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AMERICAN SOCIETY FOR TESTING AND MATERIALS
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# Standard Practice for Calculating International Friction Index of a Pavement Surface[1]

This standard is issued under the fixed designation E 1960; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This practice covers the calculation of the International Friction Index (IFI) from a measurement of pavement macrotexture and wet pavement friction. The IFI was developed in the PIARC International Experiment to Compare and Harmonize Texture and Skid Resistance Measurements. The index allows for the harmonizing of friction measurements with different equipment to a common calibrated index.

1.2 The IFI consists of two parameters that report the calibrated wet friction at 60 km/h (F60) and the speed constant of wet pavement friction ($S_p$).

1.3 The mean profile depth (MPD) and mean texture depth (MTD) have been shown to be useful in predicting the speed constant (gradient) of wet pavement friction.[2]

1.4 A linear transformation of the estimated friction at 60 km/h provides the calibrated F60 value. The estimated friction at 60 km/h is obtained by using the speed constant to calculate the estimated friction at 60 km/h from a measurement made at any speed.

1.5 The values stated in SI (metric) units are to be regarded as standard. The inch–pound equivalents are rationalized, rather than exact mathematical conversions.

1.6 *This standard does not purport to address all of the safety concerns, if any 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.*

## 2. Referenced Documents

2.1 *ASTM Standards:*

E 867 Terminology of Vehicle-Pavement Systems[3]

E 965 Test Method for Measuring Pavement Macrotexture Depth Using a Volumetric Technique[3]

E 1911 Test Method for Measuring Paved Surface Frictional Properties using the Dynamic Friction Tester[3]

E 1845 Practice for Calculating Pavement Macrotexture Mean Profile Depth[3]

2.2 *ISO Standard:*

DIS 13473-1 Acoustics – Characterization of Pavement Texture using Surface Profiles – Part 1: Determination of Mean Profile Depth[4]

## 3. Terminology

3.1 Terminology used in this standard conforms to the definitions included in Terminology E 867.

## 4. Summary of Practice

4.1 This practice uses measured data of the pavement surface on: (*1*) macrotexture, and (*2*) measured friction (FRS) on wet pavement. The practice accommodates these data measured with different equipment at any measuring speed.

4.2 Measurement of the pavement macrotexture is used to estimate the speed constant ($S_p$).

4.3 The measured friction (*FRS*) at some slip speed ($S$) is used with the speed constant of the pavement ($S_p$) to calculate the friction at 60 km/h (FR60) and a linear regression is used on FR60 to find the calibrated friction value at 60 km/h (F60).

4.4 F60 and $S_p$ are then reported as IFI (F60, $S_p$).

## 5. Significance and Use

5.1 This is the practice for calculating the IFI of the pavement. The IFI has proven useful for harmonization of the friction measuring equipment. F60 and $S_p$ have proven to be able to predict the speed dependence of wet pavement–related measurements of the various types of friction-measuring equipment.[2] The two IFI parameters (F60 and $S_p$) have been found to be reliable predictors of the dependence of wet pavement friction on tire slip and vehicle speed.

5.2 The IFI parameters, F60 and $S_p$, can be used to calculate the calibrated friction at another–slip speed using a transformation equation.

5.3 The IFI model given below describes the relationship between the values of wet pavement friction FRS measured at a slip speed of $S$ and between the friction values measured by different types of equipment.

5.4 A significance of the IFI Model is that the measurement

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[1] This practice is under the jurisdiction of Committee E-17 on Vehicle-Pavement Systems and is the direct responsibility of Subcommittee E17.23 on Surface Characteristics Related to Tire-Pavement Friction.

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[2] Wambold, J. C., Antle, C. E., Henry, J. J., and Rado, Z, International PIARC Experiment to Compare and Harmonize Texture and Skid Resistance Measurements, Final report, *Permanent International Association of Road Congresses* (PIARC), Paris 1995.

[3] *Annual Book of ASTM Standards*, Vol. 04.03.

[4] Draft International Standard under the jurisdiction of ISO/TC43/SC1 currently under ballot.

of friction with a device does not have to be at one of the speeds run in the experiment. FRS can be measured at some $S$ and is always adjusted to FR60. Thus, if a device can not maintain its normal operating speed and must run at some speed higher or lower because of traffic, the model still works well. In that case $S$ is determined by the vehicle speed ($V$) which can be converted to $S$ by multiplying $V$ by the percent slip for fixed slip equipment or by multiplying $V$ by the sine of the slip angle for side force equipment.

5.5 This practice does not address the problems associated with obtaining a measured friction or measured macrotexture.

## 6. Profile or Mean Texture Depth Requirements

6.1 The amount of data required to calculate the mean profile depth (MPD) ideally comprises a continuous profile made along the entire length of the test section.

A minimum requirement shall be 10 evenly spaced profiles (in the direction of travel) of 100 mm (3.9 in.) in length for each 100 m (3900 in.) of the test section. However, for a uniform test section it is sufficient to obtain 16 evenly spaced profiles regardless of test section length. For surfaces having periodic texture (that is, grooved or tined surfaces) the total profile length shall include at least ten periods of the texture.

NOTE 1—When characterizing a long test section with relatively short sample lengths it is important to ensure that the texture is sufficiently homogeneous to provide a representative measure. It is necessary for the user to use sound judgement to determine the minimum number of samples to characterize a non–homogeneous pavement.

NOTE 2—The texture of roads that have been in service varies across the pavement. In this case the transverse location of the measurements shall be determined by the intended use of the data.

6.2 *Resolution*:

6.2.1 Vertical resolution shall be at least 0.05 mm (0.002 in.). Vertical range shall be no less than 20 mm (0.75 in.) and vertical non–linearity shall be no greater than 2 % of the range.

NOTE 3—For stationary devices on smooth pavements a lesser range may be used. In this case non–linearity need not exceed the above requirement of 0.4 mm (0.015 in.). The higher range is usually required to allow for a sensor mounted on a moving vehicle.

6.2.2 Maximum spot size for a laser or other electro–optical device shall be no greater than 1 mm (0.04 in.). The stylus in a contact device shall have a tip having a major diameter no greater than 1 mm (0.04 in.).

6.2.3 The sampling interval shall not be more than 1 mm (0.04 in). Variations of the sampling interval shall not be more than ± 10 %. This requires that the sensor speed over the surface be maintained within ± 10 % whether the device is stationary or mounted on a moving vehicle.

6.3 The angles between the radiating emitting device surface and between the radiation receiving device and the surface shall be no more than 30°. The angle of the stylus relative to the surface shall be no more than 30°. Larger angles will underestimate deep textures.

6.4 Calibration shall be made using calibration surfaces having a known profile. The vertical accuracy of the calibration surface in relation to its theoretical profile shall be at least 0.05 mm (0.002 in.). The calibration shall be designed to provide a maximum error of 5 % or 0.1 mm (0.004 in) whichever is lower.

NOTE 4—One suitable calibration surface is a surface machined to obtain a triangular profile with a peak–to–peak amplitude of 5–20 mm (0.2–0.75 in). This gives an indication of not only the amplitude, but also the nonlinearity and the texture wavelength scale.

6.5 If mean texture depth (MTD) is used, 10 evenly spaced measurements should be made on every 150-meter section or every 15 m as a minimum. MTD is not practical for survey work, but may be used in calibration of other equipment if a texture profilometer is not available.

## 7. Friction Requirements

7.1 Only friction measuring equipment that have been calibrated to measure IFI and that remain within their own calibration limits shall be used.

7.2 The equipment shall have a resolution of at least 0.005 and shall have a standard deviation less than 0.03.

7.3 The equipment shall meet its own standard test method and shall be operated accordingly.

## 8. Data Processing

8.1 *Outliers*—Invalid readings should be eliminated when their value is higher or lower than the range of that surrounding their location. The invalid value for that location should be replaced or dropped according to the standard practice for that device.

8.2 Transformation equations[2]:

8.2.1 The speed constant ($S_p$ in inch) is first computed from a macrotexture measurement (TX in mm) as follows:

$$S_p = a + b \times TX \tag{1}$$

where $a$ and $b$ are constants depending upon the method used to determine the macrotexture as given in Table 1.

8.2.2 The next step uses the FRS at a given $S$ to adjust the friction to a common slip speed of 60 km/h. This is accomplished using the speed number predicted by the texture measurement in the previous step and using the following relationship:

$$FR60 = FRS \times EXP\,[(S-60)/S_p] \tag{2}$$

where:

FR60 is the adjusted value of friction from a slip speed of S to 60 km/h for the equipment,

*FRS* is the friction measured by the equipment at slip speed S, and

$S$ is the slip speed of the equipment as described in 8.2.2.

8.2.3 The final step in harmonization is the calibration of the equipment, by regression of the adjusted measurement *FR*60, with the calibrated Friction Number F60:

$$F60 = A + B \times FR60 + C \times TX \tag{3}$$

$A$, $B$ and $C$ are calibration constants for a particular device and are given in Appendix X1 for devices already calibrated. For other devices a calibration must be performed as outlined in the appendix to establish the $A$, $B$ and $C$ for that device. For

**TABLE 1 Values of a and b for Estimating the Speed Constant ($S_p$):**

| TX | a | b |
|---|---|---|
| MPD per Practice E 1845 | 14.2 | 89.7 |
| MTD per Test Method E 965 | –11.6 | 113.6 |

many devices the value of $C$ was found to be zero or so small it could be neglected, in particular $C$ is not needed for smooth treaded tires.

8.2.4 Combining the results above, F60 can be expressed in terms of the friction and texture measurements (FRS and TX):

$$F60 = A + B \times FRS \times EXP\,[-(60–S)/(a + b \times TX)] + C \times TX \tag{4}$$

8.2.5 F60 is the prediction of the calibrated Friction Number and $S_p$ is the prediction of the calibrated Speed Number. The values of F60 and $S_p$ are then reported as the International Friction Index.

8.2.6 (Optional) Friction at some other slip speed $S$ may be calculated with:

$$FS = F60 \times EXP\,[(60–S)/S_p] \tag{5}$$

## 9. Report

9.1 The test report for each test surface shall contain the following items:

9.1.1 Date of friction and profile measurement,

9.1.2 Location and identification of the test surface,

9.1.3 Description of the surface type,

9.1.4 Description of surface contamination which could not be avoided by cleaning, including moisture,

9.1.5 Observations of surface condition such as excessive cracking, potholes, etc.,

9.1.6 The position of the friction measurement and profile on the surface, for example in relation to the wheel track, etc.,

9.1.7 Identification of the friction and profile equipment and its operators,

9.1.8 Type and date of calibration,

9.1.9 Measurement speed,

9.1.10 Percentage of invalid readings eliminated (dropouts),

9.1.11 Total length measured and the number of segments analyzed,

9.1.12 The IFI values, F60 and $S_p$, and

9.1.13 (Optional) The friction at some other slip speed, FS.

## 10. Precision and Bias

10.1 *Precision*—The reproducibility using two different texture profile systems and test crews was found in the same experiment[2] to be 0.15 mm (0.006 in.) corresponding to 10 % of the average MPD values included in the experiment. The reproducibility of the friction devices varied, but was generally within 0.03[2]. However at low friction values 0.02 should be obtained.

10.2 *Bias*—There is no basis for determination of the bias in F60 and $S_p$. With respect to the average “calibrated” value, the maximum error and average error are given for each device in Table X1.1 in Appendix X1. With respect to the MTD, the MPD is biased by 0.2 mm (0.008 in.) which is due to the finite size of the glass spheres used in the volumetric technique.

## APPENDIXES

### (Nonmandatory Information)

### X1. LIST OF EQUIPMENT

X1.1 Table X1.1 lists the equipment to be used.

**TABLE X1.1 List of Equipment that Have Been Calibrated and Their Regression to Predict F60 using the PIARC Model**

$F60 = A + B \times FRS \times EXP[(S\text{-}60)/S_p] + C \times TX$, where $S_p$ is determined using MPD

| | Blank Tire Devices: | S | A | B | C | MAX[E][A] | AVE[E][B] | RMSE[C] | R[D] |
|---|---|---|---|---|---|---|---|---|---|
| Locked Wheel: | ASTM E 274 (USA) | 65 | 0.045 | 0.925 | 0 | 0.095 | 0.02 | 0.027 | .97 |
| | LCPC Skid Trailer (F) | 60 | 0.002 | 1.008 | 0 | 0.06 | 0.016 | 0.024 | 0.98 |
| Fixed Slip | OSCAR at 86 % (N)[E] | 52 | –0.03 | 0.864 | 0 | 0.038 | 0.021 | 0.027 | 0.96 |
| | OSCAR at 20 % (N)[E] | 12 | 0.119 | 0.643 | 0 | 0.089 | 0.031 | 0.041 | 0.92 |
| | Komatsu Skid Trailer (J) | 10 | 0.042 | 0.849 | 0 | 0.091 | 0.031 | 0.039 | 0.94 |
| | DWW Trailer (NL) | 43 | 0.019 | 0.868 | 0 | 0.203 | 0.043 | 0.058 | 0.84 |
| | Griptester (UK) | 9.4 | 0.082 | 0.910 | 0 | 0.086 | 0.027 | 0.035 | 0.85 |
| Side Force | Stradograph (DK) | 12.5 | 0.054 | 0.770 | 0 | 0.091 | 0.029 | 0.036 | 0.94 |
| | Odoliograph Wallon (B) | 12.9 | 0.113 | 0.729 | 0 | 0.081 | 0.024 | 0.030 | 0.96 |
| | Odoliograph CRR (B) | 20.5 | 0.113 | 0.746 | 0 | 0.085 | 0.025 | 0.031 | 0.96 |
| | SCRIM Flemish (B) | 20.5 | 0.049 | 0.967 | 0 | 0.074 | 0.023 | 0.03 | 0.96 |
| | SCRIM CEDEX (E) | 20.5 | 0.019 | 0.813 | 0 | 0.131 | 0.043 | 0.056 | 0.84 |
| | SCRIM MOPT (E) | 20.5 | 0.032 | 0.873 | 0 | 0.063 | 0.02 | 0.026 | 0.96 |
| | SCRIM SRM (D) | 20.5 | 0.017 | 0.850 | 0 | 0.067 | 0.018 | 0.026 | 0.97 |
| | SCRIM GEOCISA (E) | 20.5 | 0.021 | 0.928 | 0 | 0.113 | 0.039 | 0.052 | 0.88 |
| | SCRIM (F) | 20.5 | –0.006 | 0.862 | 0 | 0.085 | 0.026 | 0.034 | 0.95 |
| | *SUMMS (I)* | 20.5 | 0.002 | 0.987 | 0 | 0.094 | 0.031 | 0.037 | 0.94 |
| | *SCRIMTEX (UK)* | 17.1 | 0.033 | 0.872 | 0 | 0.112 | 0.30 | 0.039 | 0.93 |
| | Ribbed Tire Devices: | | | | | | | | |
| Locked Wheel | Stuttgarter Reibungmesser (CH) | 60 | 0.022 | 0.0500 | 0.082 | 0.085 | 0.033 | 0.042 | 0.90 |
| | Skiddometer (CH) | 60 | 0.026 | 0.504 | 0.099 | 0.114 | .039 | 0.049 | 0.90 |
| | Stuttgarter Reibungmesser (A) | 60 | –0.072 | 0.767 | 0.086 | 0.124 | 0.038 | 0.049 | 0.90 |
| | ASTM E 274 (USA) | 65 | –0.023 | 0.607 | 0.098 | 0.115 | 0.033 | 0.043 | 0.92 |
| | Friction Tester (PL) | 60 | –0.025 | 0.807 | 0.068 | 0.011 | 0.033 | 0.041 | 0.93 |
| Fixed Slip | Stuttgarter Reibungmesser (CH) | 12 | 0.141 | 0.323 | 0.074 | 0.126 | 0.05 | 0.062 | 0.83 |
| | Skiddometer | 12 | 0.03 | 0.918 | –0.014 | 0.073 | 0.028 | 0.035 | 0.95 |
| | BV-11 (S) | 12 | 0.04 | 0.856 | –0.016 | 0.084 | 0.029 | 0.037 | 0.94 |
| | Stuttgarter Reibungmesser (A) | 12 | 0.02 | 0.867 | –0.006 | 0.118 | 0.033 | 0.041 | 0.92 |
| | Slider Devices: | | | | | | | | |
| | DF Tester at 60 km/h (J) | 60 | –0.034 | 0.771 | 0 | 0.086 | 0.027 | 0.048 | 0.9 |
| | DF Tester at 20 km/h (J) | 20 | 0.081 | 0.732 | 0 | 0.069 | 0.026 | 0.031 | 0.96 |
| | Pendulum Tester BPT (USA) | 10 | 0.056 | 0.008 | 0 | 0.109 | 0.043 | 0.053 | 0.87 |
| | Pendulum Tester SRT (CH) | 10 | 0.044 | 0.01 | 0 | 0.173 | 0.03 | 0.045 | 0.91 |

[A] Max|E| = maximum absolute error.
[B] Ave|E| = average absolute error.
[C] RMSE = root mean square of the residual error.
[D] R = correlation constant.
[E] N = number of data points.

## X2. CALIBRATION OF OTHER EQUIPMENT

X2.1 Using one of the methods that follow, estimate the calibrated values with F60 and $S_p$ on a statistical representative number of sites encompassing a sufficiently wide range of texture and friction (a minimum of 10 is suggested). Equipment that is new and has never been calibrated, or equipment that needs to be recalibrated would then measure the same sites and regressions using the PIARC Model would need to be run to find the constants *a*, *b*, *A*, and *B* (also *C* if the device uses treaded tires).

X2.1.1 As an example, suppose it is desired to use a new texture measuring system other than the MPD. First the device would measure the test (calibration) sites with the texture device and determine F60 and Sp for each site. The measurements would then be repeated using the new texture device, called $TX_{NEW}$. Then a linear regression of $S_p$ and $TX_{NEW}$ would be performed as follows:

$$S_p = a + b \times TX_{NEW} \quad \text{(X2.1)}$$

and the constants *a* and *b* are determined. Then, the slip speed for each run must be determined and the second regression of $FRS_{NEW}$ and F60 needs to be performed as follows:

$$F60 = A + B \times FRS_{NEW} \times EXP\,[(S-60)/Sp] + C \times TX_{NEW} \quad \text{(X2.2)}$$

and the constants A, B and C are determined. Now, with a, b, A, B and C determined, N is calibrated to use $FRS_{NEW}$ and $TX_{NEW}$

X2.2 In all of the sections that follow only equipment that was calibrated in the experiment should be used to establish the calibrated values for recalibration and each must insure that their calibrations have not changed.

X2.2.1 *Using Friction Devices That Were in the Experiment*:

X2.2.1.1 On the ten or more sites with different frictional properties, one can use the equipment that participated in the experiment to measure and estimate the values (F60 and Sp) for the sites, then the new equipment can be calibrated to the estimated "true value" (called target here) as shown above. This method could be improved if several devices that participated in the experiment were used. Then each of them would calculate F60 and $S_p$ and the values would be averaged to estimate the target values for these sites. Obviously the devices that had the better correlation in the experiment would be the better choice to use here as the secondary standard.

X2.2.2 *Using DF tester or Griptester (at Walking Speed)*:

X2.2.2.1 These devices are singled out since they are small and can easily be shipped to a location where there is no equipment that participated in the experiment. Again, ten or more sites are measured with either device along with a texture measure to get *F*60 and $S_p$. Then the new equipment is calibrated in the same manner, except the estimated Target values, F60 and $S_p$, are determined by the DF tester and a texture measure or the Griptester at 5 km/h and a texture measure. Both the DF tester and the Griptester had excellent correlation and are similar to the BPT, but measure over a much larger area than the BPT.