Designation: E 1960 – 03

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. This practice provides for harmonization of friction reporting for devices that use a smooth tread test tire.

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:* [3]

E 867 Terminology of Vehicle-Pavement Systems

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

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

E 1845 Practice for Calculating Pavement Macrotexture Mean Profile Depth

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

[1] This practice is under the jurisdiction of Committee E17 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] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

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

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 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. Mean Profile Depth Determination

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 km/h is determined from the Mean Profile Depth (MPD) in mm as follows:

$$S_p = 14.2 + 89.7\,MPD \quad (1)$$

where *a* and *b* are constants depending upon the method used to determine the macrotexture.

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:

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

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:

$$F60 = A + B \times FR60 \quad (3)$$

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

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

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:

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

9. Calibration of Friction Testers

9.1 Select a set of at least 10 pavements having a range of macrotexture and microtexture. Determine the DFT number at 20 km/h in accordance with Test Method E 1911 for each of the sections. Determine the MPD of each of the sections in accordance with Practice E 1845.

NOTE 5—The pavements should have profile depths for the range: 0.25 < MPD < 1.5 mm and friction values for the range: 0.30 < DFT^{20} < 0.90.

9.2 Compute the values of the Speed Constant and the Friction Number: $S^p = 14.2 + 89.7\,MPD$ $F60 = 0.081 + 0.732\,DFT^{20} exp(-40/S^p)$

9.3 Using the device to be calibrated, determine the friction values (FRS) of the test pavements and calculate the FR60: $FR60 = FRS\,exp[(S - 60)/S^p]$

9.4 Determine the calibration constants (A,B) from a linear regression of the values of FR60 of 9.3 and the F60 values of 9.1: $F60 = A + B\,FR60$

10. Report

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

10.1.1 Date of friction and profile measurement,

10.1.2 Location and identification of the test surface,

10.1.3 Description of the surface type,

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

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

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

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

10.1.8 Type and date of calibration,

10.1.9 Measurement speed,

10.1.10 Percentage of invalid readings eliminated (drop-outs),

10.1.11 Total length measured and the number of segments analyzed,

10.1.12 The IFI values, F60 and S_p, and

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

10.1.14 The date of the most recent calibration of the friction measuring device used.

11. Precision and Bias

11.1 *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.

11.2 *Bias*—There is no basis for determination of the bias in F60 and S_p. 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.

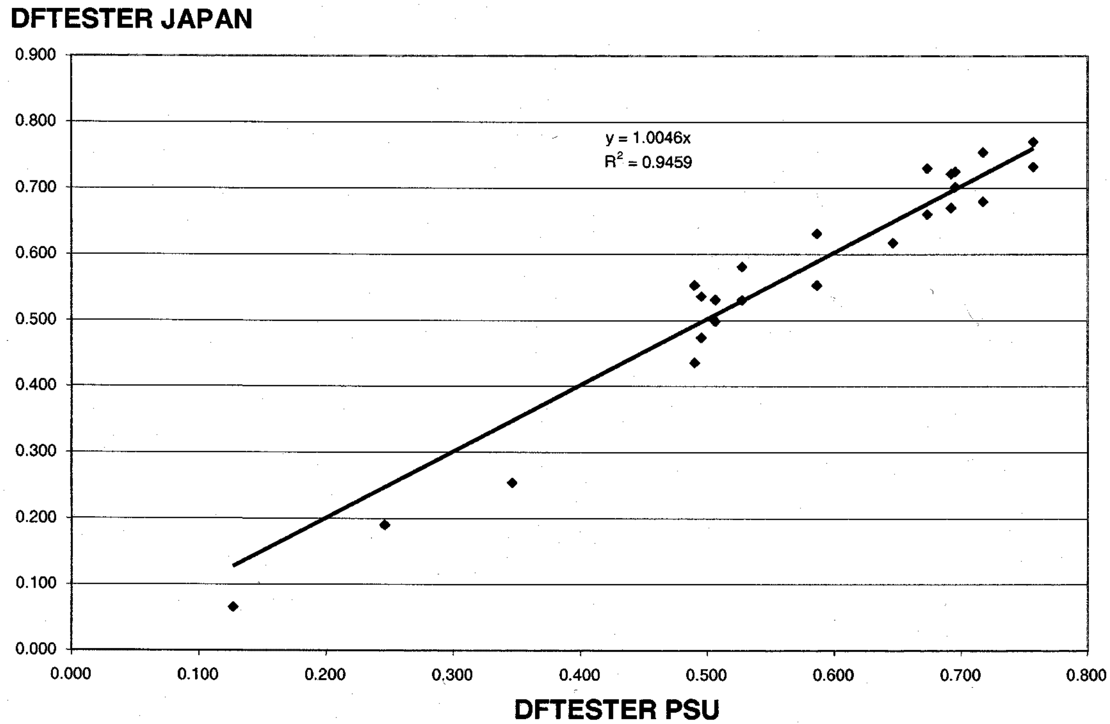

FIG. 1 DFT 20 1996 & 1999 for Two DFTesters

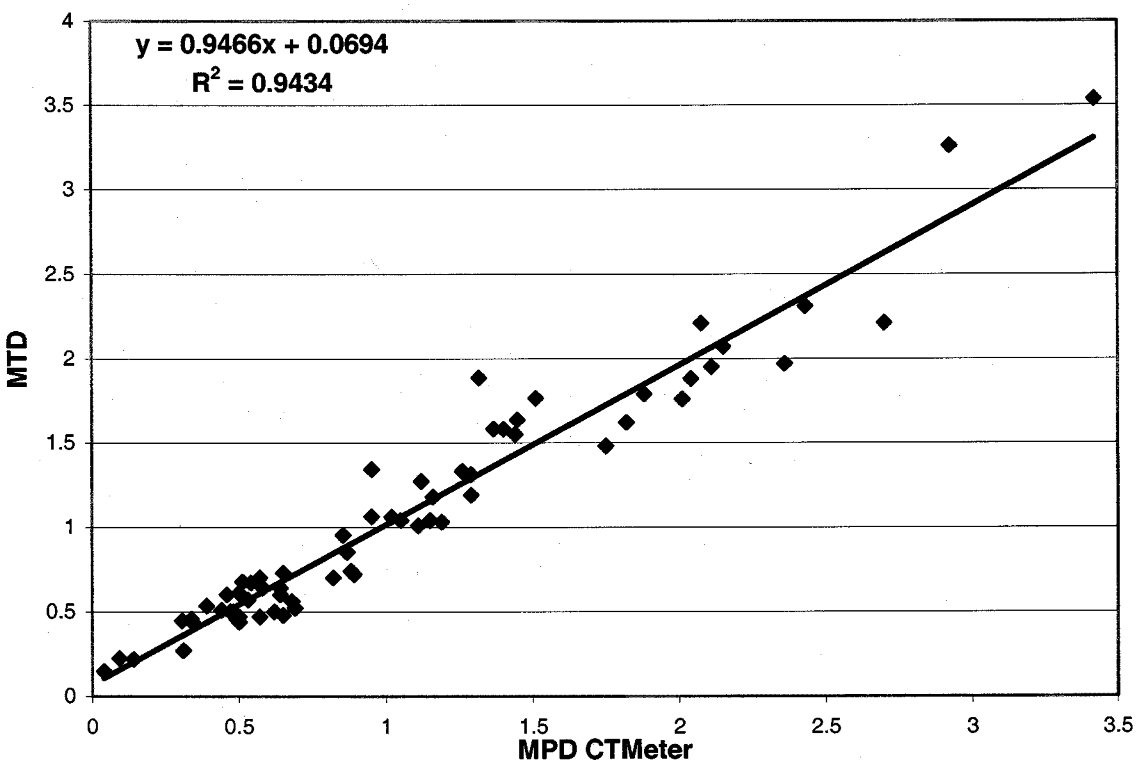

FIG. 2 MTD vs MPD-All 1998–2000

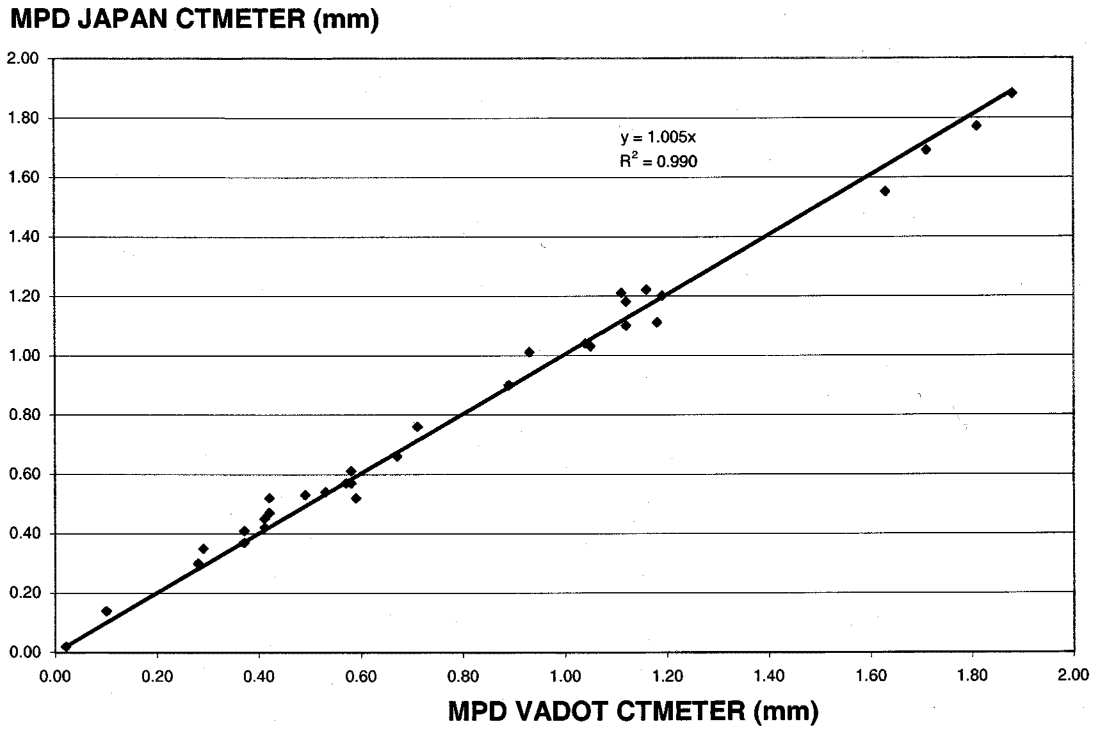

FIG. 3 MPD 2001 & 2002 Data for Two CTMeters