Designation: D7064/D7064M − 08 (Reapproved 2013)

Standard Practice for Open-Graded Friction Course (OGFC) Mix Design[1]

This standard is issued under the fixed designation D7064/D7064M; 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 mix design of open-graded friction course (OGFC) using the superpave gyratory compactor (SGC) or other suitable forms of compaction. The OGFC mix design is based on the volumetric properties of the mix in terms of air voids, and the presence of stone-on-stone contact. Information found in Guide D6932 should be reviewed before starting the mix design. Where applicable, Specification D3666 should be applied as a minimum for agencies testing and inspecting road and paving materials.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the 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]

C29/C29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate
C127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate
C131 Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
C136 Test Method for Sieve Analysis of Fine and Coarse Aggregates
C1252 Test Methods for Uncompacted Void Content of Fine Aggregate (as Influenced by Particle Shape, Surface Texture, and Grading)
D946 Specification for Penetration-Graded Asphalt Cement for Use in Pavement Construction
D2041 Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
D2419 Test Method for Sand Equivalent Value of Soils and Fine Aggregate
D3203 Test Method for Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures
D3381 Specification for Viscosity-Graded Asphalt Cement for Use in Pavement Construction
D3666 Specification for Minimum Requirements for Agencies Testing and Inspecting Road and Paving Materials
D4791 Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate
D5821 Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate
D6114 Specification for Asphalt-Rubber Binder
D6373 Specification for Performance Graded Asphalt Binder
D6390 Test Method for Determination of Draindown Characteristics in Uncompacted Asphalt Mixtures
D6752 Test Method for Bulk Specific Gravity and Density of Compacted Bituminous Mixtures Using Automatic Vacuum Sealing Method
D6857 Test Method for Maximum Specific Gravity and Density of Bituminous Paving Mixtures Using Automatic Vacuum Sealing Method
D6925 Test Method for Preparation and Determination of the Relative Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor
D6926 Practice for Preparation of Bituminous Specimens Using Marshall Apparatus
D6932 Guide for Materials and Construction of Open-Graded Friction Course Plant Mixtures

2.2 *AASHTO Standards:*[3]

R 30 Mixture Conditioning of Hot Mix Asphalt (HMA)
T 283 Resistance of Compacted Bituminous Mixture to

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[1] This practice is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.23 on Plant-Mixed Bituminous Surfaces and Bases.

Current edition approved Dec. 1, 2013. Published February 2014. Originally approved in 2004. Last previous edition approved in 2008 as D7064/D7064M – 08$^{\varepsilon 1}$. DOI: 10.1520/D7064_D7064M-08R13.

[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.

[3] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, http://www.transportation.org.

Moisture-Induced Damage[3]

2.3 *Other References:*

TRB Synthesis 284

NCAT Report No. 2001-01 Design, Construction, and Performance of New-Generation Open-Graded Friction Courses

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *open-graded friction course (OGFC), n*—special type of hot mix asphalt surface mixture used for reducing hydroplaning and potential for skidding, where the function of the mixture is to provide a free-draining layer that permits surface water to migrate laterally through the mixture to the edge of the pavement.

3.1.2 *air voids (V_a), n*—the total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture, expressed as a percent of the total volume of the compacted specimen.

3.1.3 *voids in coarse aggregate (VCA), n*—the volume in between the coarse aggregate particles, where this volume includes filler, fine aggregate, air voids, asphalt, and fiber, if used.

3.1.4 *nominal maximum size of aggregate, n—in specifications for, or descriptions of aggregate*, the smallest sieve opening through which the entire amount of aggregate is permitted to pass.

3.1.4.1 *Discussion*—Specifications on aggregates usually stipulate a sieve opening through which all of the aggregate may, but need not, pass so that a stated maximum proportion of the aggregate may be retained on that sieve. A sieve opening so designated is the nominal maximum aggregate size.

3.1.5 *maximum aggregate size, n—in specifications for, or descriptions of aggregate*, the smallest sieve opening through which the entire amount of aggregate is required to pass.

3.1.6 *stabilizing additive, n*—polymer, crumb rubber, or fibers, or both, used to minimize draindown of the asphalt during transport and placement of the OGFC.

4. Summary of Practice

4.1 *Materials Selection*—Aggregates, asphalt, and additives that meet specification are selected.

4.2 *Select Optimum Grading*—At least three trial aggregate gradings from the selected aggregate stockpiles are blended. Gradings for OGFC are based on volume. The dry-rodded unit weight for the coarse aggregate for each trial grading is determined in accordance with Test Method C29/C29M. For each trial grading, an initial trial asphalt content between 6.0 and 6.5 % (generally higher for asphalt-rubber Specification D6114) is selected and at least two specimens are compacted using 50 gyrations of the Superpave Gyratory Compactor (SGC) (Test Method D6925) or other suitable compactor. An optimum grading is selected to ensure stone-on-stone contact.

NOTE 1—If a standard aggregate grading and asphalt content has been successfully used, three trial gradings may not be necessary. Examples of commonly used gradings and asphalt contents are shown in Appendix X1.

4.3 *Design Asphalt Content Selection*—Replicate specimens are compacted using 50 gyrations of a SGC or other suitable compactor at three asphalt contents. The design asphalt content is selected on the basis of satisfactory conformance with the requirements of Section 12.

4.4 *Evaluating Moisture Susceptibility*—The moisture susceptibility of the designed mixture shall be evaluated using the AASHTO T 283 test method. If the mixture fails the selected moisture susceptibility requirement, it is suggested that appropriate modifiers such as liquid anti-strip, or hydrated lime, or both are evaluated to meet the requirement.

5. Significance and Use

5.1 The procedure described in this practice is used to design OGFC mixtures that will provide good performance in terms of permeability (tending to reduce hydroplaning and potential for skidding), and durability when subjected to high volumes of traffic.

6. Material Selection

6.1 The first step in the mix design process is to select materials suitable for the OGFC. Materials include aggregates, asphalt, and additives.

6.1.1 *Selection of Coarse Aggregate*—Coarse aggregate should have abrasion values of less than 30 % in accordance with Test Method C131. Crushed gravel (if used) must have at least 90 % particles with two faces and 95 % particles with one face resulting from crushing in accordance with Test Method D5821. The percentage of flat and elongated particles should not exceed 10 %, with a ratio of 5:1 in maximum to minimum dimension, respectively in accordance with Test Method D4791.

6.1.2 *Selection of Fine Aggregate*—The fine aggregate should have an uncompacted voids content of least 40 % when tested in accordance with Test Methods C1252, Method C. It is important that the aggregate be clean. The sand equivalent value of the fine aggregate passing the 2.36 mm [No. 8] sieve, according to Test Method D2419, should be at least 45 % or greater. It is recommended that the material to be tested be separated on the 2.36 mm [No. 8] sieve because of the coarse grading of the aggregate. It is also very important to remove any coatings or fines adhering to the coarse material.

6.1.3 *Asphalt Grade Selection*—The asphalt grade selection is based on environment, traffic, and expected functional performance of the OGFC. The preferred specified asphalt grade should meet Specification D6373, however other grades of asphalt, such as viscosity-graded Specification D3381 or penetration graded Specification D946 may be suitable. A PG-grade, one or two grades stiffer (at high temperature) than normally used at the location of the pavement, has been shown to perform successfully. Mixes with modified asphalt cements have shown significant improvement in performance. The use of modified asphalt cements is permitted provided that the selected asphalt grade has a PG temperature range exceeding 95. This is determined by subtracting the low from the high specification temperature grade (for example, PG 70 – 28 = 70 – (–28) = 98). A value less than 95 may be used if satisfactory performance has been noted with the selected PG grade.

6.1.4 *Selection of Additives*—Either a cellulose fiber or a mineral fiber may be used to minimize draindown. Typically a dosage rate of 0.3 % by mixture mass (or weight of total mix) is used but the draindown target of 0.3 % maximum should be the acceptance guideline for the dosage rate of the fiber stabilized additive. The dosage rate of fiber stabilizer additive used should be in the range listed in 12.8.

NOTE 2—For some mixes which use polymer-modified asphalt or asphalt rubber, fiber additives may not be required or necessary to obtain good performance or control draindown.

7. Test Specimens

7.1 *Numbers of Samples*—Twelve samples are initially required: four samples at each of the three trial gradings. Each sample is mixed with the trial asphalt content (typically between 6.0 and 6.5 % for neat liquid asphalts), and three of the four samples for each trial grading are compacted. The remaining sample of each trial grading is then used to determine the theoretical maximum density according to Test Method D2041 or Test Method D6857.

NOTE 3—For some polymer modified asphalt and asphalt-rubber, the typical asphalt content may be higher; see Appendix X1.

7.2 *Preparation of Aggregates*—Dry aggregates to a constant mass at 105 to 110°C [220 to 230°F] and separate the aggregates by dry-sieving into the desired size fractions (Test Method C136).

7.3 *Determination of Mixing and Compaction Temperatures:*

7.3.1 The temperature to which an asphalt must be heated to produce a viscosity of 0.00017 ± 0.00002 m^2/s [170 ± 20 cSt] shall be the mixing temperature.

7.3.2 The temperature to which the asphalt must be heated to produce a viscosity 0.00028 ± 0.00003 m^2/s [280 ± 30 cSt] shall be the compaction temperature.

7.3.3 However, while the temperatures shown in 7.3.1 and 7.3.2 will work for most unmodified asphalt, the selected temperatures may need to be changed for polymer modified asphalt or asphalt-rubber. For polymer modified asphalt and asphalt-rubber, the manufacturer or supplier guidelines for mixing and compaction temperatures should be followed.

7.4 *Preparation of Mixtures:*

7.4.1 A mechanical mixing apparatus shall be used.

7.4.2 An initial batch shall be mixed for the purpose of coating (buttering) the mixture bowl and stirrers. This batch shall be wasted after mixing and the sides of the bowl and stirrers shall be cleaned of mixture residue by scraping with a small limber spatula. The bowl shall not be wiped with cloth or washed clean with solvent, except when a change is to be made in the asphalt or at the end of a design.

7.4.3 For each test specimen, weigh into separate pans the amount of each size fraction required to produce a batch of aggregate that will result in a compacted specimen of the correct size. Mix the aggregate in each pan; place in an oven set to a temperature not exceeding the mixing temperature established in 7.3 by more than approximately 28°C [80°F]. Heat the asphalt to the established mixing temperature. The stabilizing additive or fiber (if used), should be added to the heated aggregate prior to the introduction of the asphalt. The stabilizing additive should be dry-mixed thoroughly with the heated aggregate. This procedure is needed to ensure an even distribution of the stabilizing additive during the laboratory mixing process. Slightly longer mixing times may be required due to the increased surface area added by the fiber, compared to mixes without fibers. The supplier recommended mixing temperature should compensate for this stiffening.

NOTE 4—For polymer modified asphalt and asphalt-rubber, the additives should be incorporated into the liquid asphalt and thoroughly interacted according to the procedure recommended by the manufacturer or supplier of the additives before the asphalt is mixed with the aggregate.

7.4.4 Form a crater in the dry blended aggregate and to this add stabilizing fiber additive if used, and then add the weighed preheated required amount of asphalt into the crater formed in the aggregate blend. Exercise care to prevent loss of the mix during subsequent handling. At this point, the temperature of the aggregate and asphalt shall be within the limits of the mixing temperature established in 7.3. Mix the aggregate and asphalt rapidly until thoroughly coated.

7.5 *Size and Shape of Compacted Specimens*—Specimen diameter shall be 100 mm [4 in.] and nominal height shall be 63.5 mm [2.5 in.].

7.6 *Compaction of Specimens*—The compaction temperature is determined in accordance with 7.3. Laboratory samples of OGFC are short-term aged in accordance with AASHTO R 30 and then compacted using 50 gyrations of the SGC or other compactor providing equivalent compacted density.

8. Selection of Trial Gradings

8.1 Three trial gradings should be selected to be within the recommended master range of grading shown in Table 1, or a grading shown in Appendix X1 or a grading that has demonstrated good performance. The three trial gradings should generally fall along the coarse and fine limits of the grading range, along with one falling in the middle. These trial gradings are obtained by adjusting the amount of fine and coarse aggregate in each blend.

NOTE 5—If a satisfactory grading has been successfully used on previous projects or a grading shown in Appendix X1 is selected by the designer, Sections 8 through 11 may be disregarded.

9. Selection of Trial Asphalt Content

9.1 For each trial aggregate grading, an asphalt content between 6.0 and 6.5 % should be initially selected based on the aggregates' bulk specific gravity. Higher asphalt contents should be selected for polymer modified asphalt or asphalt-rubber, as noted in Appendix X1.

TABLE 1 Example Trial Grading Band for OGFC (Percent Passing by Mass)

Sieve	Percent Passing
19.0 mm [¾ in.]	100
12.5 mm [½ in.]	85 – 100
9.5 mm [⅜ in.]	35 – 60
4.75 mm [No. 4]	10 – 25
2.36 mm [No. 8]	5 – 10
0.075 mm [No. 200]	2 – 4

10. Determination of VCA in the Coarse Aggregate Fraction

10.1 For best performance, the OGFC mixture must have a coarse aggregate skeleton with stone-on-stone contact. The stone skeleton is that portion of the total aggregate blend retained on the 4.75 mm [No. 4] sieve. The condition of stone-on-stone contact within an OGFC mixture is defined as the point at which the percent voids of the compacted mixture is less than the VCA of the coarse aggregate in the dry-rodded test in accordance with Test Method C29/C29M.

10.2 The VCA of the coarse aggregate only fraction (VCA_{DRC}) is determined by compacting the stone with the dry-rodded technique according to Test Method C29/C29M. When the dry-rodded density of the coarse fraction has been determined, the VCA_{DRC} can be calculated using the following equation from Test Method C29/C29M:

$$VCA_{DRC} = \frac{G_{CA}\gamma_w - \gamma_s}{G_{CA}\gamma_w} \times 100 \tag{1}$$

where:

G_{CA} = bulk specific gravity of the coarse aggregate (Test Method C127),
γ_s = bulk density of the coarse aggregate fraction in the dry-rodded condition (kg/m^3) (Test Method C29/C29M), and
γ_w = density of water 998 kg/m^3 [62.3 lb/ft^3].

11. Selection of Desired Grading

11.1 After the trial samples have been compacted and allowed to cool, they are removed from the molds and tested to determine their bulk specific gravity using geometric measurements of diameter and height (Test Method D3203 or Test Method D6752). The uncompacted samples are used to determine the theoretical maximum density in accordance with Test Method D2041 or Test Method D6857. Using the bulk specific gravity and the theoretical maximum density, the percent air voids (V_a), and VCA of the compacted mixture (VCA_{MIX}) can be calculated using the following equations:

$$V_a = 100 \times \left(1 - \frac{G_{mb}}{G_{mm}}\right) \tag{2}$$

$$VCA_{MIX} = 100 - \left(\frac{G_{mb}}{G_{CA}} \times P_{CA}\right)$$

where:

P_{CA} = percent coarse aggregate in the total mixture,
G_{mb} = bulk specific gravity of the compacted mixture,
G_{mm} = theoretical maximum density of the mixture, and
G_{CA} = bulk specific gravity of the coarse aggregate fraction.

11.2 Of the three trial gradings evaluated, the one with the highest air voids (minimum acceptable is generally 18 % by Test Method D3203 or Test Method D6857) and a VCA_{MIX} equal to or less than that determined by the dry-rodded technique (VCA_{DRC}) is considered optimum and is selected as the desired grading.

12. Selection of Optimum Asphalt Cement/Binder Content

12.1 Once the optimum grading of the mixture has been selected in Section 11, it is necessary to evaluate various asphalt contents to obtain the optimum percentage of asphalt in the mixture. In this case, additional samples are prepared using the selected grading with at least three asphalt contents in increments of 0.5 %.

12.2 The number of samples needed for this portion of the procedure is 24. This will provide for six compacted (abrasion loss on three unaged and three aged) and two uncompacted specimens (one used to determine the theoretical maximum density and one for the draindown test) at each of the three asphalt contents. The optimum asphalt content is selected based on the test results of air voids, and draindown test results, with consideration of optional abrasion loss on unaged and aged specimens if necessary (see 12.7).

12.3 The draindown test is conducted on a loose mixture at a temperature 15°C [60°F] higher than the anticipated production temperature using Test Method D6390.

12.4 The air voids are calculated using the procedure given in 11.1 after measuring the bulk specific gravity of compacted specimens.

12.5 At the discretion of the designer, the OGFC mixture may be tested by the Cantabro abrasion test to ensure adequate durability (see Note 6).

NOTE 6—The Cantabro abrasion test has been used in Europe for many years; however it has seen very little use in the USA. Thus considerable engineering judgement and caution should be exercised in analyzing the results of the test. Conduct the Cantabro abrasion test on the gyratory compacted or other suitably compacted unaged specimens (see Appendix X2). This test measures resistance of compacted OGFC specimens to abrasion and is carried out in the abrasion machine (Test Method C131). The mass of the specimen is determined to the nearest 0.1 g [0.0002 lb], and is recorded as P_1. The test specimen is then placed in the abrasion machine without the charge of steel balls. The operating temperature should be 25 ± 5°C [77 ± 10°F]. The machine is operated for 300 revolutions at a speed of 30 to 33 revolutions per min. The test specimen is then removed and its mass is determined to the nearest 0.1 g (P_2). The percentage abrasion loss (P) is calculated according to the following formula:

$$P = \frac{P_1 - P_2}{P_1} \times 100 \tag{3}$$

Aged compacted OGFC should also be subjected to the Cantabro abrasion test to evaluate the effect of accelerated laboratory aging on the resistance to abrasion. Aging is accomplished by placing three suitably compacted specimens in a forced draft oven set at 60°C [140°F] for 168 h (7 days). The specimens are then cooled to 25°C [77°F] and stored for 4 h prior to conducting the Cantabro test.

12.6 *Laboratory Permeability Testing (optional)*—The laboratory permeability or porosity testing of compacted specimens using an approved method is optional. Laboratory permeability/porosity values greater than 100 m/day [300 feet/day] are recommended.

12.7 It is suggested that the selected OGFC mixture have properties that meet the air voids and draindown (12.7.1 and 12.7.2) criteria. The Cantabro abrasion (12.7.3 and 12.7.4) criteria are optional and judgement should be exercised in applying them.

12.7.1 *Air Voids*—A minimum of 18 % (according to Test Method D3203 or Test Method D6752) is generally acceptable, although higher void contents are desirable.

12.7.2 *Draindown*—The maximum permissible draindown should not exceed 0.3 % by total mixture mass.

12.7.3 *Optional—Abrasion Loss on Unaged Specimens*—The average abrasion loss from the Cantabro test should not exceed 20%.

12.7.4 *Optional—Abrasion Loss on Aged Specimens*—The abrasion loss from the Cantabro abrasion test should not exceed 30 % on average while the loss for any individual specimen should not exceed 50 %.

12.8 *Adjusting Mixture to Meet Properties*—If none of the asphalt contents meet the appropriate criteria, 12.7.1 – 12.7.4, the mix may need to be further evaluated. The following are suggested mix changes that may be helpful in making a mix that meets the mix criteria. Air voids within an OGFC mixture are controlled by the asphalt content. If the air voids are too low, the asphalt content should be reduced. If the abrasion loss on unaged specimens is greater than 20 %, more asphalt is needed. Either increasing the asphalt content or changing the type of additive will generally remedy abrasion loss values of aged specimens in excess of 30 %. If draindown values are in excess of 0.3 %, the amount of asphalt and/or type or amount of stabilizer can be adjusted. Fiber stabilizers are typically incorporated into the mix at a rate of 0.2 to 0.5 % of the total mix mass.

13. Evaluation of Moisture Susceptibility

13.1 Moisture susceptibility of the selected mixture shall be determined using the AASHTO T 283 test method. The retained tensile strength (TSR) should be at least 80 %. The AASHTO T 283 test shall be conducted with five freeze/thaw cycles in lieu of one cycle. The AASHTO T 283 test shall also be modified as follows:

13.1.1 Compact the OGFC specimens with 50 gyrations.

13.1.2 Apply a vacuum of 87.8 kPa (660 mm [26 in.] of mercury) for 10 min to saturate the compacted specimens to whatever saturation level is achieved.

13.1.3 Submerge the specimens in water during freeze cycles to maintain saturation.

13.2 If the mixture fails to meet the moisture susceptibility requirements, hydrated lime, or liquid anti-strip, or both, additives can be used. If these measures prove ineffective, the aggregate source, or asphalt, or both, source can be changed to obtain better aggregate/asphalt compatibility.

NOTE 7—The results of the AASHTO T 283 test should be carefully weighed against actual field performance of the aggregate source being evaluated. If past experience indicates the need for the use of anti-strip or hydrated lime, then such modifiers should be used notwithstanding the test results.

14. Report

14.1 The report should include the following information:

14.1.1 Identification of the project and the project number,

14.1.2 Aggregate source, asphalt source and grade, type and amount of stabilizing additive, and material quality characteristics,

14.1.3 Results of the grading optimization (results of trial gradings) or selected grading from experience,

14.1.4 Selected optimum grading and optimum asphalt content,

14.1.5 Volumetric properties, abrasion loss on unaged and aged specimens, and draindown for each trial blend and at the optimum asphalt content,

14.1.6 Moisture susceptibility recommendations, and

14.1.7 Recommended job-mix formula for the OGFC.

15. Keywords

15.1 bituminous paving mixtures; mix design; open-graded friction course; surface treatments

APPENDIXES

(Nonmandatory Information)

X1.

TABLE X1.1 Summary of 9.5 mm [⅜ in.] Open-Graded Friction Course Mixture Designs

	Arizona Unmodified AC		Arizona Asphalt Rubber		California		Florida		Nevada		Wyoming		Georgia	
Grading	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
12.5 mm [½ in.]	100		100		100		100		100		100		100	
9.5 mm [⅜ in.]	100		100		90	100	85	100	95	100	97	100	85	100
4.75 mm [No. 4]	35	55	30	45	29	36	10	40	40	65	25	45	20	40
2.36 mm [No. 8]	9	14	4	8	7	18	—	—	—	—	10	25	5	10
2.00 mm [No. 10]	—	—	—	—	—	—	4	12	—	—	—	—	—	—
1.18 mm [No. 16]	—	—	—	—	—	—	—	—	12	22	—	—	—	—
0.075 mm [No. 200]	0	2.5	0	2.5	0	0	2	5	0	4	2	7	2	4

Asphalt	PG 64-16	PG 64-16 plus 20 % rubber	AR 4000 AR 8000 or PBA-6	AC 30 plus 12 % rubber	AC 20P or AC 30	PG 64-22 or PG 70-28	PG 67-22
Content	6.0 %	8.5 to 10 %	6.5 to 8.0 %	5.5 to 7.0 %	6.5 % typical	6.3 to 6.8 %	6.0 to 7.3 %

X2. THE CANTABRO ABRASION TEST

X2.1 Scope

X2.1.1 This test method describes the procedure to be followed to determine the abrasion loss value of bituminous mixes using the Los Angeles abrasion machine. The procedure can be used for both laboratory mix designs and quality control of mixes during construction.

X2.1.2 The procedure is applied to open-graded bituminous mixes with a maximum grading size of less than 25 mm [1 in.].

X2.1.3 This test is used to indirectly assess the cohesion, bonding, and effects of traffic abrasion and suction.

X2.2 Apparatus and Materials

X2.2.1 Compaction should be conducted in accordance with Practice D6926.

X2.2.2 *Los Angeles Abrasion Machine*—Test procedure shall be conducted in accordance with Test Method C131.

X2.2.3 *Thermometers,* to measure the temperatures of the aggregate, binder, and bituminous mix, metal thermometers with a scale up to 200°C [390°F] and an accuracy of ± 3°C [± 5°F] or better shall be used. To measure the test temperature, a thermometer with a scale from 0°C [32°F] to 50°C [122°F] and an accuracy of ± 0.5°C [± 1.0°F] shall be used.

X2.2.4 *Balance,* with a capacity of 2 kg [5 lb] and an accuracy of ± 0.1 g [± 0.0002 lb] for weighing the samples shall be used.

X2.2.5 *Balance,* with a capacity of 5 kg [11 lb] and an accuracy of ± 1 g [± 0.002 lb] or better for preparing the mixes shall be used.

X2.2.6 *General Material*—Trays, pots, spatulas, asbestos gloves, grease pencils, curved scoops, filter paper rings, and so forth.

X2.3 Procedure

X2.3.1 *Sample Preparation:*

X2.3.1.1 *Number of Samples*—At least 4 samples must be prepared for each binder percentage.

X2.3.1.2 *Aggregate Preparation*—The different aggregate fractions that make up the mix are dried in an oven at 105 to 110°C [220 to 230°F] until a constant weight is reached.

X2.3.1.3 *Temperature of the Mix and Compactness*—For the mixing and compacting of the samples, the liquid asphalt binder is heated to a temperature (viscosity) that allows a good covering of the aggregate particles without the asphalt running.

X2.3.1.4 *Preparation of the Mixes*—The quantities for each fraction of aggregate necessary to make the sample shall be weighed successively so that the total quantity of aggregate is approximately 1 kg [2.2 lb].

X2.3.1.5 *Size and Shape of Compacted Specimens*—Specimen diameter shall be 100 mm [4 in.] and nominal height shall be 63.5 mm (2.5 in.).

X2.3.1.6 *Compaction of the Mix*—The energy of compaction shall be 50 blows per side.

X2.3.1.7 *Density and Voids*—The relative density of the samples can be determined as soon as they have cooled to ambient temperature. The procedure to determine the density and void percentage shall be based on geometric procedures.

X2.3.2 *Execution of Test:*

X2.3.2.1 The compacted sample shall be weighed to within ± 0.1 g [± 0.0002 lb] and the value recorded as *P*1. Before testing the samples, they shall be kept at the test temperature for at least 6 h.

X2.3.2.2 After the sample has been kept at the test temperature for the required period of time, it is placed into the Los Angeles abrasion machine without the abrasion load (balls), and the drum shall be turned at 30 to 33 revolutions per minute. The number of revolutions during the test shall be fixed at 300.

X2.3.2.3 In accord with the local climatic zone, the test temperature may be either 18 ± 1°C [50 ± 2°F] or 25 ± 1°C [77 ± 2°F], or other (see Note X2.1).

NOTE X2.1—The 18°C [50°F] and 25°C [77°F] test temperatures are representative of two climate zones in Spain; these can be adjusted to an average temperature better suited for the climate where the mix is intended to be placed.

X2.3.2.4 After 300 revolutions, the sample is removed and weighed to within ± 0.1 g [± 0.0002 lb] and this value is recorded as *P*2.

X2.4 Results

X2.4.1 The result of the test is determined using the following equation:

$$P = \left[(P1 - P2)/P1 \right] \times 100 \quad \text{(X2.1)}$$

where:

P = Cantabro abrasion loss,
$P1$ = initial weight of the sample, and
$P2$ = final weight of the sample.

X2.4.2 The values obtained from the test are reported together with the test temperature.

NOTE X2.2—The Cantabro test method is derived from the original version developed in Spain in 1986, entitled "Cantabrian Test of Abrasion Loss." The original Spanish test was based on a 50 blow Marshall compaction effort. If the user is unfamiliar with the Cantabro test, the results should be evaluated with considerable engineering judgment until some experience related to actual performance has been developed. Additional information about the test is available[4].

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