Designation: D7643 – 16

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 estimate the continuous grading temperatures and continuous grade for an asphalt binder graded in accordance with the requirements specified in Specification D6373.

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 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.

3.2.3 *difference between estimated continuous grading temperature for S and the m-value, ΔT_C*—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, 64 °C, 22 °C, and –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.

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

4. Summary of Practice

4.1 The continuous grading temperature for each specification requirement is determined by interpolating between 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 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

[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.

(Test Methods D2872 and D7175). The intermediate continuous grade is equal to the intermediate continuous grading temperature (Practice D6521, Test Method D7175). 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 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 as described below.

6.1.1 *Testing When Continuous Grading Criteria Do Not Include Failure Strain (Table 1)*—For each of the 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_1 and T_2 as described in 3.2.6. When the intermediate grading temperature is required, the difference between T_1 and 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, interpolate between T_1 and T_2 to determine the temperature at which the test results would equal the respective specification requirement. The interpolated temperatures shall be reported as the continuous grading temperatures.

6.2.1 For the upper and intermediate continuous grading temperatures the interpolation shall be on a semi-logarithmic scale using the following equation:

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

where:

T_C = continuous grading temperature 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 For the lower continuous grading temperature the interpolation for S shall be on a semi-logarithmic scale using the following equation:

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

NOTE 3—For calculation purposes, T_1 may be designated as the upper or lower temperature as long as the corresponding test result is used for P_1. When using these equations retain the negative signs for temperatures below 0 °C.

NOTE 4—Because the properties are a non-linear function of temperature adjacent grading temperatures should always be used in Eq 1 or Eq 2. Otherwise the interpolation will give differing 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 and ΔT_C as described below.

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 and lower continuous grading temperatures to the nearest 0.1 °C, and when required also report the intermediate continuous grading temperatures to the nearest 0.1 °C.

7.2 *Continuous Grade*—Report the continuous grade to the nearest 0.1 °C using the procedure described in 6.3, for example, PG 61.9-22.6.

7.2.1 *Intermediate Continuous Grade*—When required, report the intermediate continuous grading temperature as a suffix to the continuous grade, for example, PG 61.9-22.6 (19.3).

7.3 ΔT_C—When required, report ΔT_C to the nearest 0.1 °C.

7.4 *Grading Criteria Used*—Report the use of Table 1 failure strain or Table 2, if used.

8. Keywords

8.1 continuous grade; continuous grading temperature; performance graded binders (PG Grade)

APPENDIX

(Nonmandatory Information)

X1. SAMPLE PROBLEMS AND COMMENTARY

X1.1 Table X1.1, *Column 1*—Data necessary to verify the Specification D6373 Table 1 PG grade for sample A are given in column 1. Passing test results are shown for each specification requirement. A single test result for each specification requirement is sufficient to verify a PG grade. Note that the test results that satisfy the specification requirement are underlined in Table X1.1. The symbol 'X' indicates that there is insufficient information to complete the required calculation, either due to a data error or insufficient information.

X1.2 Table X1.1, *Column 2*—The additional data required to determine the continuous grading temperatures for Sample A have been added to column 2. In order to determine the continuous grading temperature, passing and failing test results are needed for each specification requirement. For each specification requirement, the continuous grading temperature is then calculated using Eq 1 or Eq 2. The lower of the two continuous grading temperatures (87.2 °C versus 87.6 °C) determines the upper continuous grade and the upper of the two

TABLE X1.1 Sample Problems with Commentary: D6373 Table 1

NOTE 1—X = Insufficient information to make determination.

Comments		Column 1 Asphalt Binder A Grading Only	Column 2 Asphalt Binder A with ΔT_C	Column 3 Asphalt Binder B	Column 4 Asphalt Binder C
PG Grade:[A]		82-28(31)	82-28(31)	76-34(25)	X-28(X)
Continuous Grade:		X-X(X)	87.2-32.8-29.3	X-35.4-26.8	X-32.9(X)
ΔT_C, °C:		X	+0.4	−4.1	+0.7
Upper Original: $G^*/\sin\delta \geq 1.00$	T_1, °C	82	82	76	76
	$G^*/\sin\delta$ at T_1, kPa	1.83	1.83	1.98	1.49
	T_2, °C	88	88	82	82
	$G^*/\sin\delta$ at T_2, kPa	0.91	0.91	0.98	0.82
Highest Passing Temperature, °C		82	82	76	76
Continuous Grading Temperature, °C		87.2	87.2	81.8	80.0
Upper RTFOT: $G^*/\sin\delta \geq 2.20$	Test Temp. T_1, °C	82	82	82	76
	$G^*/\sin\delta$ at T_1, kPa	4.21	4.21	2.30	2.31
	Test Temp.T_2, °C		88		82
	$G^*/\sin\delta$ at T_2, kPa		2.10		4.29
Highest Passing Temperature, °C		82	82	82	X
Continuous Grading Temperature, °C			87.6	X	X
Intermediate PAV: $G^*/\sin\delta \leq 5000$	Test Temp. T_1, °C	28	31	28	28
	$G^*/\sin\delta$ at T_1, kPa	3920	3920	3850	2490
	Test Temp.T_2, °C		28	25	25
	$G^*/\sin\delta$ at T_1, MPa		6020	7610	7120
Lowest Passing Temperature, °C		28	31	28	28
Continuous Grading Temperature, °C			29.3	26.8	X
Lower PAV: $S(60) \leq 300$	Test Temp. T_1, °C	−18	−18	−24	−18
	S(60) at T_1, MPa	163	163	153	147
	Test Temp.T_2, °C		−24	−30	−24
	S(60) at T_1, MPa		350	321	350
Lowest Passing Temperature, °C		−28	−28	−34	−18
Continuous Grading Temperature, °C			−32.8	−39.5	−32.9
Lower PAV: $m(60) \geq 0.300$	Test Temp. T_1, °C	−18	−18	−24	−18
	m-value at T_1	0.363	0.363	0.303	0.331
	Test Temp.T_2, °C		−24	−34	−24
	m-value at T_2		0.290	0.278	0.298
Lowest Passing Temperature, °C		−28	−28	−34	−28
Continuous Grading Temperature, °C			−33.2	−35.4	−33.6

[A] Intermediate PG Grade calculated from test results as (4 °C + average of upper and lower grading temperatures).

lower continuous grading temperatures (–32.8 °C versus –33.2 °C) determines the lower continuous grade. For the intermediate grading temperature, the continuous grade is equal to the continuous grading temperature (26.3 °C).

X1.3 Table X1.1, *Column 3*—In column 3 the continuous grading temperature for the original binder is in one grade interval (between 76 °C and 82 °C) below the interval for the RTFOT (between 82 °C and 88 °C). The continuous grading temperature for the original controls the continuous grade and a second (failing) test result for the RTFOT condition is not needed. However, the 82 °C test result is needed to determine the continuous grading temperature for the RTFOT condition and the continuous upper grade. A similar situation can occur at the lower temperature if the continuous grading temperature for S and the m-value fall in different grading temperature intervals.

X1.4 Table X1.1, *Column 4*—Several data errors that prevent the correct calculation of either the continuous grading temperature or the continuous grade are illustrated in column 4. The test results for the RTFOT residue do not bracket the specification requirement. Therefore the continuous grading temperature cannot be determined and as a consequence the upper continuous grade cannot be determined. The test results for the intermediate temperature were obtained at a 6-°C interval whereas 3-°C interval is required for the intermediate temperature. The continuous grading temperature and continuous grade cannot be determined because the intermediate temperature test results were obtained with a 6-°C interval as opposed to the required 3-°C interval.

X1.5 Table X1.2, *Column 1 (Specification D6373 Table 1, 1 % Strain)*—The PG grade is 64-28, controlled by the percent strain (≥1.00 %), S (between 300 and 600 MPa, and the

TABLE X1.2 Sample Problems with Commentary: D6373 Table 1 1 % Strain and D6373 Table 2

NOTE 1—n/a = Does not apply to this requirement

Comments		Column 1 Asphalt Binder D ε_f	Column 2 Asphalt Binder E T_{CR}
PG Grade:[A]		64-28(22)	76-34(28)
Continuous Grade:		66.4-X(26.5)	87.2-34.7(26.5)
ΔT_C, °C:		X	+0.4
Upper Original: $G^*/\sin\delta \geq 1.00$	T_1, °C	64	76
	$G^*/\sin\delta$ at T_1, kPa	1.21	1.48
	T_2, °C	70	82
	$G^*/\sin\delta$ at T_2, kPa	0.75	0.78
Highest Passing Temperature, °C		64	76
Continuous Grading Temperature, °C		66.4	79.7
Upper RTFOT: $G^*/\sin\delta \geq 2.20$	Test Temp. T_1, °C	64	76
	$G^*/\sin\delta$ at T_1, kPa	3.17	3.62
	Test Temp.T_2, °C	70	82
	$G^*/\sin\delta$ at T_2, kPa	1.69	1.77
Highest Passing Temperature, °C		64	76
Continuous Grading Temperature, °C		67.5	80.2
Intermediate PAV: $G^*/\sin\delta \leq 5000$	Test Temp. T_1, °C	22	28
	$G^*/\sin\delta$ at T_1, kPa	2340	3340
	Test Temp.T_2, °C	19	25
	$G^*/\sin\delta$ at T_1, MPa	5690	7621
Lowest Passing Temperature, °C		22	28
Continuous Grading Temperature, °C		19.4	26.5
Lower PAV: $S(60) \leq 300$	Test Temp. T_1, °C	–18	–18
	S(60) at T_1, MPa	312	147
	Test Temp.T_2, °C	–24	–24
	S(60) at T_1, MPa	650	350
Lowest Passing Temperature, °C		X	–18
Continuous Grading Temperature, °C		X	–32.9
Lower PAV: $m(60) \geq 0.300$	Test Temp. T_1, °C	–18	–18
	m-value at T_1	0.312	0.331
	Test Temp.T_2, °C	–24	–24
	m-value at T_2	0.278	0.298
Lowest Passing Temperature, °C		–28	–28
Continuous Grading Temperature, °C		–30.1	–33.6
Lower PAV: ε_f, % ≥ 1.000	Test Temp. T_1, °C	–18	n/a
	ε_f, % at T_1	4.2	n/a
	Test Temp.T_2, °C	–24	n/a
	ε_f, % at T_2	0.9	n/a
Lower PAV: T_{CR}, (Practice D6816), °C		n/a	–34.8

[A] Intermediate PG Grade calculated from test results as (4 °C + average of upper and lower grading temperatures).

m-value (>0.300). The lower continuous grade is determined from a set of passing-failing temperatures for S and the m-value. A third BBR test at –12 °C is required to determine the continuous grading temperature for S and the low temperature grade. ΔT_C is always based upon the continuous grading temperatures where S is equal to 300 MPa and the m-value is equal to 0.300.

X1.6 *Illustration of Table 2 (Specification D6373 Table 2, T_{CR})*—The two pairs of test results for S and the m-value determine the continuous grading temperatures and ΔT_C. The PG grade is equal to T_{CR} as determined from Practice D6816. A set of test results for S and the m-value at multiple test times (not shown) would be required to determine the critical cracking temperature. ΔT_C is always based upon the continuous grading temperatures where S is equal to 300 MPa and the m-value is equal to 0.300.