Pavement Materials & Design

Asphalt Mixtures specific gravities

Introduction

1

HMA Mix Design

Asphalt Mixtures Types

2

2

What Is Asphalt Mixture

- Asphalt mixture is combination of asphalt cement and aggregate that will give long-lasting performance as part of the pavement structure

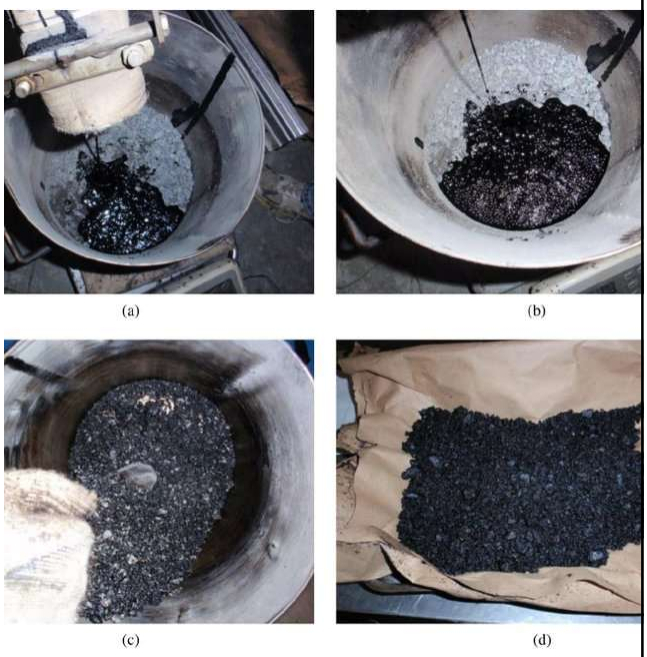

Image source: https://www.floridaridesonus.org/learning-center/asphalt-101/

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3

Introduction

- The fundamental performance properties are not directly measured in a normal mix design;
  - *Therefore, asphalt content is selected on the basis of a measured volumetric parameter that best controls the pavement performance.*
- The volumetric properties are determined using
  - *the mass and/or volume measurements of a mixture and its constituent components (binder, aggregate, air).*
- Volumetric have historically provided a good indication of the mixture's probable performance during its service life

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Mixture phases

Loose Mixture

Field

Laboratory

Image source: http://asphaltmagazine.com/fix-your-mix/ Image source: https://www.floridaridesonus.org/learning-center/asphalt-101/ 5

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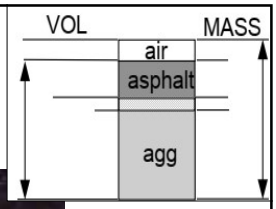
Mixture phases

Compacted Mixture

Field compacted



Laboratory compacted

Image source: http://asphaltmagazine.com/fix-your-mix/ Image source: https://www.floridaridesonus.org/learning-center/asphalt-101/ 6

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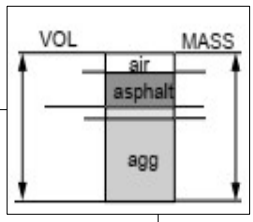
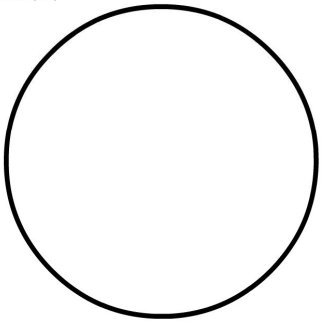
Asphalt Mixture

The volumetric relationship HMA

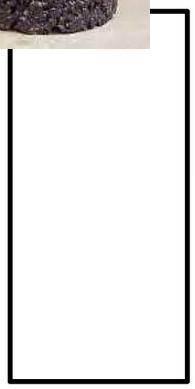


Select Volumes for Display

- ☐ Aggregate
- ☐ Voids in the Mineral Aggregate (VMA)
- ☐ Asphalt Binder
- ☐ Air Voids (Va)



HMA Close-Up



Volume Diagram

*Image source:*https://pavementinteractive.org/reference-desk/design/mix-design/hma-weight-volume-terms-and-relationships/

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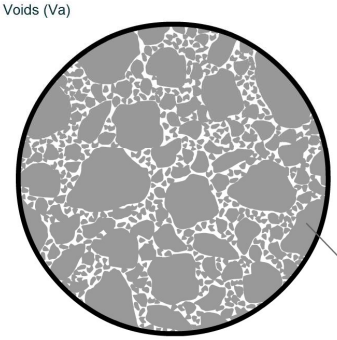
Asphalt Mixture

The volumetric relationship HMA

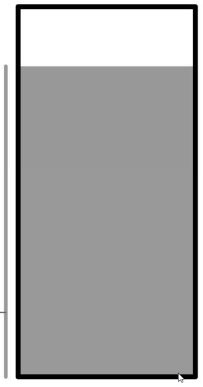
Select Volumes for Display

- ☑ Aggregate
- ☐ Voids in the Mineral Aggregate (VMA)
- ☐ Asphalt Binder
- ☐ Air Voids (Va)



Aggregate

HMA Close-Up



Volume Diagram

*Image source:*https://pavementinteractive.org/reference-desk/design/mix-design/hma-weight-volume-terms-and-relationships/

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Asphalt Mixture

The volumetric relationship HMA

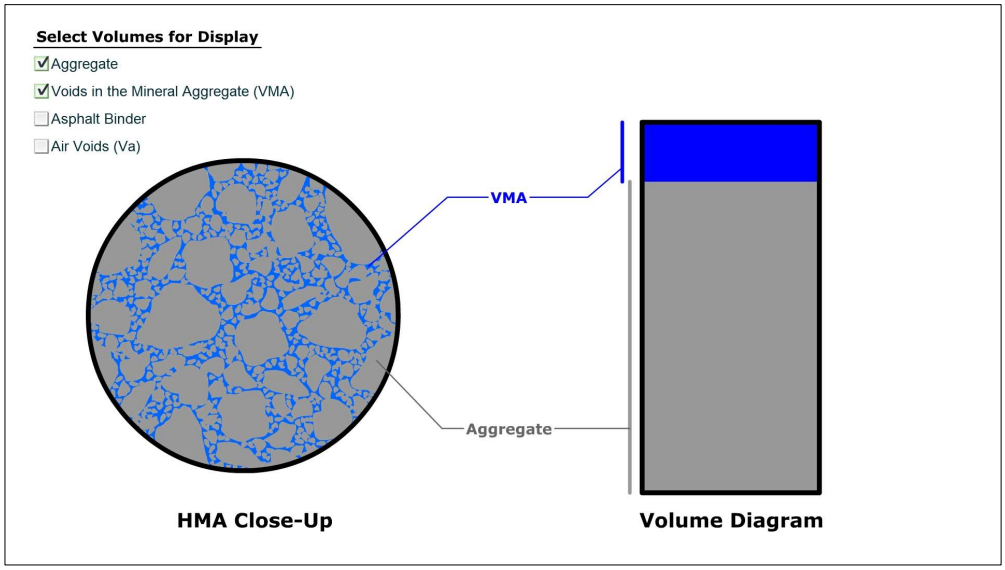

*Image source:*https://pavementinteractive.org/reference-desk/design/mix-design/hma-weight-volume-terms-and-relationships/

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Asphalt Mixture

The volumetric relationship HMA

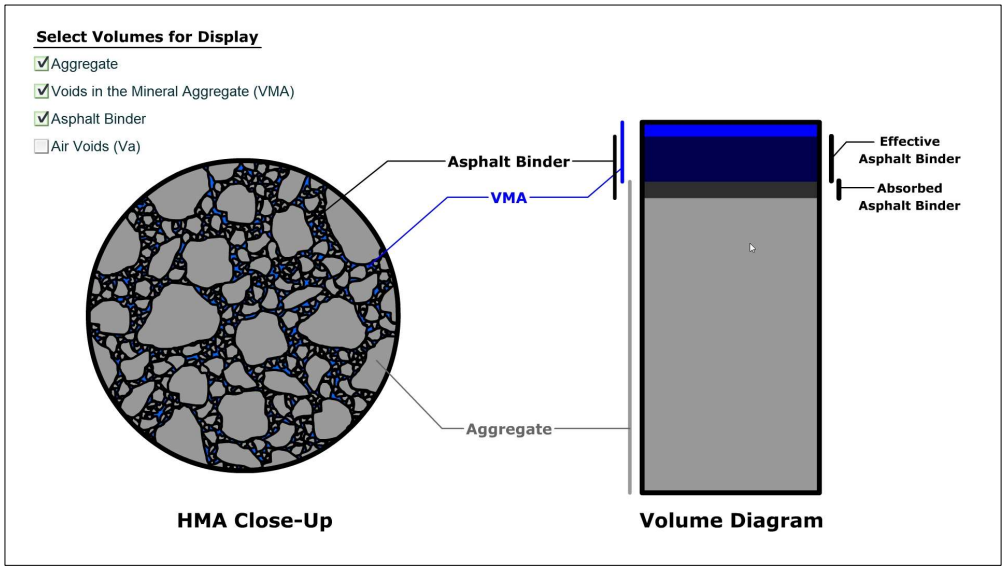

*Image source:*https://pavementinteractive.org/reference-desk/design/mix-design/hma-weight-volume-terms-and-relationships/

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Asphalt Mixture

The volumetric relationship HMA

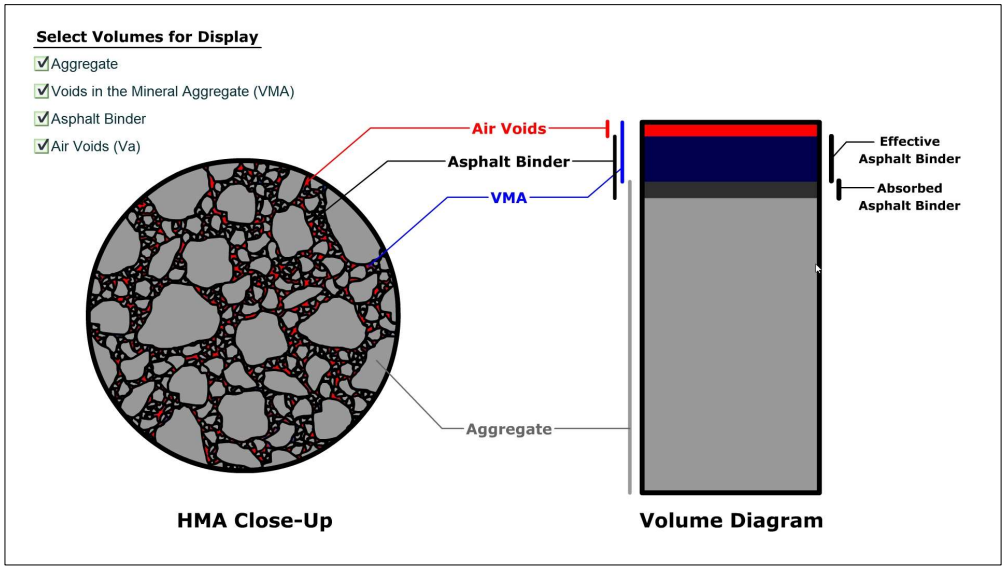

*Image source:*https://pavementinteractive.org/reference-desk/design/mix-design/hma-weight-volume-terms-and-relationships/

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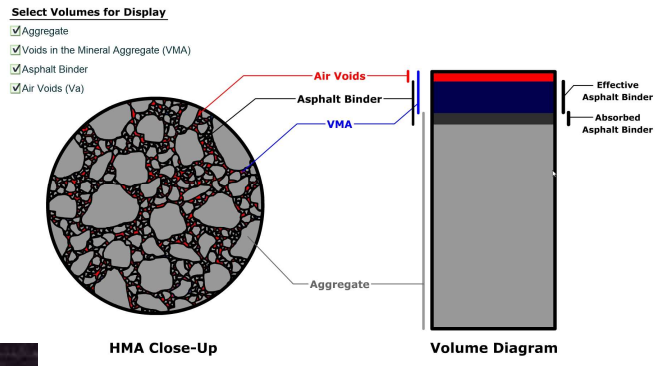
Asphalt Mixture

The volumetric relationship HM



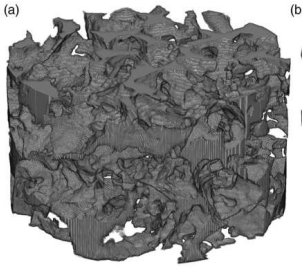


Figure 8. 3D connected air void structure of (a.) PA 11 and (b.) PA1

*Image source:*https://pavementinteractive.org/reference-desk/design/mix-design/hma-weight-volume-terms-and-relationships/

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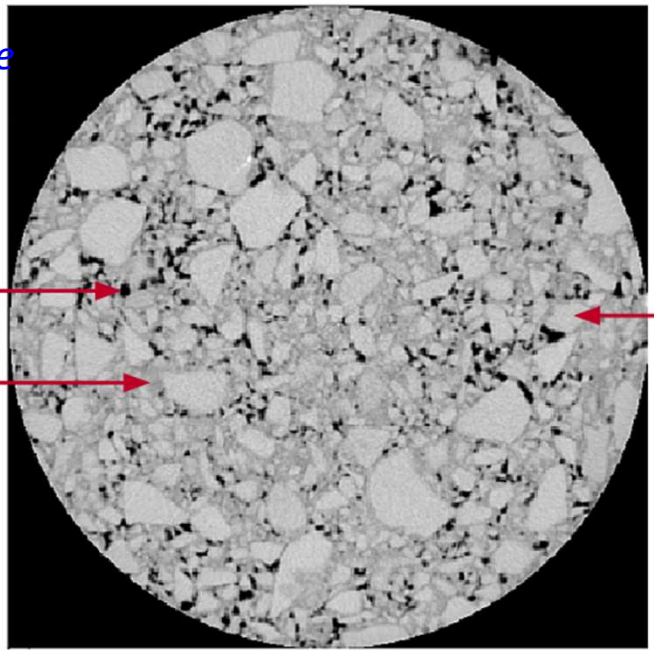
Mixture phases

Compacted Mixture



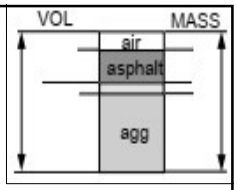


Image source: http://asphaltmagazine.com/fix-your-mix/

Image source: https://www.floridaridesonus.org/learning-center/asphalt-101/

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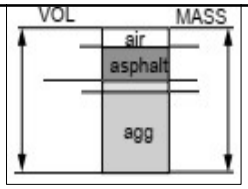
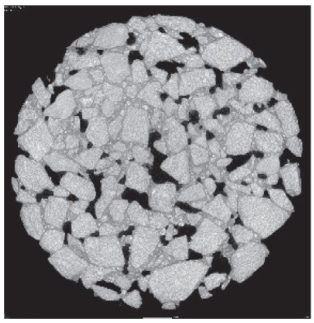
Mixture phases

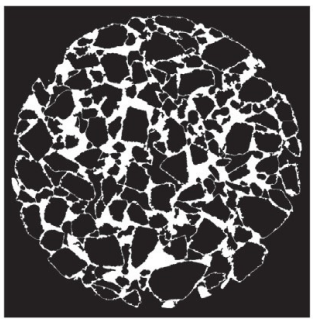
Compacted Mixture





a) original slice image

(b) binary image of air voids



(c) binary image of asphalt mastic

(d) binary image of coarse aggregate

Zhao, Yanjing; Wang, Xiaowei; Jiang, Jiwang; Zhou, Lan (2019). *Characterization of interconnectivity, size distribution and uniformity of air voids in porous*

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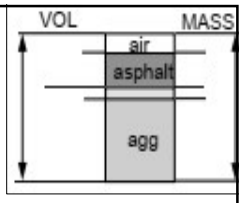
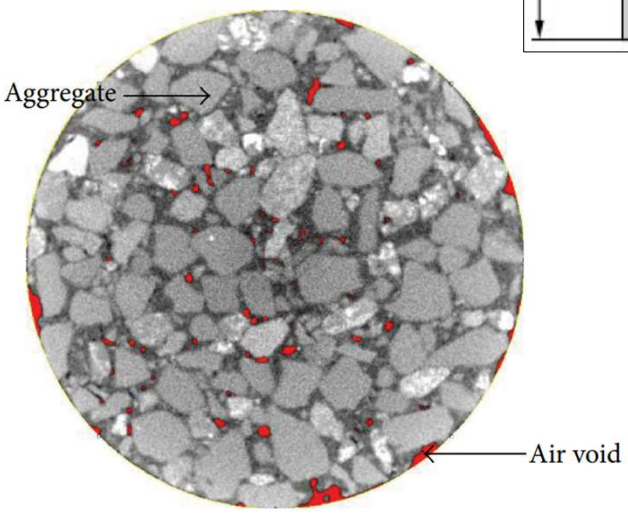
Mixture phases

Compacted Mixture





https://downloads.hindawi.com/journals/amse/2014/507082.pdf

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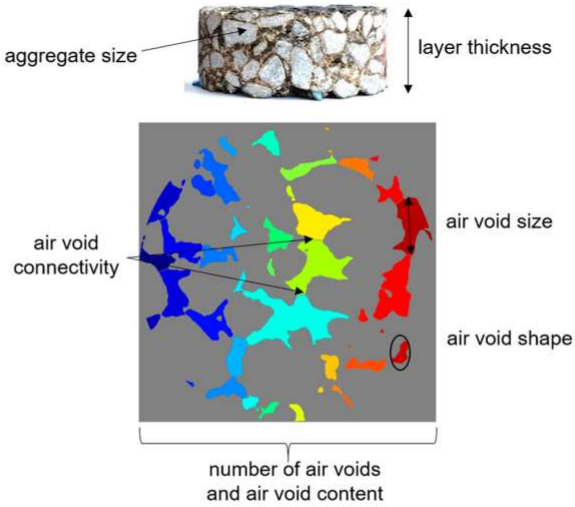

Figure 1. Asphalt drill core and CT image of air voids (coloured areas) showing factors investigated in air void analyses and discussed in this literature review.

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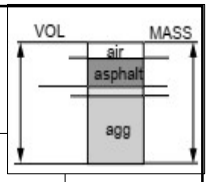
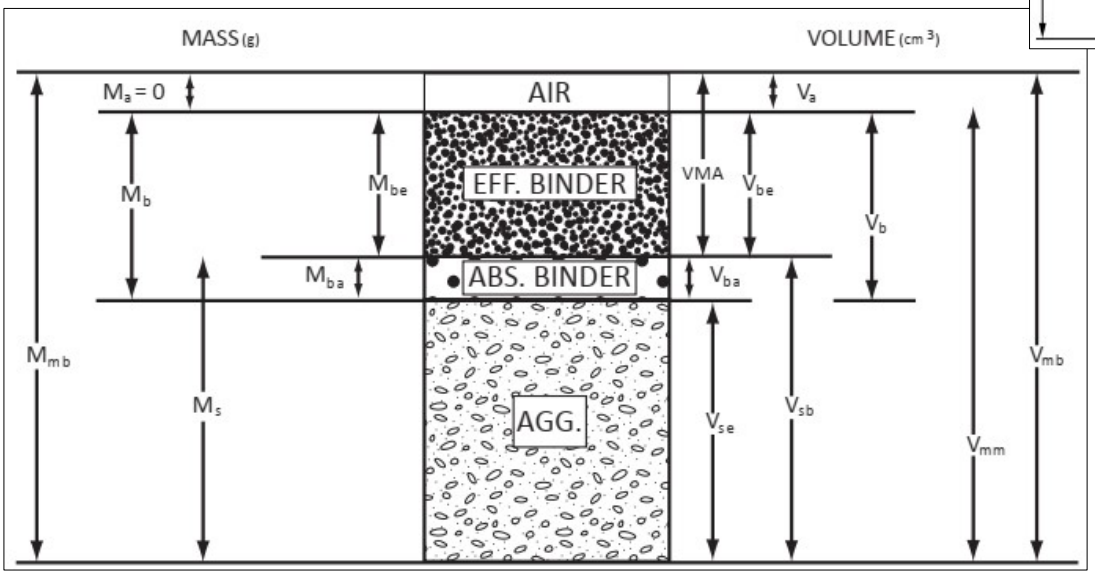
Volumetric analysis

Phase Diagram





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The idea of measuring the Specific gravity

Archimedes Principle

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18

Pavement Materials & Design

AASHTO T 166-13

Bulk Specific Gravity (G_{mb})
اختبار الكثافة الظاهرية للإسفلت

Dr. Hamza Alkuime

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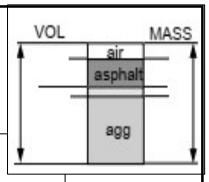
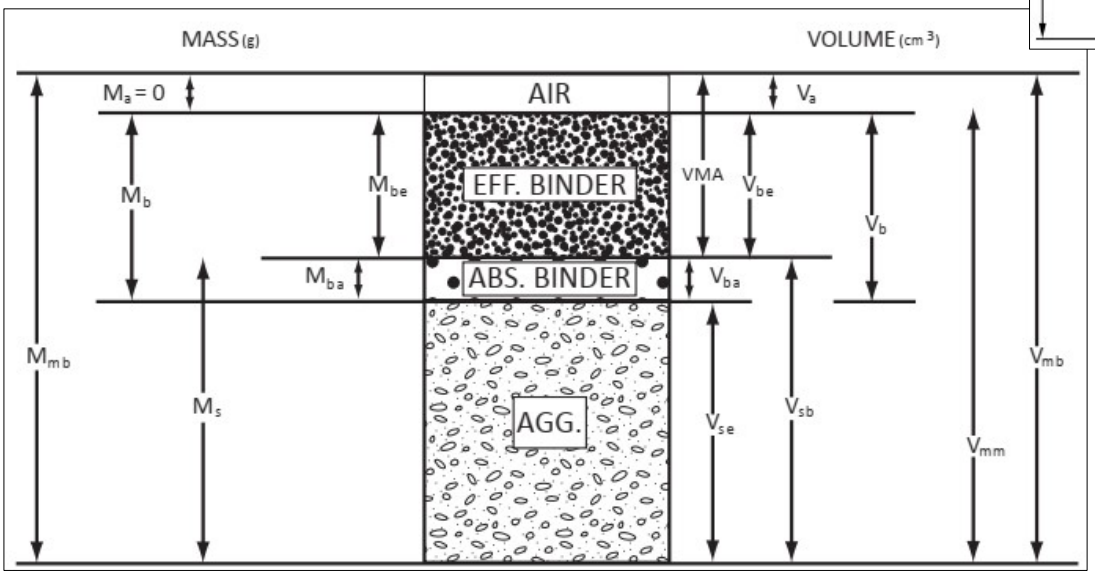
Volumetric analysis

Phase Diagram





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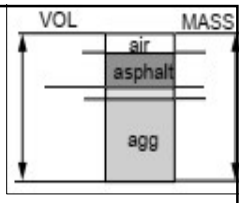
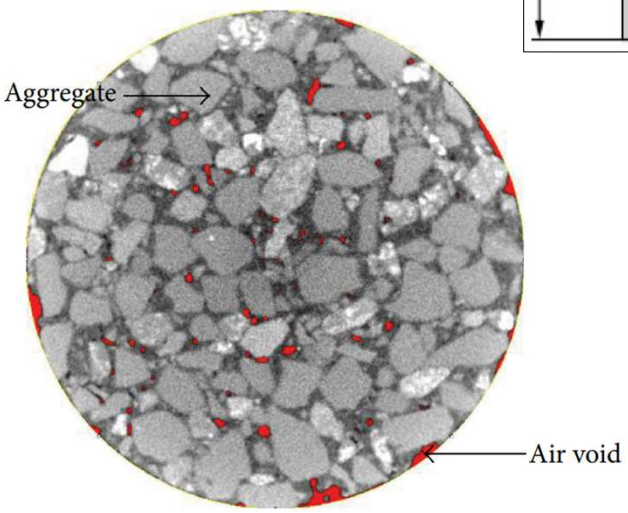
Mixture phases

Compacted Mixture





https://downloads.hindawi.com/journals/amse/2014/507082.pdf

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Several factors affect the permeability of HMA, such as voids in total mix, size of air voids, percent of interconnected air voids, aggregate gradation, NMAS, aggregate particle shape, percent binder (P_b), lift thickness and compaction effort. In the recent years, there has been a considerable effort in determination of permeability of HMA in field as well as in laboratory.

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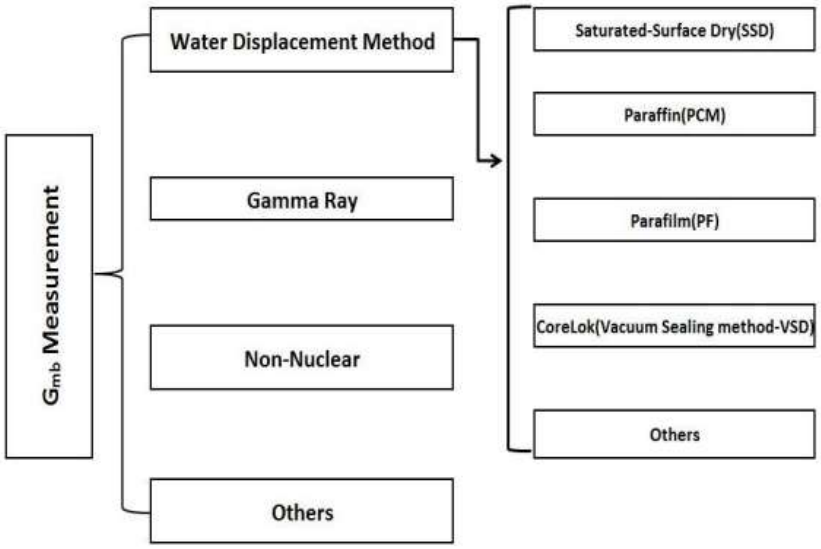

Figure 1. Different Methods for G_{mb} Measurement

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Available standards to measure G_{mb}

- AASHTO T 166:
  - *Standard Method of Test for Bulk Specific Gravity (Gmb) of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens*
- AASHTO T 275:
  - *Standard Method of Test for Bulk Specific Gravity (Gmb) of Compacted Asphalt Mixtures Using Paraffin-Coated Specimens*
- AASHTO T 331 :
  - *Standard Method of Test for Bulk Specific Gravity (Gmb) and Density of Compacted Asphalt Mixtures Using Automatic Vacuum Sealing Method*

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Standard Method of Test for

Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens

AASHTO Designation: T 166-13

AASHTO

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AASHTO T 166-13

Terminology

26

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3. TERMINOLOGY

3.1. *Definitions*:

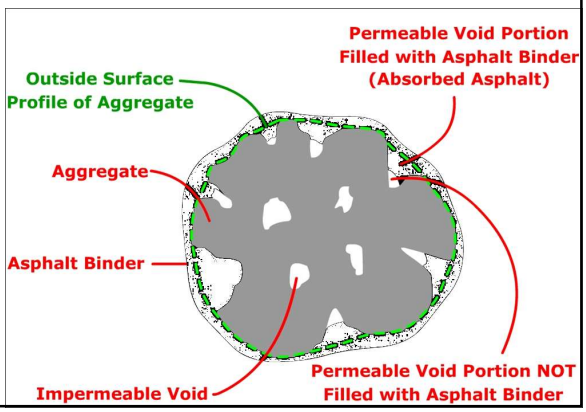
3.1.1. *bulk specific gravity (of solids)* (G_{mb})—the ratio of the mass in air of a unit volume of a permeable material (including both permeable and impermeable voids normal to the material) at a stated temperature to the mass in air of equal density of an equal volume of gas-free distilled water at a stated temperature. The form of the expression shall be:

bulk specific gravity (G_{mb}) at x/y °C *(1)*

where:

x = temperature of the material; and

y = temperature of the water.



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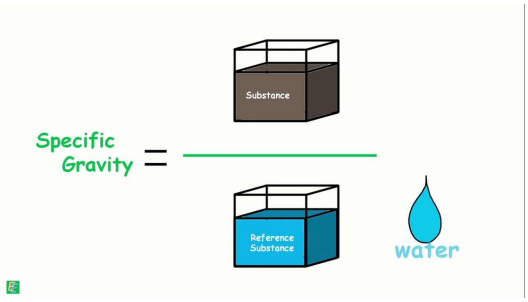

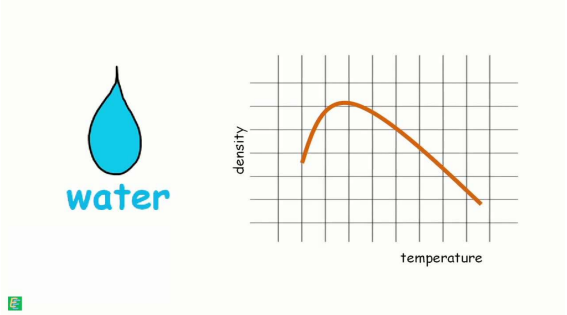

https://www.youtube.com/watch?v=xcQERGBkvhs

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AASHTO T 166-13

Scope

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1. SCOPE

1.1. This method of test covers the determination of bulk specific gravity (G_{mb}) of specimens of compacted hot mix asphalt (HMA).

1.2. This method should not be used with samples that contain open or interconnecting voids or absorb more than 2.0 percent of water by volume, as determined in Sections 7.2 or 10.2 herein. If the sample contains open or interconnecting voids or absorbs more than 2.0 percent of water by volume, then T 275 or T 331 should be used.

1.3. The bulk specific gravity (G_{mb}) of the compacted HMA may be used in calculating the unit mass of the mixture.

Note 1—The values for bulk specific gravity (G_{mb}) obtained from T 275 or T 331 may differ. Care should be exercised when comparing test results from T 275 and T 331.

1.4. The values stated in SI units are to be regarded as the standard.

1.5. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all 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.*

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AASHTO T 166-13

Referenced documents

32

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2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 231, Weighing Devices Used in the Testing of Materials
- T 275, Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt (HMA) Using Paraffin-Coated Specimens
- T 331, Bulk Specific Gravity (G_{mb}) and Density of Compacted Hot Mix Asphalt (HMA) Using Automatic Vacuum Sealing Method

2.2. *ASTM Standards:*

- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- D7227/D7227M, Standard Practice for Rapid Drying of Compacted Asphalt Specimens Using Vacuum Drying Apparatus

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AASHTO T 166-13

Test specimen

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4. TEST SPECIMENS

4.1. Test specimens may be either laboratory-compacted HMA or sampled from HMA pavements.

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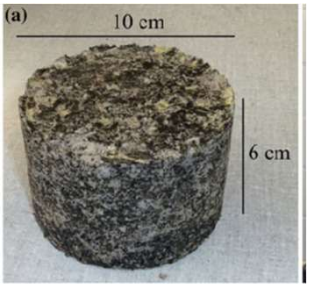
4.2. *Size of Specimens*—It is recommended that: (1) the diameter of cylindrically compacted or cored specimens, or the length of the sides of sawed specimens, be at least equal to four times the maximum size of the aggregate; and (2) the thickness of specimens be at least one and one-half times the maximum size of the aggregate.



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4.3. Specimens shall be taken from pavements with a core drill, diamond or carborundum saw, or by other suitable means.

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4.4. Care shall be taken to avoid distortion, bending, or cracking of specimens during and after the removal from the pavement or mold. Specimens shall be stored in a safe, cool place.

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4.5. Specimens shall be free from foreign materials such as seal coat, tack coat, foundation material, soil, paper, or foil.

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4.5. Specimens shall be free from foreign materials such as seal coat, tack coat, foundation material, soil, paper, or foil.

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4.5. Specimens shall be free from foreign materials such as seal coat, tack coat, foundation material, soil, paper, or foil.

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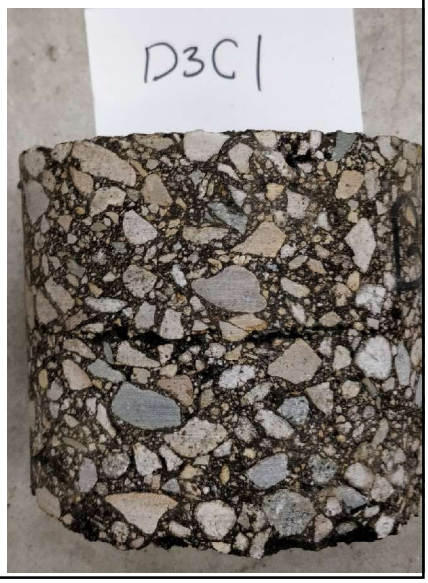
4.6. If desired, specimens may be separated from other pavement layers by sawing or other suitable means. Care should be exercised to ensure sawing does not damage the specimens.



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3. TERMINOLOGY

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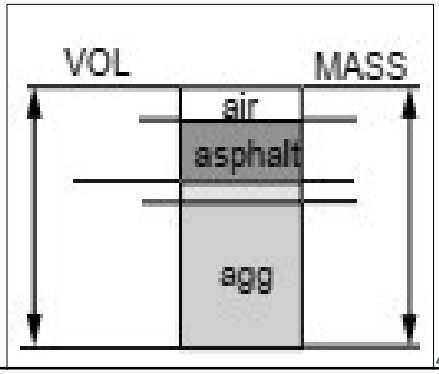
bulk specific gravity (G_{mb}) at x/y °C *(1)*

where:

x = temperature of the material; and

y = temperature of the water.

In other words, Gmb, the mass of the asphalt and aggregate mixture divided by the volume, including the air voids



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AASHTO T 166-13

Measuring methods

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Measuring methods

- ❑ Method A
- ❑ Method B
- ❑ Method C

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AASHTO T 166-13

Measuring methods

Method A

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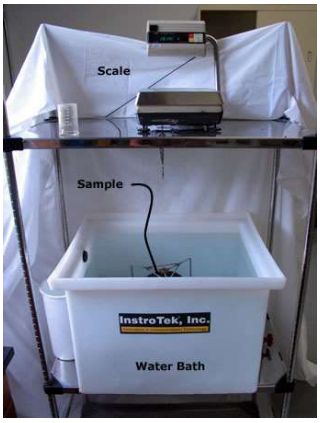
Method A

Apparatus

5.1. *Weighing Device*—The weighing device shall have sufficient capacity, be readable to 0.1 percent of the sample mass or better, and conform to the requirements of M 231. The weighing device shall be equipped with a suitable suspension apparatus and holder to permit weighing the specimen while suspended from the center of the scale pan of the weighing device.



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Method A

Apparatus

5.2. *Suspension Apparatus*—The wire suspending the container shall be the smallest practical size to minimize any possible effects of a variable immersed length. The suspension apparatus shall be constructed to enable the container to be immersed to a depth sufficient to cover it and the test sample during weighing. Care should be exercised to ensure no trapped air bubbles exist under the specimen.

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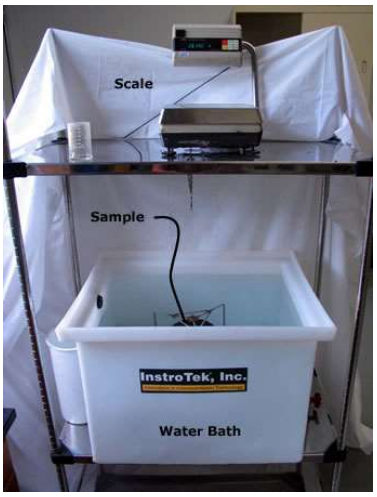
Method A

Apparatus

5.3. *Water Bath*—For immersing the specimen in water while suspended under the weighing device, equipped with an overflow outlet for maintaining a constant water level.



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METHOD A

PROCEDURE

6.1. Dry the specimen to a constant mass at a temperature of 52 ± 3°C (125 ± 5°F). Samples saturated with water shall initially be dried overnight and then weighed at 2-h drying intervals. Recently compacted laboratory samples, which have not been exposed to moisture, do not require drying. As an alternative to oven drying to constant mass, drying the sample according to ASTM D7227/D7227M may be used. When using ASTM D7227/D7227M to achieve constant mass, perform the drying procedure at least twice, with a mass determination after each drying cycle.

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3.1.2. *constant mass*—shall be defined as the mass at which further drying does not alter the mass by more than 0.05 percent when weighed at 2-h intervals when using oven drying, or by more than 0.05 percent when weighed after at least two drying cycles of the vacuum-drying apparatus required in ASTM D7227/D7227M.

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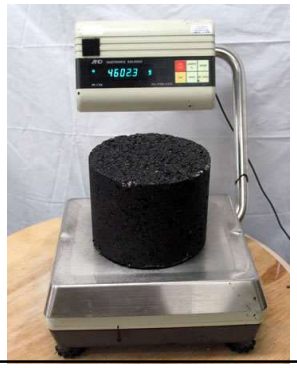
METHOD A

PROCEDURE

6.2. Cool the specimen to room temperature at 25 ± 5°C (77 ± 9°F), and record the dry mass as *A* (Note 2). Immerse each specimen in the water bath at 25 ± 1°C (77 ± 1.8°F) for 4 ± 1 min, and record the immersed mass as *C*. Remove the specimen from the water bath; damp-dry the specimen by blotting it with a damp towel, and determine the surface-dry mass as *B* as quickly as possible *(the entire operation is not to exceed 15 s)*. Any water that seeps from the specimen during the weighing operation is considered part of the saturated specimen. Each specimen shall be immersed and weighed individually.



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Videos source: https://www.youtube.com/watch?v=U6-8C1hRdDk

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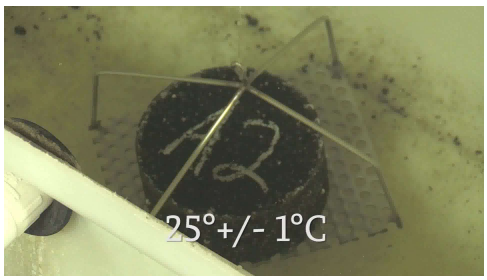
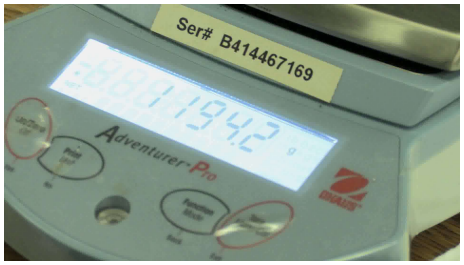
METHOD A

PROCEDURE

6.2. Cool the specimen to room temperature at 25 ± 5°C (77 ± 9°F), and record the dry mass as *A* (Note 2). Immerse each specimen in the water bath at 25 ± 1°C (77 ± 1.8°F) for 4 ± 1 min, and record the immersed mass as *C*. Remove the specimen from the water bath; damp-dry the specimen by blotting it with a damp towel, and determine the surface-dry mass as *B* as quickly as possible *(the entire operation is not to exceed 15 s)*. Any water that seeps from the specimen during the weighing operation is considered part of the saturated specimen. Each specimen shall be immersed and weighed individually.





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Videos source: https://www.youtube.com/watch?v=U6-8C1hRdDk

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METHOD A

PROCEDURE

6.2. Cool the specimen to room temperature at 25 ± 5°C (77 ± 9°F), and record the dry mass as *A* (Note 2). Immerse each specimen in the water bath at 25 ± 1°C (77 ± 1.8°F) for 4 ± 1 min, and record the immersed mass as *C*. Remove the specimen from the water bath; damp-dry the specimen by blotting it with a damp towel, and determine the surface-dry mass as *B* as quickly as possible *(the entire operation is not to exceed 15 s)*. Any water that seeps from the specimen during the weighing operation is considered part of the saturated specimen. Each specimen shall be immersed and weighed individually.

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Videos source: https://www.youtube.com/watch?v=U6-8C1hRdDk

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METHOD A

PROCEDURE

Note 2—If desired, the sequence of testing operations may be changed to expedite the test results. For example, first the immersed mass *C* can be taken, then the surface-dry mass *B*, and finally the dry mass *A*.

Note 3—Terry cloth has been found to work well for an absorbent cloth. Damp is considered to be when no water can be wrung from the towel.

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Method A

Calculations

7.1. Calculate the bulk specific gravity (G_{mb}) of the specimen as follows:

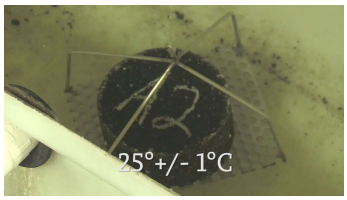
$$\text{bulk specific gravity} = \frac{A}{B - C}$$

where:

A = mass of the specimen in air, g;

B = mass of the surface-dry specimen in air, g; and

C = mass of the specimen in water, g.



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Method A

Calculations

7.2. Calculate the percent of water absorbed by the specimen (on a volume basis) as follows:

$$\text{percent of water absorbed by volume} = \frac{B - A}{B - C} \times 100 \qquad (3)$$

where:

A = mass of the specimen in air, g;

B = mass of the surface-dry specimen in air, g; and

C = mass of the specimen in water, g.

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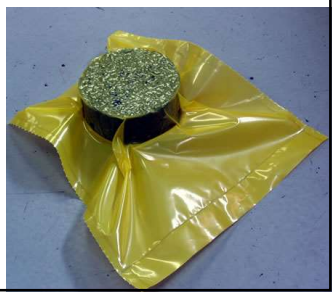
Method A

Calculations

7.3. If the percent of water absorbed by the specimen as calculated in Section 7.2 exceeds 2.0 percent, use either T 275 or T 331 to determine the bulk specific gravity (G_{mb}).

- AASHTO T 275:
  - *Standard Method of Test for Bulk Specific Gravity (Gmb) of Compacted Asphalt Mixtures Using Paraffin-Coated Specimens*
- AASHTO T 331 :
  - *Standard Method of Test for Bulk Specific Gravity (Gmb) and Density of Compacted Asphalt Mixtures Using Automatic Vacuum*



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Measuring methods

The concept behind Method A

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Calculations Concept

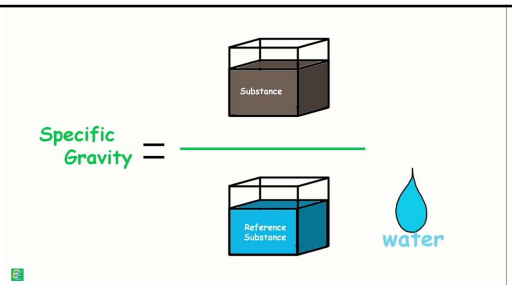
$$\text{bulk specific gravity} = \frac{A}{B - C}$$

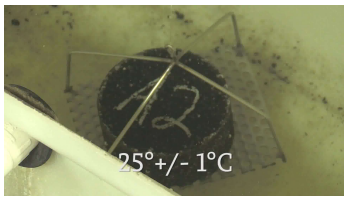
where:

A = mass of the specimen in air, g;

B = mass of the surface-dry specimen in air, g; and

C = mass of the specimen in water, g.





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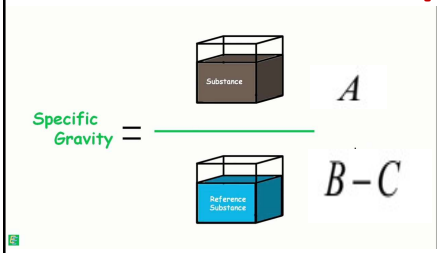
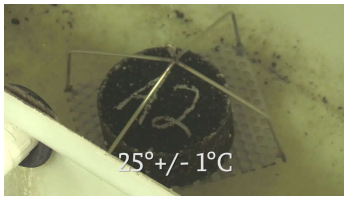
Calculations Concept

B = mass of the surface-dry specimen in air, g; and

C = mass of the specimen in water, g.





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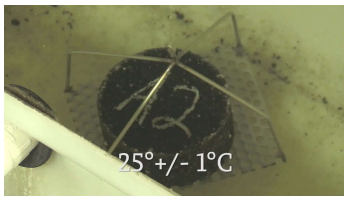
Calculations Concept

B = mass of the surface-dry specimen in air, g; and
C = mass of the specimen in water, g.

$$\text{Specific Gravity} = \frac{A}{B-C}$$



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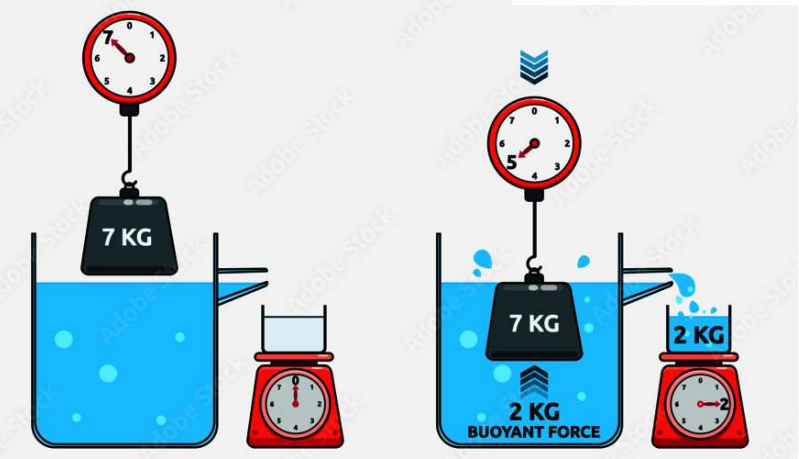
Method A

Archimedes concept

● إذا غمر جسم في سائل جزئياً أو كلياً فإنه يلقى دفعاً من أسفل إلى أعلى يساوي مقدار وزن السائل المزاح بواسطة الجسم المغمور فيه.

حجم الجزء المغمور = حجم السائل المزاح

"إذا غمر جسم في سائل فإنه يفقد من وزنه بمقدار وزن السائل المزاح".



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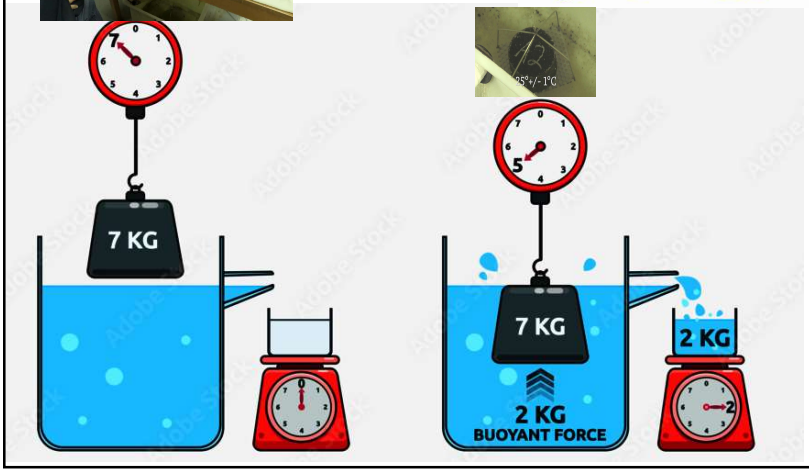
Method A

Calculations

● إذا غمر جسم في سائل جزئياً أو كلياً فإنه يلقى دفعاً من أسفل إلى أعلى يساوي مقدار وزن السائل المزاح بواسطة الجسم المغمور فيه.

حجم الجزء المغمور = حجم السائل المزاح

"إذا غمر جسم في سائل فإنه يفقد من وزنه بمقدار وزن السائل المزاح".



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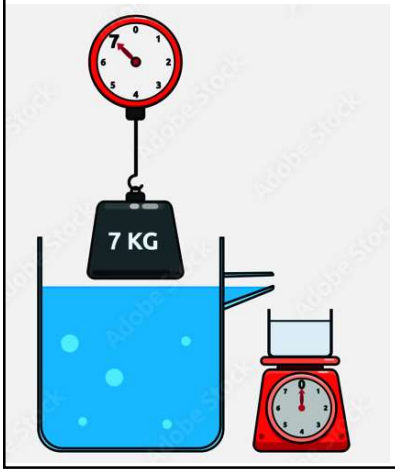
Method A

Calculations

● إذا غمر جسم في سائل جزئياً أو كلياً فإنه يلقى دفعاً من أسفل إلى أعلى يساوي مقدار وزن السائل المزاح بواسطة الجسم المغمور فيه.

حجم الجزء المغمور = حجم السائل المزاح

"إذا غمر جسم في سائل فإنه يفقد من وزنه بمقدار وزن السائل المزاح".



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Why using B-C rather Than A-C

Immersed Volume Vs. SSD Volume

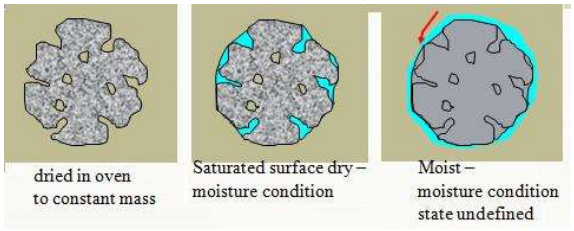
$$\text{bulk specific gravity} = \frac{A}{B-C}$$

where:

A = mass of the specimen in air, g;

B = mass of the surface-dry specimen in air, g; and

C = mass of the specimen in water, g.



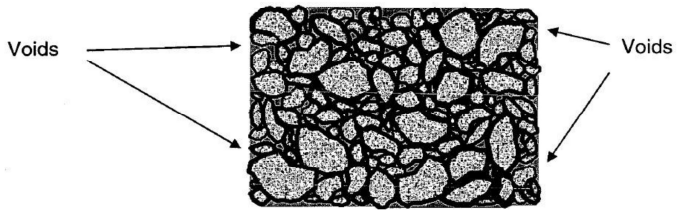


Figure 3. Compacted Asphalt Pill with Voids Filled with Water (6)

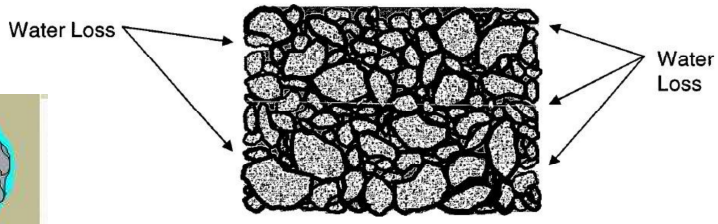


Figure 4. Compacted Asphalt Pill in SSD Condition with Potential Water Loss (6)

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Immersed Volume Vs. SSD Volume

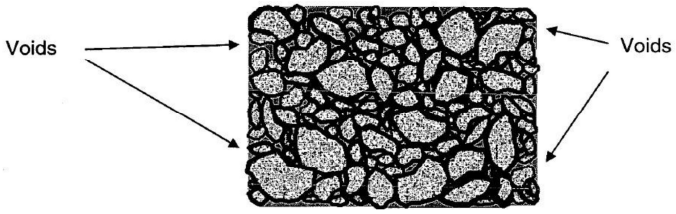

Figure 3. Compacted Asphalt Pill with Voids Filled with Water (6)

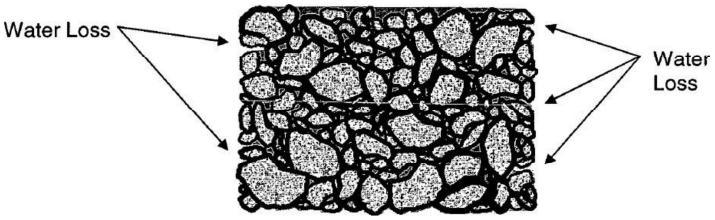

Figure 4. Compacted Asphalt Pill in SSD Condition with Potential Water Loss (6)

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Report

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13.	REPORT
13.1.	*The report shall include the following*:
13.1.1.	The method used (A, B, or C).
13.1.2.	Bulk specific gravity (G_{mb}) reported to the nearest thousandth.
13.1.3.	Absorption reported to the nearest hundredth.

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AASHTO T 166-13

Measuring methods

Method B

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METHOD B

PROCEDURE

METHOD B

8. APPARATUS

8.1. *Weighing Device*—The weighing device shall have sufficient capacity, be readable to 0.1 percent of the sample mass or better, and conform to the requirements of M 231.

8.2. *Water Bath*—For immersing the specimen in water.

8.3. *Thermometer*—ASTM 17C (17F), having a range of 19 to 27°C (66 to 80°F), graduated in 0.1°C (0.2°F) subdivisions.

8.4. *Volumeter*[1]—Calibrated to 1200 mL, or an appropriate capacity depending on the size of the test sample. The volumeter shall have a tapered lid with a capillary bore.

9. PROCEDURE

9.1. Dry the specimen to a constant mass at a temperature of 52 ± 3°C (125 ± 5°F). Samples saturated with water shall initially be dried overnight and then weighed at 2-h drying intervals. Recently compacted laboratory samples, which have not been exposed to moisture, do not require drying. As an alternative to oven drying to constant mass, drying using ASTM D7227/D7227M may be used. When using ASTM D7227/D7227M to determine the constant mass, follow the drying procedure at least twice, with a mass determination after each drying procedure.

9.2. Cool the specimen to room temperature at 25 ± 5°C (77 ± 9°F), and record the dry mass as *A* (Note 2). Immerse the specimen in the water bath at 25 ± 1°C (77 ± 1.8°F), and let it saturate for at least 10 min. At the end of the 10-min period, fill a calibrated volumeter with distilled water at 25 ± 1°C (77 ± 1.8°F), and weigh the volumeter. Designate this mass as *D*. Remove the saturated specimen from the water bath and damp-dry the specimen by blotting with a damp towel (Note 3) as quickly as possible (not to exceed 5 s). Weigh the specimen, and record the surface-dry mass as *B*. Any water that seeps from the specimen during the weighing operation is considered part of the saturated specimen.

9.3. Place the specimen into the volumeter, and let it stand for at least 60 s. Bring the temperature of the water to 25 ± 1°C (77 ± 1.8°F), and cover the volumeter, making certain that some water escapes through the capillary bore of the tapered lid. Wipe the outside of the volumeter dry with a dry, absorbent cloth, and weigh the volumeter and its contents (Note 4). Record this weight as *E*.

Note 4—If desired, the sequence of testing operations can be changed to expedite the test results. For example, first the mass of the saturated, damp-dry specimen *B* can be taken. Then the volumeter containing the saturated specimen and water *E* can be weighed. The dry mass of the specimen *A* can be determined last.

Note 5—Method B is not acceptable for specimens that have more than 6 percent air voids.

10. CALCULATIONS

10.1. Calculate the bulk specific gravity (G_{mb}) of the specimen as follows:

$$\text{bulk specific gravity} = \frac{A}{B + D - E} \qquad (4)$$

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METHOD B

PROCEDURE

- https://www.youtube.com/watch?v=y-ChdK1nlKw

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Method B

Apparatus

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Method B

Procedure

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Method B

Calculations

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Measuring methods

Method C

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Method C

Apparatus

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Method C

Procedure

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Method C

Calculations

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