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Standard Practice for Determining the Continuous Grading Temperatures and Continuous Grades for PG Graded Asphalt Binders[1]

This standard is issued under the fixed designation D7643; 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 is used to ~~determine~~estimate the continuous grading temperatures and continuous grade for an asphalt binder graded in accordance with the ~~specification criteria~~ requirements specified in ~~D6373,~~Specification D6373~~Standard Specification for Performance-Graded Asphalt Binders.~~.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *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:*[2]

D8 Terminology Relating to Materials for Roads and Pavements
D2872 Test Method for Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test)
D6373 Specification for Performance Graded Asphalt Binder
D6521 Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)
D6648 Test Method for Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)
D6723 Test Method for Determining the Fracture Properties of Asphalt Binder in Direct Tension (DT)
D6816 Practice for Determining Low-Temperature Performance Grade (PG) of Asphalt Binders
D7175 Test Method for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer

3. Terminology

3.1 *Definitions:* Definitions for many terms common to asphalt cement and asphalt binder are found in Terminology D8.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *continuous grade, n*—a grade defined by the estimated upper and lower continuous grading temperatures.

3.2.2 *continuous grading temperatures, T_c, n*—the ~~high, intermediate, and low~~ estimated temperatures at which the properties of an asphalt binder are equal to the specification requirements given in Tables 1 or 2 of Specification D6373 ~~are met.~~.

3.2.3 ~~*continuous grade,*~~*difference between estimated continuous grading* ~~*n—*~~*temperature for S and the m-value, ΔT_c*~~—a grade defined by upper and lower continuous grading temperatures.~~ determined by subtracting the continuous grading temperature for the m-value from the continuous grading temperature for S.

3.2.4 *PG grading temperatures, T_{PG}, n*—the temperatures listed in Specification D6373 used to designate the grade of a PG binder, for example, ~~64ºC, 22ºC~~64 °C, 22 °C, and ~~-28ºC~~–28 °C for a PG 64-28.

3.2.5 *specification requirements, n*—the limiting values given in Specification D6373 that are used to grade an asphalt binder, for example, 1.00 kPa for G*/sinδ, 300 MPa for S, etc.

[1] This practice is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.44 on Rheological Tests.

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[2] 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.

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3.2.6 *test temperatures, T_1 and T_2, n*—two PG grading temperatures, one grade apart ~~and with $T_2 > T_1$~~ such that the ~~test~~measured properties at the two temperatures bracket the specification requirement for the property in question.

~~3.2.5 *specification requirements, n*—the limiting values given in Specification D6373 that are used to grade an asphalt binder, for example, 1.00 kPa for G*/sinδ, 300 MPa for S(60), etc.~~

4. Summary of Practice

4.1 The ~~temperatures required to determine the continuous grading temperatures and grade are obtained from test results obtained at the specification grading temperatures as listed in Specification~~ continuous grading temperature D6373 ~~and,~~ for each specification ~~requirement, at a second temperature above or below the specification grading temperature. The continuous grading temperature~~ requirement is determined by interpolating between ~~the two test temperatures to calculate the test temperature at which~~ test results obtained at two adjacent specification temperatures. The two temperatures are chosen so that the test result at one temperature is greater than the specification requirement ~~is met. The continuous grading temperatures are then used~~ and the test result at the other temperature is less than the specification requirement. The upper continuous grade is determined as the lower of the two continuous grading temperatures determined for the original and RTFOT condition (Test Methods D2872 and D7175~~to determine the continuous~~). The intermediate continuous grade is equal to the intermediate continuous grading temperature (Practice D6521, Test Method D7175~~grade of the asphalt binder.~~). The lower continuous grade is determined as the higher of the continuous grading temperatures for S and the m-value (Practice D6521, Test Method D6648).

5. Significance and Use

5.1 The continuous grading temperatures and continuous grade are used for informational purposes only and ~~are~~shall not be used for the sale or purchase of asphalt binders. The continuous grading temperatures and continuous grade may be used for forensic or research studies and when producing, blending, modifying, or otherwise evaluating asphalt binders. This guide is applicable to Specification D6373, Tables 1 and 2.

6. Procedure

6.1 ~~*Conduct tests*—For each of the specification properties (for example, G*/sinδ, S(60), etc.) for which a~~ Conduct tests as described below.~~T_C is to be calculated determine the test results at two temperatures, T_1 and T_2 such that T_2 is greater than T_1. The difference between T_1 and T_2 shall be 6ºC for the upper and lower test temperatures and 3ºC for the intermediate temperature. The two temperatures shall provide test results that bracket the specification requirements.~~

~~NOTE 1—For example, a PG 64-XX tested for G*/sinδ at 64ºC and 70ºC may give test results of 1.86 and 0.89 kPa respectively. These results bracket the specification requirement, 1.00 kPa.~~

6.1.1 *Testing When Continuous Grading Criteria Do Not Include Failure Strain (Table 1)*—~~If the results~~ For each of the ~~applicable specification provides a temperature rather than a limiting property value (for example,~~ specification properties (for example, G*/sinδ, S, m-value, etc.) for which a continuous grading temperature is to be determined, obtain test results at two test temperatures, T_{CR1} and T_2 as described in 3.2.6~~Specification. D6373, Table 2) then the temperature shall be used as the~~When the intermediate grading temperature is required, the difference between ~~*continuous*~~T_1 ~~grading~~and ~~*temperature.*~~T_2 shall be 3 °C.

NOTE 1—For example, a PG 64-XX tested for G*/sinδ at 64 °C and 70 °C may give test results of 1.86 and 0.89 kPa, respectively. These results bracket the specification requirement 1.00 kPa.

6.1.2 *Testing When Continuous Grading Criteria Include Failure Strain (Table 1)*—For the low temperature, obtain test results for S and the m-value (as described in 6.1.1) and determine the strain at failure at two test temperatures, T_1 and T_2, such that test results bracket 1 %.

NOTE 2—Additional testing may be required to verify that S is between 300 and 600 MPa at the low temperature PG grade.

6.1.3 *Testing When Using Table 2*—For the low temperature, only perform the testing needed to determine the critical cracking temperature.

6.2 *Perform Interpolation to Determine Continuous Grading Temperatures*—For each pair of test results obtained as per 6.1 ~~determine the continuous grading temperature by interpolating~~, interpolate between T_1 and T_2 to determine the temperature at which the test results would equal the respective specification requirement. The interpolated ~~temperature~~temperatures shall be reported as the continuous grading ~~temperature.~~temperatures.

6.2.1 ~~The interpolation for each of the properties, except the m-value, shall be done using a linear relationship between the test results (log~~For the upper and intermediate continuous grading temperatures the interpolation shall be on a semi-logarithmic scale using the ~~$_{10}$ scale) and the test temperature (arithmetic scale). The interpolation takes the following form:~~following equation:

$$T_C = T_1 + \left(\frac{log_{10}(P_S) - log_{10}(P_1)}{log_{10}(P_2) - log_{10}(P_1)}\right)(T_2 - T_1) \quad (1)$$

$$T_C = T_1 + \{\log_{10}(P_S) - \log_{10}(P_1)\}\{T_2 - T_1\} / \{\log_{10}(P_2) - \log_{10}(P_1)\} \quad (1)$$

where:

~~T_C = Continuous grading temperature, °C,~~
~~T_1 = Lower of the two test temperatures, °C,~~
~~P_S = Specification requirement for property in question; determined at the respective PG grading temperature for the respective property,~~
~~P_1 = Test result for the specification property in question at T_1,~~
~~P_2 = Test result for the specification property in question at T_2, and~~
~~T_2 = Higher of two test temperatures, °C.~~

T_C = continuous grading temperature for the specification requirement in question, °C,
T_1, T_2 = test temperatures, °C,
P_S = specification requirement for property in question, and
P_1, P_2 = test result for the specification property in question at T_1 and T_2, respectively.

6.2.2 ~~The interpolation for the m-value shall be done using an arithmetic scale. The interpolation takes the following form:~~For the lower continuous grading temperature the interpolation for S shall be on a semi-logarithmic scale using the following equation:

$$T_C = T_1 + \left(\frac{P_S - P_1}{P_2 - P_1}\right)(T_2 - T_1) \quad (2)$$

$$T_C = T_1 + \{\log_{10}(P_S) - \log_{10}(P_1)\}\{T_2 - T_1\} / \{\log_{10}(P_2) - \log_{10}(P_1)\} - 10° \text{ C} \quad (2)$$

NOTE 3—~~Equations~~For ~~and~~calculation purposes, T_1 ~~are valid whether the test results increase with temperature~~may be designated as the upper or lower temperature as long as the corresponding test result is used for ~~or~~P_1. ~~decrease with temperature.~~ When using these equations retain the negative signs for temperatures below ~~0°C.~~0 °C.

NOTE 4—Because the properties are a non-linear function of temperature ~~linear interpolation results in a~~adjacent grading temperatures should always be used in Eq 1 ~~slight~~or Eq 2~~error in the estimated values of T~~. Otherwise the interpolation will give differing$_{GC}$ results.

NOTE 5—The TREND function in Excel performs linear regression and can be used to solve Eq 1 and 2. However, when using the TREND function, arithmetic values of T_1 and T_2 must be used for the *Y*s and logarithmic values of P_1,P_2, and P_S must be used for the *X*s. The arithmetic value of the properties and specification requirement are used in the TREND function when calculating the continuous grading temperature for the m-value and failure strain.

6.2.3 For the lower continuous grading temperature, the interpolation for the m-value shall be on an arithmetic scale using the following equation:

$$T_C = T_1 + \{P_S - P_1\}\{T_2 - T_1\} / \{P_2 - P_1\} - 10° \text{ C} \quad (3)$$

6.3 ~~*Determine Continuous Grade*—~~Determine ~~the~~ continuous grade ~~based on the upper and lower~~and ΔT_C ~~continuous grading temperature using the same rationale as presented in Specification~~ as described below.~~D6373. The lower of the two upper continuous grading temperatures (for G*/sinδ, Original and RTFO) shall determine the upper continuous grade. The upper of the two continuous grading temperatures (for S and m, PAV) shall determine the lower continuous grade. The intermediate temperature criterion as given in Specification D6373 is not considered when determining the continuous grade but may be reported in parenthesis as a suffix to the continuous grade. Sample problems are given in Appendix X1.~~

6.3.1 *Continuous Grade When the Criteria Do Not Include Failure Strain (Table 1)*—Determine the continuous grade based on the upper and lower continuous grading temperatures using the same rationale as presented in Specification D6373. The lower of the two upper continuous grading temperatures (for G*/sinδ, original, and RTFO) shall determine the high temperature for the PG grade. The upper of the two continuous grading temperatures (for S and the m-value) shall determine the low temperature for the PG grade.

6.3.2 *Continuous Grade When the Criteria Include Failure Strain, Table 1*—The upper of the two continuous grading temperatures for the m-value and the failure strain at 1% shall determine the low temperature for the PG grade with the requirement that S must be between 300 and 600 MPa.

6.3.3 *Table 2*—The low temperature for the PG grade is equal to the thermal cracking temperature, T_{CR}, as determined by using Test Method D6723 and Practice D6816.

6.3.4 *ΔT_C*—Calculate ΔT_C as the continuous grading temperature for S minus the continuous grading temperature for the m-value.

NOTE 6—ΔT_C is positive if the continuous grading temperature for S is above the continuous grading temperature for the m-value and negative if the continuous grading temperature for the m-value is above the continuous grading temperature for S.

7. Report

7.1 *Continuous Grading Temperatures*—Report the ~~upper, intermediate,~~ upper and lower continuous grading temperatures to the nearest ~~0.1°C using the procedure as described in~~0.1 °C, and when required also report the intermediate continuous grading temperatures ~~6.2.~~to the nearest 0.1 °C.

~~7.2 *Intermediate Continuous Grading Temperature (Optional)*—Although the intermediate criteria is not considered when determining the continuous grade, the intermediate continuous grading temperature may be included for informational purposes as part of the continuous grade.~~

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