WHY FIXED SLIP DEVICES CAN NOT MEASURE THE SPEED GRADIENT DUE TO THE PAVEMENT

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This paper covers why measurements at various speeds with continuous friction measurement equipment (CFME) are not able to measure the speed - friction gradient of the pavement as determined by the macro-textural features of the surface.
Most CFMEs measure friction in the slip ratio range of 10% to 18%. In this range it is shown that the friction versus slip speed of these devices are mainly determined by the coupled properties of the surface micro-texture and relevant tire properties and to a minimal extent only by pavement macro-texture properties.
Effect of Speed and Slip on Braking and Side Friction

Friction-Slip for Wet Concrete

- Braking Friction-$\mu$ at 20 mph
- Braking Friction-$\mu$ at 50 mph
- Side Friction-SFC at 20 mph
- Side Friction-SFC at 50 mph

Longitudinal Slip %

mu/side force coefficient

0 10 20 30 40 50 60 70 80 90 100
Where tire and pavement mainly affect friction versus slip speed
A Comprehensive Friction Model

Comprehensive Friction Curve

Vehicle Speed [km/h]

% Slip [s]

Coefficient of Friction
Tire/Road Friction

Weight, $F_w$

Rotation $\omega$

Direction of motion

Friction Force, $F$
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Time [s]

Friction

0% Slip
15% Slip
Slip @ Peak
100% Slip

0.15s
0.3s
0.8 s

15% Slip
Pavement Surface Characteristics and tire friction

Free rolling

Low slip %
Pavement Surface Characteristics and tire friction

High slip %

100% slip
$\omega = 0$

100% Slip
Typical Speed Data for CFMEs and Locked Wheel Testers

Typical Data from Experiments

- **Mu** vs. **Slip Speed km/h**
- Points for 100% and CFME conditions
Typical Speed Data for one CFME and one Locked Wheel Tested
Mu vs Slip Speed and Vehicle Speed for Semi-Stiff

- 100%
- 65 km/h
- 20 km/h
- 95 km/h
- 120 km/h
- 10%
- 15%
- 12%
- 18%

Slip Speed in km/h

0 20 40 60 80 100 120

0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80
Graphs from Historical Data

Measurements with Three devices:
- CFME #1 @ 13.5% slip
- CFME #2 @ 18.0% slip
- Locked Wheel Tester

Devices measured three speeds:
40km/h; 60km/h; and 80km/h

Sample Surface F1 at the Pennsylvania State University Test track

Sample Surface F2 at the Pennsylvania State University Test track
Graphs from Historical Data

CFME’s measure virtually the same slope on both surfaces! Independent of actual macro-texture depth!

100% slip devices measure different speed gradients proportional to actual macro-texture!
CORRELATIONS OF CFMEs

Both the PIARC and FEHRL experiments were conducted to correlate or harmonize different friction devices. Similarly the NASA Runway Friction Workshops and then the continuation Friction Workshops at Penn State were conducted to look into how to harmonize devices. The 2010 and 2011 workshops at Penn State found that the water flow rates and distributions varied significantly. Thus, water distribution and different slip ratios as well as tire differences all affect the friction reading of CFMEs.
It is recommended that

1. CFMEs should not be run at several speeds to determine speed gradient, but should be run at a single speed and use macro-texture measurements to obtain the pavement speed gradient.
It is recommended that

2. The data from the HERMES project should be revisited with this in mind to revise the EFI. To a lesser extent the PIARC data could be revised; however, the locked wheel data did dominate the golden values and thus is not as critical.