roughness due to the layout of the aggregate, or artifically created texture such as tining or grooving.

(B) Inspection and Monitoring of Runway Skid Resistance

EFFECT OF PAVEMENT SURFACE TEXTURE

Microtexture – governs skid resistance at low speeds

Macrotexture – directly influences the ability of water to escape from under the tyre, hence governs the rate of decrease of skid resistance with increasing speed.

(For a given microtexture and macrotexture, skid resistance decreases with vehicle speed because at higher speed, there is less time for water to escape)

(B) Inspection and Monitoring of Pavement Skid Resistance

MEASUREMENT OF SURFACE TEXTURE

Microtexture – Indirect measurement using the low-speed British Pendulum Test

Macrotexture – Sand-Patch Test, Grease Smear Test

(C) Pavement Skid Resistance Maintenance

Pavement factors affecting COF :

- Macrotexture
- Microtexture
- Type & Degree of Surface Contaminants
- Environmental Factors / Amount of Rainfall

(C) Pavement Skid Resistance Maintenance

Routine Maintenance :

- **Periodic cleaning of pavements**

  (e.g. loose sand, oil patch and debris)
- **Periodic cleaning of drains and ditches**
- **Minor Correction or removal of potential skid resistance risks**

  (e.g. small patches of grease or oil, etc)

(C) Pavement Skid Resistance Maintenance

Corrective Maintenance :

- **Rubber deposit removal**
- **Milling / patching to repair depressed or rutted pavement**
- **Repair areas of asphalt bleeding**
- **Skid resistance overlay or re-surfacing** (e.g. friction seal coat)
- **Treatment to pavement surface (Grinding, grooving, etc)**

(C) Pavement Skid Resistance Maintenance

Preventive Maintenance :

(work activities similar to corrective maintenance, but with advance planning and programming)

- **Rubber deposit removal**
- **Milling / patching to repair depressed or rutted pavement**
- **Repair areas of asphalt bleeding**
- **Skid resistance re-surfacing or overlay**
- **Treatment to pavement surface**

(D) Skid Resistance Enhancement and Treatment

Major rehabilitation or re-building to raise the skid resistance performance to a higher level

- **New pavement layer**
- **Pavement overlay**
- **Grooving or other forms of surface treatment**

References

- Chapter 21 “Pavement Skid Resistance Management” in The Handbook of Highway Engineering, edited by T. F. Fwa. (2006)
- Ong, G. P. and Fwa, T. F. (2007) Wet-Pavement Hydroplaning Risk and Skid Resistance: Modeling. ASCE Journal of Transportation Engineering, Vol. 133, No. 10, pp. 590-598.
- Fwa, T. F. and Ong, G. P. (2007) Wet-Pavement Hydroplaning Risk and Skid Resistance: Analysis. Accepted for publication in the *ASCE Journal of Transportation Engineering*.