

---

**Standard Method of Test for**

# **Determining the Dielectric Constant of Compacted Asphalt Mixture Specimens**

---

**AASHTO Designation: T 414-24<sup>1</sup>**

**First Published: 2024**

**Technical Subcommittee: TS 5c, Quality Assurance  
and Environmental**



**American Association of State Highway and Transportation Officials  
555 12th Street NW, Suite 1000  
Washington, DC 20004**

# Determining the Dielectric Constant of Compacted Asphalt Mixture Specimens

AASHTO Designation: T 414-24<sup>1</sup>



First Published: 2024

Technical Subcommittee: TS 5c, Quality Assurance and Environmental

## 1. SCOPE

- 1.1. This standard covers the standard test method for obtaining the dielectric constant of compacted dense-graded asphalt mixture specimens using a laboratory dielectric measurement system (LDMS).
- 1.2. The values stated in SI units are to be regarded as the standard.
- 1.3. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all the safety concerns associated with its use. It is the responsibility of the user of this procedure to establish appropriate health and safety practices and to determine the applicability of regulatory limitations prior to its use.*
- 1.4. *The quality of the results produced by this standard is dependent on the competence of the personnel performing the procedure and the capability, calibration, and maintenance of the equipment used. Agencies that meet the criteria of R 18 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with R 18 alone does not completely assure reliable results. Reliable results depend on many factors; following the suggestions of R 18 or some similar acceptable guideline provides a means of evaluating and controlling some of those factors.*

## 2. REFERENCED DOCUMENTS

- 2.1. *AASHTO Standards:*
  - R 35, Superpave Volumetric Design for Asphalt Mixtures
  - R 37, Application of Ground Penetrating Radar (GPR) to Highways
  - T 312, Preparing and Determining the Density of Asphalt Mixture Specimens by Means of the Superpave Gyratory Compactor
  - PP 98-19, Asphalt Surface Dielectric Profiling System Using Ground Penetrating Radar
- 2.2. *ASTM Standards:*
  - D8, Standard Terminology Relating to Materials for Roads and Pavements
  - D150, Standard Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation
  - D2520, Standard Test Methods for Complex Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials at Microwave Frequencies and Temperatures to 1650°C

- D3549/D3549M, Standard Test Method for Thickness or Height of Compacted Asphalt Mixture Specimens
- D4748, Standard Test Method for Determining the Thickness of Bound Pavement Layers Using Short-Pulse Radar

### 2.3.

#### *Other Documents:*

- Hoegh, K., R. Roberts, S. Dai, and E. Zegeye Teshale. Toward Core-Free Pavement Compaction Evaluation: An Innovative Method Relating Asphalt Permittivity to Density. *Geosciences*, Vol. 9, No. 7, 2019, p. 280. Available from <https://doi.org/10.3390/geosciences9070280>
- Hoegh, K., T. Steiner, E. Zegeye Teshale, and S. Dai. Minnesota Department of Transportation Case Studies for Coreless Asphalt Pavement Compaction Assessment. *Transportation Research Record* 2674, No. 2, 2020, pp. 291–301. Available from <https://www.dot.state.mn.us/materials/dps/publications.html>
- Leiva, F., A. Brenes, S. Chowdari, and J. Musselman. Continuous Asphalt Mixture Compaction Assessment Using Density Profiling System (DPS). National Center for Asphalt Technology Report. National Pooled Fund TPF-5(443), June 2022. Available from <https://www.dot.state.mn.us/materials/dps/publications.html>
- Parker, R. A., C. Scott, V. Inácio, and N. T. Stevens. Using Multiple Agreement Methods for Continuous Repeated Measures Data: A Tutorial for Practitioners. *BMC Medical Research Methodology*, Vol. 20, No. 1, 2020. Available from <https://doi.org/10.1186/s12874-020-01022-x>
- Sias, J. and E. Dave. *NCHRP IDEA Final Report for Project 229: Laboratory Dielectric Measurement System (LDMS) for Asphalt Mixture Bulk Specific Gravity Determination*. Transportation Research Board, National Research Council, Washington, DC, 2023. Available from <https://www.trb.org/Main/Blurbs/182942.aspx>
- Steiner, T., K. Hoegh, E. Zegeye Teshale, and S. Dai. Method for Assessment of Modeling Quality for Asphalt Dielectric Constant to Density Calibration. *Journal of Transportation Engineering, Part B: Pavements*, Vol. 146, No. 3, 2020. Available from <https://doi.org/10.1061/JPEODX.0000210>

## 3. TERMINOLOGY

3.1. The definitions shall be in accordance with the terms and symbols given in terminologies and definitions from R 37 and PP 98-19.

3.2. *Definitions of Terms Specific to This Standard:*

3.2.1. *laboratory dielectric measurement system (LDMS)*—an instrument that measures the dielectric constant ( $\epsilon$ ) of an asphalt specimen by measuring the time of flight (TOF) of an electromagnetic wave through the specimen. The LDMS is operated with a dielectric coupler, with all remaining terminology of the LDMS following that of a single-channel air coupled GPR system meeting the requirements of ASTM D4748. Hardware and factory operating requirements for the LDMS shall be in accordance with Section 5.4.

3.2.2. *dielectric constant*—the measured dielectric property of a compacted asphalt mixture specimen. The dielectric constant ( $\epsilon$ ) is directly related to the velocity of the electromagnetic wave according to R 37 Equation 2, and thus can be determined by measuring the roundtrip TOF through the depth of an asphalt specimen with known dimensions and dielectric couplers with known dimensions and dielectric constants (Hoegh et al., 2019 and 2020). Details of the measurement process are outlined in Section 2.3, “Approach 2: Dielectric Obtained from Two-Way Travel Time and Known Thickness (TOF Dielectric),” of Hoegh et al. (2019).

3.2.3. *orientations*—angle measured along the tangential direction of a cylindrical specimen with respect to the plane formed by axial and radial directions.

3.2.4. *representative dielectric measurement* ( $e_{\text{MEAN}}$ )—the final dielectric value applied to the test specimen if it meets the measurement operating requirement defined in Section 3.2.8.

3.2.5. *dielectric concordance correlation coefficient (DCCC)*—the concordance correlation coefficient (CCC) is an index that is usually implemented to quantify the degree of agreement between observers or equipment for measuring a continuous characteristic (Leiva et al., 2022). The CCC combines measures of both precision and accuracy to determine how far the observed data deviate from the line of perfect concordance (that is, the line at 45 degrees on a square scatter plot or identity line). This coefficient can take values between  $-1$  and  $1$ , where  $-1$  means perfect disagreement,  $0$  would represent an independent situation where all the readings are random, and a value of  $1$  states a perfect agreement where paired observations fall exactly on the identity line of perfect concordance. Perform dielectric constant measurements on at least ten specimens where the agreement between Operator (O- DCCC), Antenna (A- DCCC), or Specimen (S- DCCC) can be assessed. Each specimen shall be unique and meet specimen requirements described in Section 6. Each specimen can be fabricated from the same mix or randomly varying mixes. The measure is designed for use in a controlled environment and any LDMS is required to pass all three measures (O-DCCC, A-DCCC, and S-DCCC) prior to use. This index can be calculated assuming a normal distribution with a designated mean,  $\mu$ , for each observations group or specimen (denoted as subscript 1 or 2 in Equation 1); its specimen variance,  $\sigma$ ; and their covariance,  $\sigma_{12}$ , as shown in Equation 1.

$$DCCC = \frac{2\sigma_{12}}{(\mu_1 - \mu_2) + \sigma_1^2 + \sigma_2^2} = \rho C_b \quad (1)$$

The Pearson correlation coefficient,  $|\rho| \leq 1$ , measures how far each observation deviated from the best-fit line (a precision measure) and  $C_b$ , the accuracy,  $0 < C_b \leq 1$ , measures how far the best-fit line deviates from the identity line.

3.2.6. *dielectric coverage probability (DCP)*—in order to determine whether the differences between the evaluated devices are small enough to be considered acceptable or whether the sensors/operators/specimen orientations are replaceable by each other, the coverage probability (CP) can be implemented. According to Parker et al. (2020), this index represents the probability that the between-device/operator/specimen orientation differences are within the boundary of some predefined tolerance interval. Higher probabilities allow two devices/operators/specimen orientations to be used interchangeably since higher probabilities indicate closer agreement. Parker et al. (2020) evidenced that the mean squared deviation (MSD) between readings by two different devices,  $Y_1$ ,  $Y_2$ , and the standard normal cumulative distribution function,  $\Phi$ , are needed for quantifying the CP at the defined acceptable limit,  $\delta$ , as shown in Equation 2 below.

$$CP(\delta) = 1 - 2 \left[ 1 - \Phi \left( \frac{\delta}{\sqrt{MSD(Y_1, Y_2)}} \right) \right] \quad (2)$$

A widely accepted criterion is that at least 90 percent of the observations shall be within the defined acceptable limit (Parker et al., 2020). Specifically, in this study, an acceptable difference of 0.06 between the dielectric constant values was selected to be 0.06 based on PP 98-19. In other words, the calculated CP for the defined limit of 0.06 shall be greater than 90 percent to be interchangeable.

3.2.7. *dielectric total deviation index (DTDI)*—the total deviation index (TDI) is strongly related to CP. For the DCP, the range of acceptable differences shall be specified and then the probability of data on that range is calculated (Parker et al., 2020). On the other hand, the DTDI reverses this process. Where for a given probability to achieve  $p$ , the TDI calculation provides the boundary within