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

This standard is issued under the fixed designation D 7064/D 7064M; 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 ~~standard~~ 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 D 6932 should be reviewed before starting the mix design. Where applicable, Specification D 3666 should be applied as a minimum for agencies testing and inspecting road and paving materials.

~~1.2The values stated in SI units are to be regarded as standard. The inch-pound units in parentheses are for information only.~~

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]

C 29/C 29M ~~Test Method for Unit Weight and Voids in Aggregate~~ Test Method for Bulk Density (Unit Weight) and Voids in Aggregate

C 127 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

C 131 Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

C 136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C 1252 Test Methods for Uncompacted Void Content of Fine Aggregate (as Influenced by Particle Shape, Surface Texture, and Grading)

D 946 Specification for Penetration-Graded Asphalt Cement for Use in Pavement Construction

D 2041 Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures

D 2419 Test Method for Sand Equivalent Value of Soils and Fine Aggregate

D 3203 Test Method for Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures

D 3381 Specification for Viscosity-Graded Asphalt Cement for Use in Pavement Construction

D 3666 Specification for Minimum Requirements for Agencies ~~testing~~Testing and Inspecting ~~Bituminous~~Road and Paving Materials

D 4791 Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate

D 5821 Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate

D 6114 Specification for Asphalt-Rubber Binder

D 6373 Specification for Performance Graded Asphalt Binder

D 6390 Test Method for Determination of Draindown Characteristics in Uncompacted Asphalt Mixtures

D 6752 Test Method for Bulk Specific Gravity and Density of Compacted Bituminous Mixtures Using Automatic Vacuum Sealing Method

D 6857 Test Method for Maximum Specific Gravity and Density of Bituminous Paving Mixtures Using Automatic Vacuum Sealing Method

[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.

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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.

D 6925 Test Method for Preparation and Determination of the Relative Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor
D 6932 Guide for Materials and Construction of Open-Graded Friction Course Plant Mixtures
2.2 *AASHTO Standards:*
~~R 30Mixture Conditioning of Hot Mix Asphalt (HMA)~~[3]
R 30 Mixture Conditioning of Hot Mix Asphalt (HMA)
T 283~~Resistance of Compacted Bituminous Mixture to Moisture-Induced Damage~~[3]
~~T 312Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by means of the Superpave Gyratory Compactor~~[3] Resistance of Compacted Bituminous Mixture to 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 C 29/C 29M. For each trial grading, an initial trial asphalt content between 6.0 and 6.5 % (generally higher for asphalt-rubber Specification D 6114~~) is selected and at least two specimens are compacted using 50 gyrations of the SGC (AASHTO T312~~) is selected and at least two specimens are compacted using 50 gyrations of the Superpave Gyratory Compactor (SGC) (Test Method D 6925) 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.

[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.

6.1.1 *Selection of Coarse Aggregate*— Coarse aggregate should have abrasion values of less than 30 % in accordance with Test Method C 131. 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 D 5821. 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 D 4791.

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 C 1252, Method C. It is important that the aggregate be clean. The sand equivalent value of the fine aggregate passing the ~~No. 8 (2.36 mm)~~2.36 mm [No. 8] sieve, according to Test Method D 2419, should be at least 45 % or greater. It is recommended that the material to be tested be separated on the ~~No. 8 (2.36 mm)~~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 D 6373, however other grades of asphalt, such as viscosity-graded Specification D 3381 or penetration graded Specification D 946 may be suitable. A ~~pg-grade,~~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°C.~~95. This is determined by subtracting the low from the high specification temperature grade ~~[for~~(for example, PG ~~70-28~~ 70 – 28 = ~~70-(-28)~~ 70 – (–28) = ~~98].~~98). A value less than ~~95°C~~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 D 2041 or Test Method D 6857.

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~~[220 to ~~230°F)~~230°F] and separate the aggregates by dry-sieving into the desired size fractions (Test Method C 136).

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 ~~170~~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 ~~280~~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 ~~(50°F).~~[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.)~~[4 in.] and nominal height shall be 63.5 mm ~~(2.5 in.).~~ [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 ~~PP2~~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.

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)~~[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 C 29/C 29M.

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 C 29/C 29M. 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 C 29/C 29M:

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

where:

G_{CA} = bulk specific gravity of the coarse aggregate (Test Method C 127),
γ_s = bulk density of the coarse aggregate fraction in the dry-rodded condition (kg/m ^{3}) (Test Method C 29/C 29M), and
γ_w = density of water ~~(998~~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 D 3203 or Test Method D 6752). The uncompacted samples are used to determine the theoretical maximum density in accordance with Test Method D 2041 or Test

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

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