Relative Density and Absorption of Aggregate

Important Properties

Gradation

Relative density and absorption

Hardness (resistance to wear)

Durability (resistance to weathering)

Shape and surface texture

Deleterious substances

Crushing strength

Soft and lightweight particles

Chemical stability

Aggregate Moisture

Though they look solid, all aggregate particles have pervious pores that can absorb water.

Water can also be present on the aggregate surface and trapped in the void spaces between particles. The latter is called “free water.”

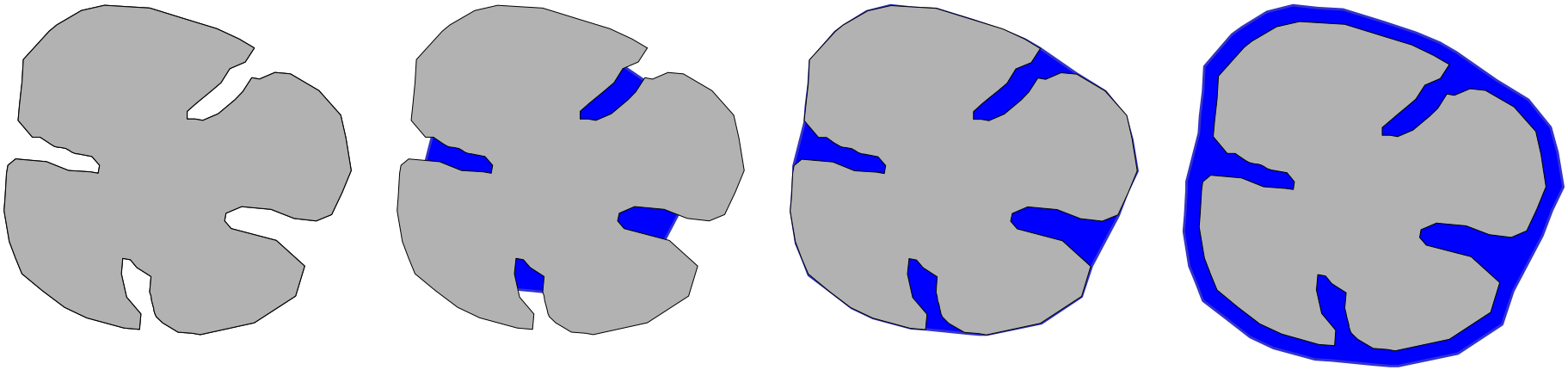
Aggregate Moisture

When designing a portland cement concrete mix, it is crucial to account for the aggregate moisture.

If the pores aren't completely filled with water, the aggregate will absorb water from the cement paste. If there is free water present, it will be incorporated into the cement paste.

Either way, the properties of the cement paste will be altered from what the mix designer intended.

Aggregate Moisture



Oven-Dry
(no moisture)

Air-Dry
(some absorbed moisture)

Cement paste will lose moisture

Saturated Surface Dry (SSD)

Cement paste is unaffected

Wet
(some surface moisture)

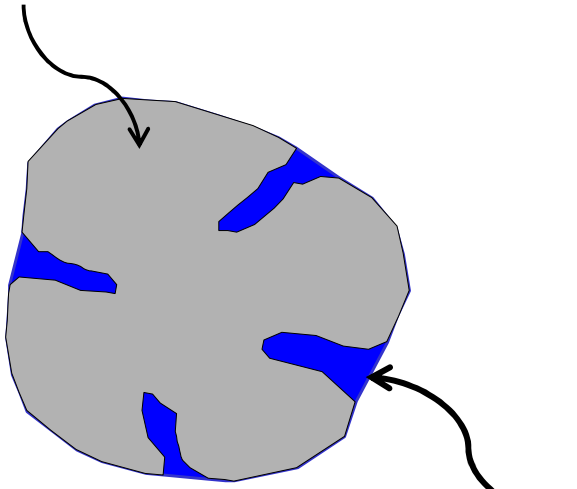
Cement paste will gain moisture

Absorption

The amount of moisture needed to make an aggregate exactly SSD is called the ***absorption***. It is generally expressed as a percentage of the dry aggregate mass.

Absorption

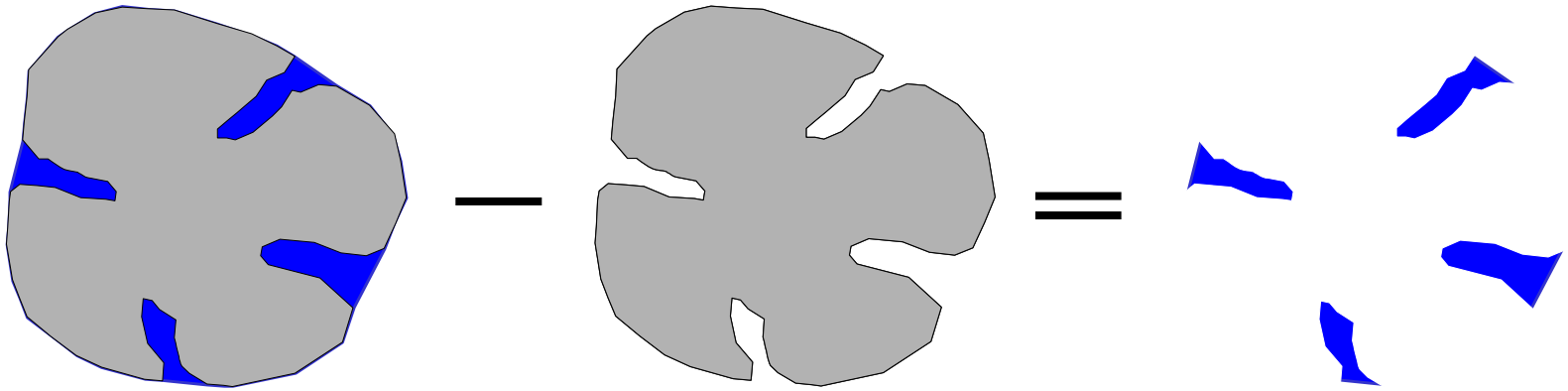
M_D = mass of dry aggregate



$$\% \text{ Abs} = \frac{M_{AW}}{M_D} \times 100\%$$

M_{AW} = mass of absorbed water

Absorption



Mass of SSD Aggregate

Mass of Oven-Dry Aggregate

Mass of Absorbed Water

Achieving an SSD State

Coarse aggregate should be soaked in room temperature water for 24±4 hours then rolled in a large absorbent cloth (i.e., towel) until all visible surface moisture is removed.

Achieving an SSD State

https://www.pavementinteractive.org/reference-desk/testing/aggregate-tests/coarse-aggregate-specific-gravity/

Achieving an SSD State

https://www.slideshare.net/BSGLY/block-9-agg-specific-gravity-13

Achieving an SSD State

Fine aggregate should be brought to a water content of at least 6% and allowed to stand for 24±4 hours. The aggregate is then spread on a nonabsorbent surface and a stream of air is blown over the sample (using a fan or a hair dryer on the lowest setting) until it attains a free-flowing condition.

Achieving an SSD State

https://www.pavementinteractive.org/reference-desk/testing/aggregate-tests/fine-aggregate-specific-gravity/

Achieving an SSD State

The accuracy of this test depends on knowing the exact point when the aggregate achieves a free-flowing condition. One way to do that is to place the aggregate into a small brass cone and lightly tamp it. If the aggregate retains the shape of the cone when it is removed, there is still free water present.

Achieving an SSD State

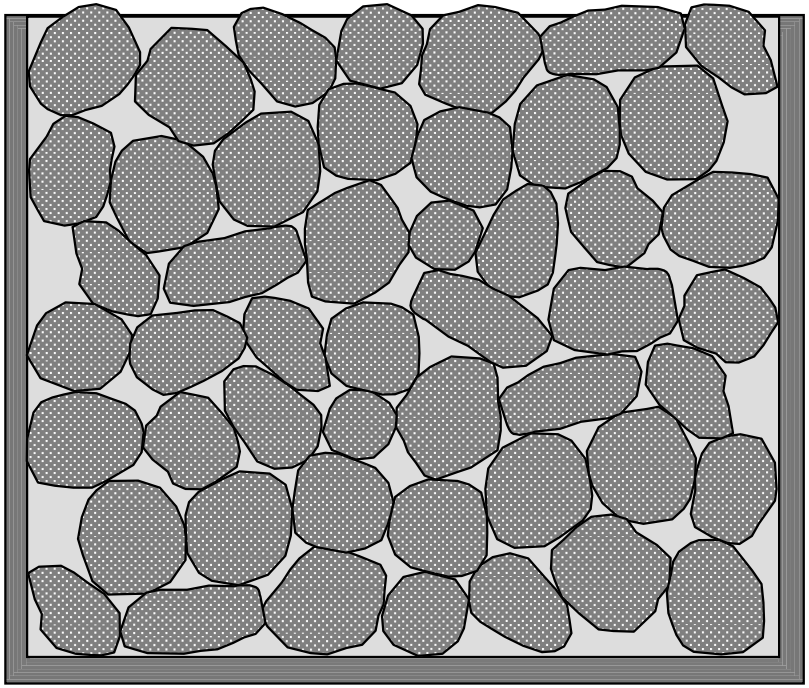
https://www.pavementinteractive.org/reference-desk/testing/aggregate-tests/fine-aggregate-specific-gravity/

Achieving an SSD State

https://www.pavementinteractive.org/reference-desk/testing/aggregate-tests/fine-aggregate-specific-gravity/

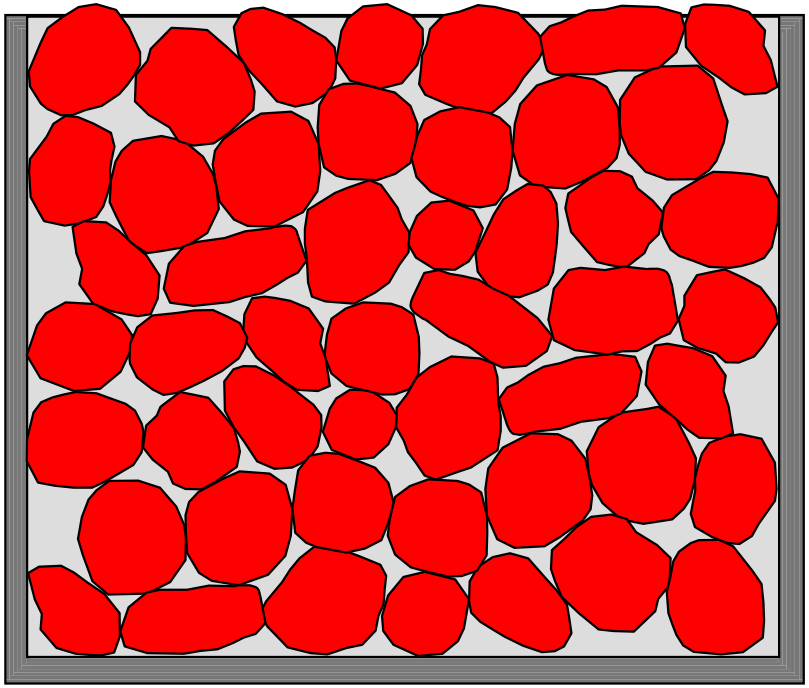
Particle Density

A 1-ft^3 bucket holds 100 lb. of aggregate. What fraction of the volume is occupied by the voids between the particles? (This is the ***void content***.)



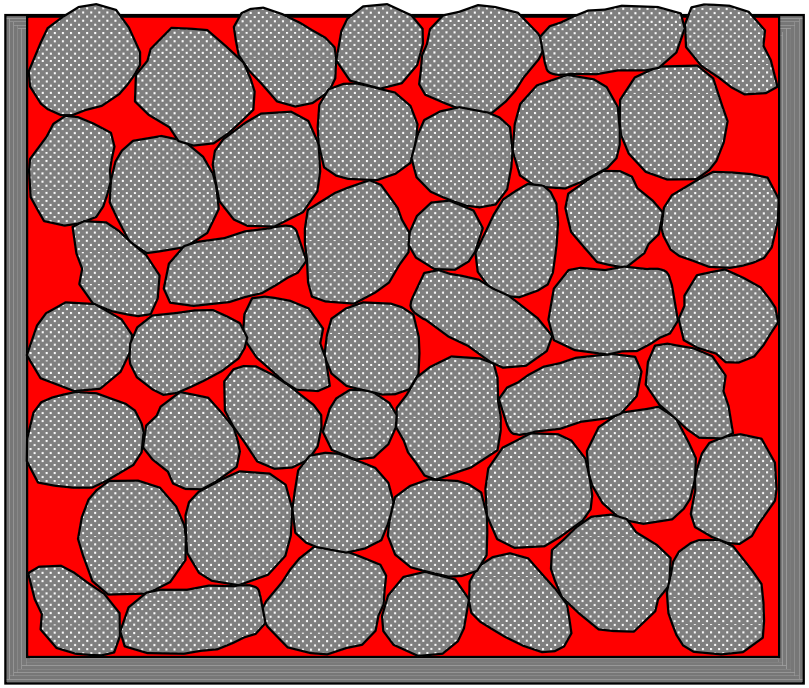
Particle Density

First we need to find the volume of the aggregate particles, which means we need to know the ***particle density***.



Particle Density

Then we can subtract the aggregate volume from the volume of the bucket to get the volume of the voids between particles.



Particle Density

Particle density is the ratio of the mass of an aggregate particle to its own volume (also called mass density of solids).

$$\rho = \frac{M}{V} \quad \left(\frac{kg}{m^3} \text{ or } \frac{g}{cm^3} \right)$$

Particle Density

Particle density can also be expressed as the ratio of the weight of an aggregate particle to its own volume.

$$\gamma = \frac{W}{V} \quad \left(\frac{lb}{ft^3} \right)$$

Relative Density

Relative density is the mass density of an object relative to the mass density of water (also called specific gravity).

$$RD = \frac{\rho}{\rho_w} = \frac{M/V}{\rho_w} = \frac{M}{V \times \rho_w}$$

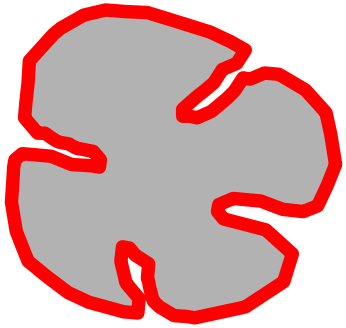
Relative Density

Relative density (specific gravity) can also be expressed in weight-based units.

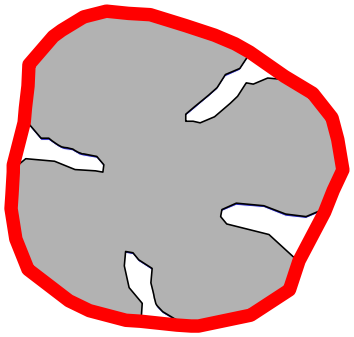
$$RD = \frac{\gamma}{\gamma_w} = \frac{W/V}{\gamma_w} = \frac{W}{V \times \gamma_w}$$

Relative Density

Relative density depends on the volume you assume for the aggregate particles.



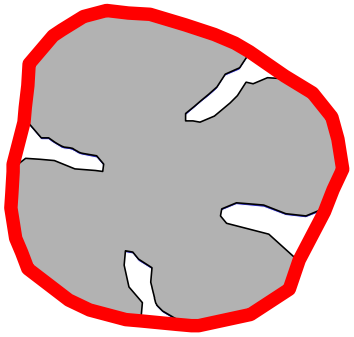
Net
Volume



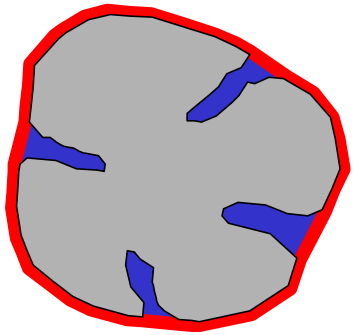
Bulk
Volume

Relative Density

It also depends on the mass you assume for the aggregate particles.



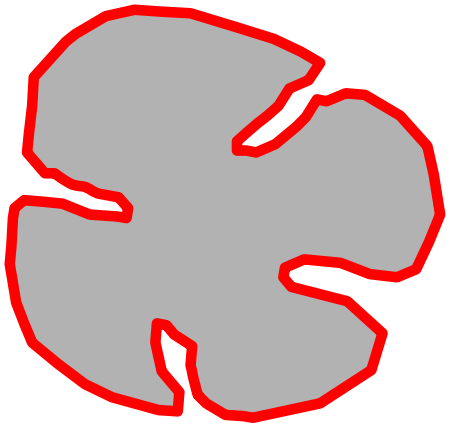
Dry
Mass



SSD
Mass

Apparent Relative Density

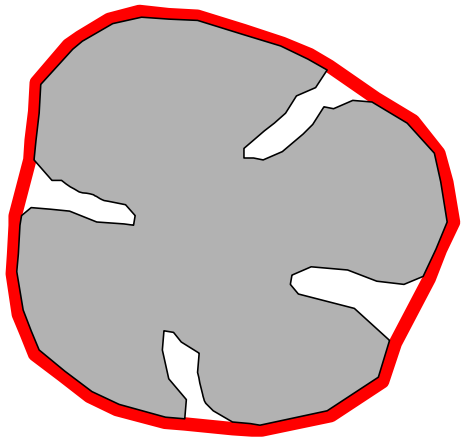
$$RD_A = \frac{M_D}{V_N \times \rho_w}$$



Net volume

Bulk (OD) Relative Density

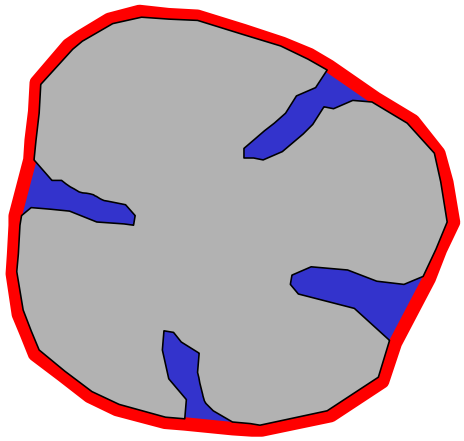
$$RD_B = \frac{M_D}{V_B \times \rho_w}$$



Bulk volume

SSD Relative Density

$$RD_{SSD} = \frac{M_{SSD}}{V_B \times \rho_w}$$



SSD aggregate

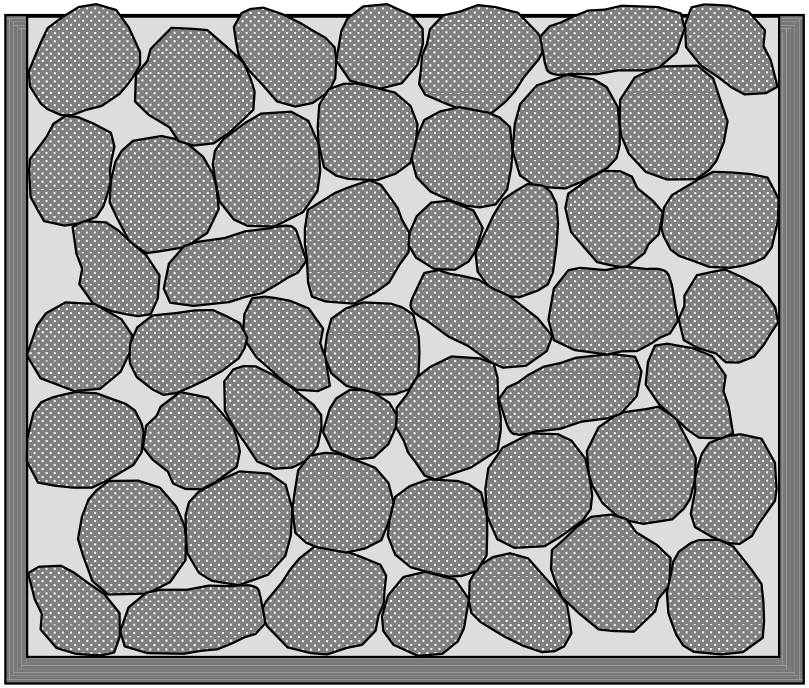
Example

An aggregate sample has an oven-dry mass of 3954.2 g, an SSD mass of 4006.8 g, and a net volume of 1532.6 cm^3.

Find RD_A, RD_B, RD_{SSD}, and %Abs

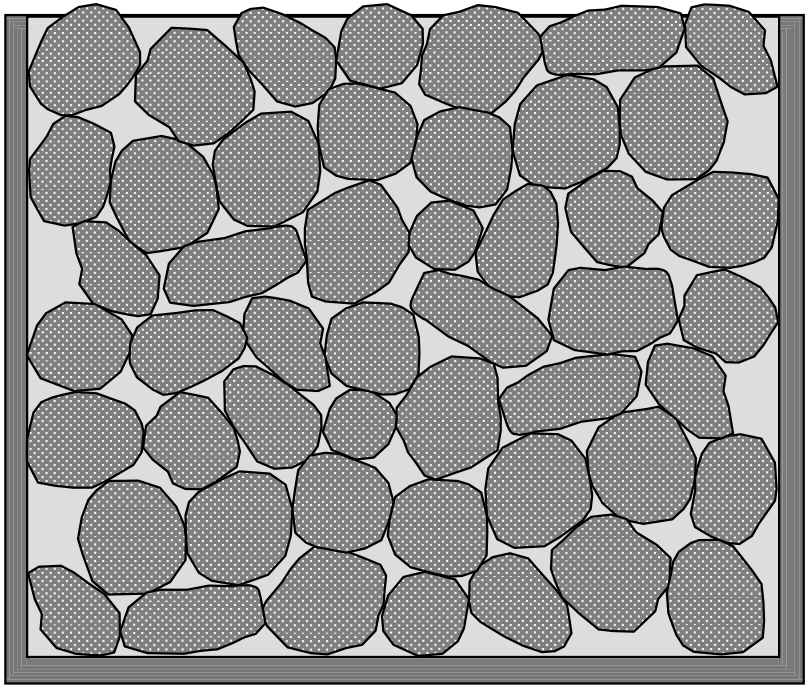
Question

A 1-ft^3 bucket holds 100 lb of the aggregate from the last example. How much volume is occupied by the voids between the aggregate particles?



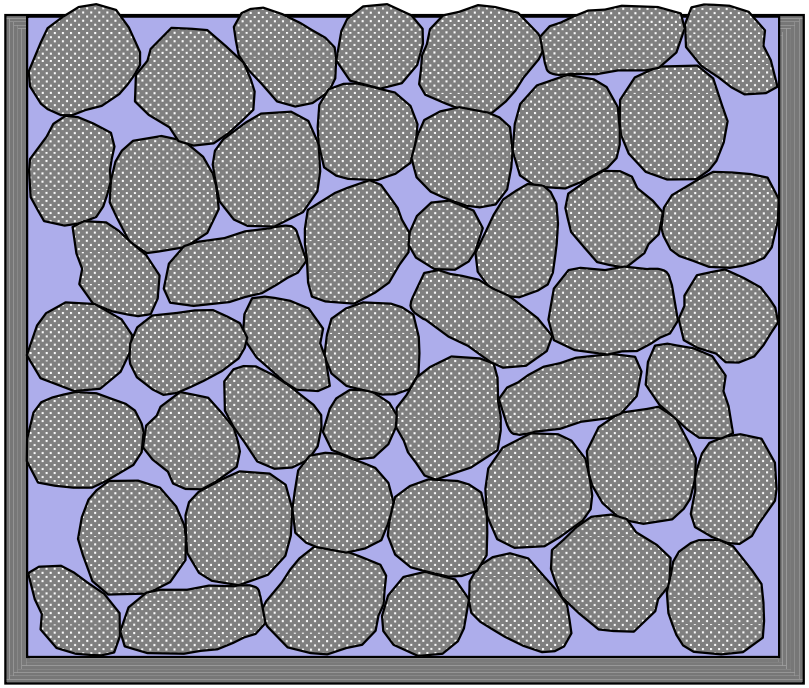
Question

A 1-m^3 bucket holds 1500 kg of the aggregate from the last example. How much volume is occupied by the voids between the aggregate particles?



Question

A 1-m^3 bucket holds 1500 kg of aggregate from the last example. How much <u>water</u> can you add to the bucket without it overflowing?



Measuring Relative Density

Coarse Aggregate

Designation: C 127 – 04

Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate[1]

This standard is issued under the fixed designation C 127; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the determination of the average density of a quantity of coarse aggregate particles (not including the volume of voids between the particles), the relative density (specific gravity), and the absorption of the coarse aggregate. Depending on the procedure used, the density (kg/m^3 (lb/ft^3)) is expressed as oven-dry (OD), saturated-surface-dry (SSD), or as apparent density. Likewise, relative density (specific gravity), a dimensionless quantity, is ex-

priate 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 Bulk Density ("Unit Weight") and Voids in Aggregate

C 125 Terminology Relating to Concrete and Concrete Aggregates

C 128 Test Method for Density, Relative Density (Specific

Measuring Relative Density

$$RD = \frac{M}{V \times \rho_w}$$

mass of water displaced

Measuring Relative Density

$$RD = \frac{M_{\text{aggregate in air}}}{M_{\text{water displaced}}}$$

Measuring Relative Density

To determine the relative density of a ***coarse aggregate*** sample, we can use the concept of buoyancy.

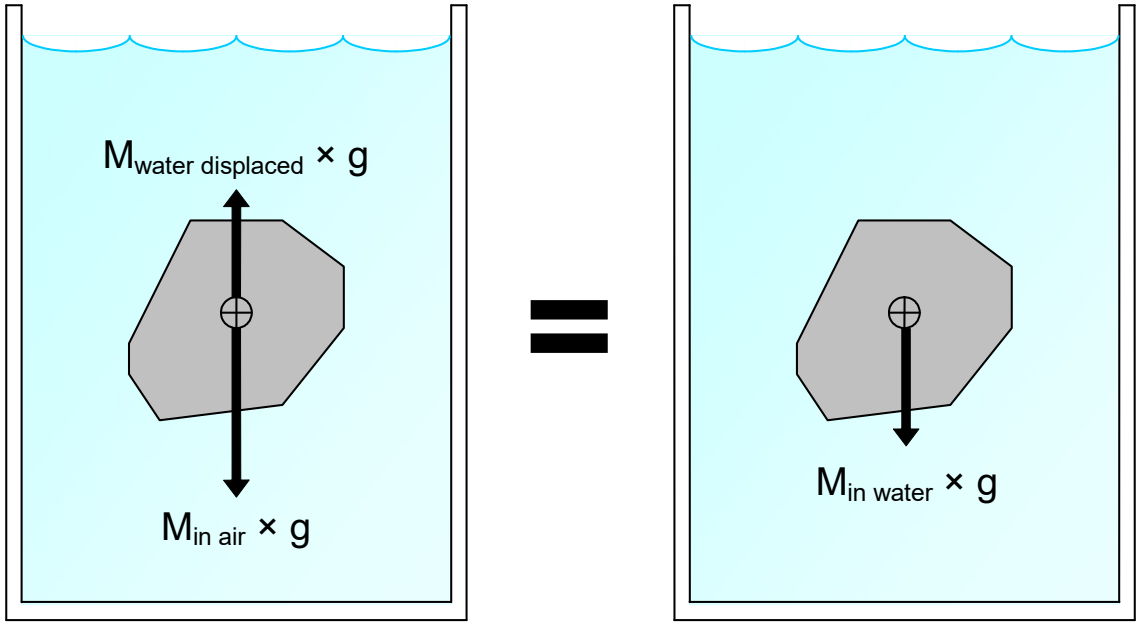
When a solid object is submerged in water, it weighs less because of the buoyant force produced by the water.

Measuring Relative Density

The buoyant force acting on a submerged object is equal to the weight of water displaced by the object.

That's why we feel lighter in the water than on land. It's also why concrete canoes float!

Buoyancy



$$M_{in\ water} = M_{in\ air} - M_{water\ displaced}$$

Measuring Relative Density

$$M_{\text{water displaced}} = M_{\text{in air}} - M_{\text{in water}}$$

$$RD = \frac{M_{\text{aggregate in air}}}{M_{\text{water displaced}}} = \frac{M_{\text{aggregate in air}}}{M_{\text{in air}} - M_{\text{in water}}}$$

Procedure

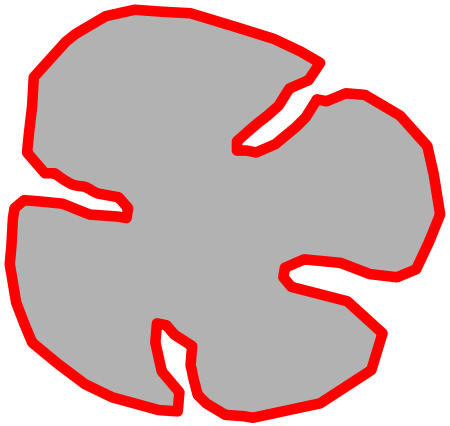
1. Soak aggregate in water for 24 ± 4 hours
2. Pour aggregate into wire basket to drain
3. Spread aggregate onto towel and dry to SSD
4. Weigh aggregate in air to obtain SSD mass
5. Place aggregate back in wire basket
6. Weigh aggregate suspended in water
7. Oven dry aggregate overnight
8. Weigh aggregate in air to obtain oven-dry mass

Measuring Relative Density

https://www.pavementinteractive.org/reference-desk/testing/aggregate-tests/coarse-aggregate-specific-gravity/

Apparent Relative Density

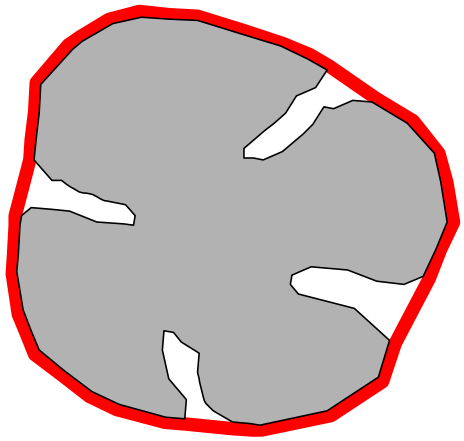
$$RD_A = \frac{M^{OD}_{\text{in air}}}{M^{OD}_{\text{in air}} - M_{\text{in water}}}$$



Net volume

Bulk (OD) Relative Density

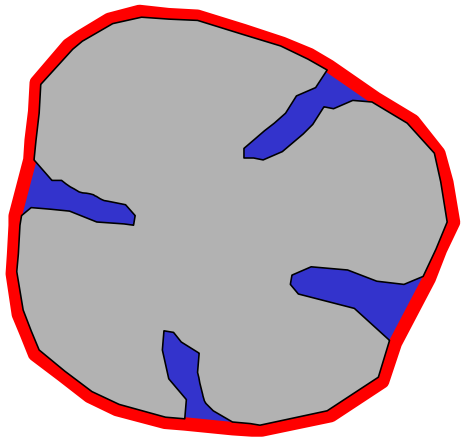
$$RD_B = \frac{M^{OD}_{\text{in air}}}{M^{SSD}_{\text{in air}} - M_{\text{in water}}}$$



Bulk volume

SSD Relative Density

$$RD_{SSD} = \frac{M_{\text{in air}}^{SSD}}{M_{\text{in air}}^{SSD} - M_{\text{in water}}}$$



Bulk volume

Example

An SSD aggregate sample has a mass in air of 4007 g and a mass suspended in water of 2426 g. After drying overnight, it has an oven-dry mass of 3954 g.

Find RD_A, RD_B and RD_{SSD}

Measuring Relative Density

Fine Aggregate

Designation: C 128 – 04a

Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate[1]

This standard is issued under the fixed designation C 128; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers the determination of the average density of a quantity of fine aggregate particles (not including the volume of voids between the particles), the relative density (specific gravity), and the absorption of the fine aggregate. Depending on the procedure used, the density, in kg/m^3(lb/ft^3) is expressed as oven-dry (OD), saturated-surface-dry (SSD), or as apparent density. Likewise, relative density (specific gravity), a dimensionless quality, is expressed as OD, SSD, or as

priate 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 Bulk Density ("Unit Weight") and Voids in Aggregate

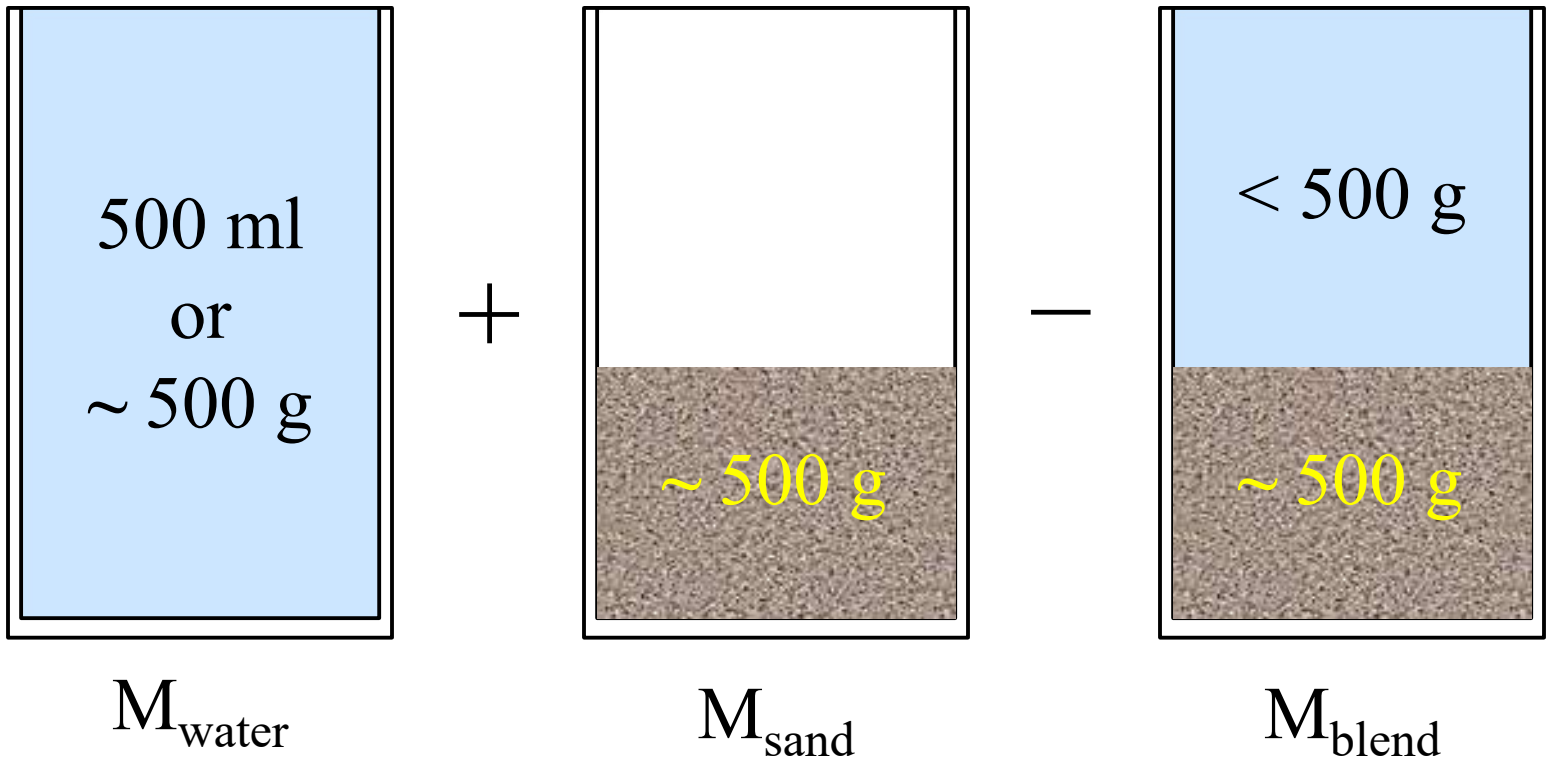
C 70 Test Method for Surface Moisture in Fine Aggregate

C 125 Terminology Relating to Concrete and Concrete

Measuring Relative Density

To determine the relative density of a ***fine aggregate*** sample, we indirectly measure the mass of water displaced by the aggregate by comparing the mass of a container filled with just water with the mass of the same container filled with aggregate and water. The difference is the mass of water that has been displaced by the aggregate.

Measuring Relative Density



Measuring Relative Density

$$M_{\text{water displaced}} = M_{\text{water}} + M_{\text{sand}} - M_{\text{blend}}$$

Measuring Relative Density

$$M_{\text{water displaced}} = M_{\text{water}} + M_{\text{sand}} - M_{\text{blend}}$$

$$RD = \frac{M_{\text{aggregate in air}}}{M_{\text{water}} + M_{\text{sand}} - M_{\text{blend}}}$$

Procedure

1. Spread moist sand on counter and dry to SSD
2. Deposit 500 ± 10 g of sand into shallow pan
3. Weigh sand in air to obtain SSD mass
4. Weigh pycnometer filled with 500 ml clean water
5. Carefully pour sand into pycnometer
6. Weigh pycnometer with sand/water blend
7. Pour sand into metal pan and oven dry overnight
8. Weigh sand in air to obtain oven-dry mass

Measuring Relative Density

"pycnometer"

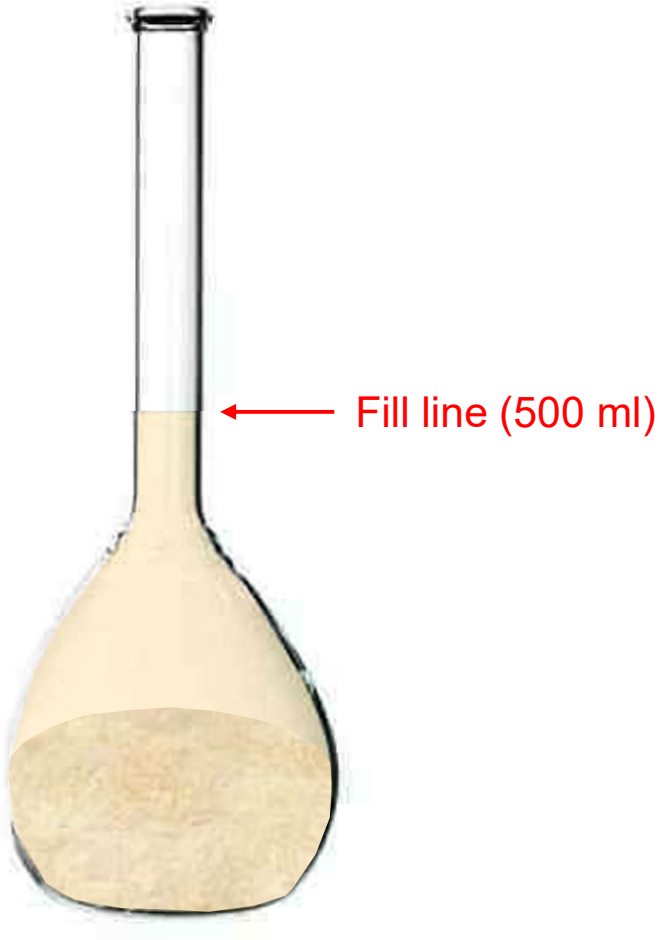
Fill line (500 ml)

Measuring Relative Density

https://www.pavementinteractive.org/reference-desk/testing/aggregate-tests/fine-aggregate-specific-gravity/

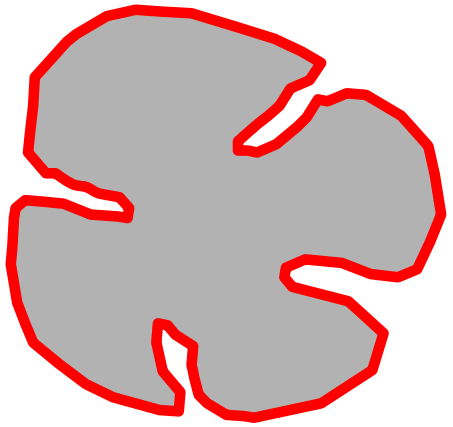
Measuring Relative Density

"pycnometer"



Apparent Relative Density

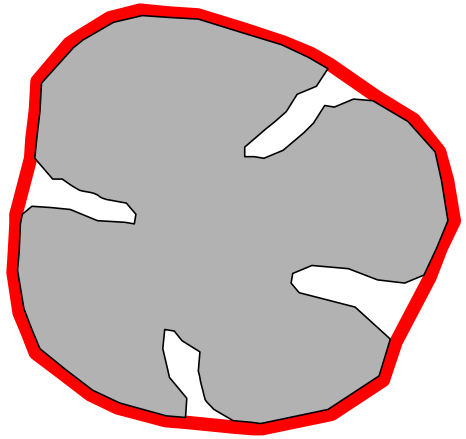
$$RD_A = \frac{M_{sand}^{OD}}{M_{water} + M_{sand}^{OD} - M_{blend}}$$



Net volume

Bulk (OD) Relative Density

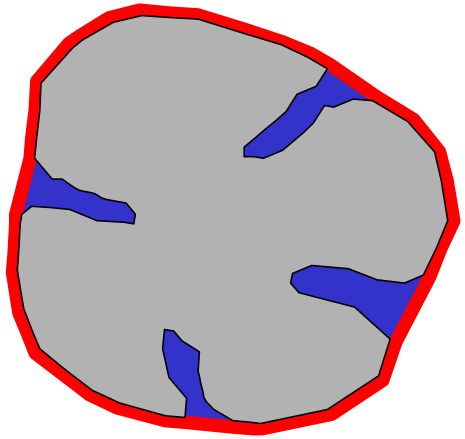
$$RD_B = \frac{M_{sand}^{OD}}{M_{water} + M_{sand}^{SSD} - M_{blend}}$$



Bulk volume

SSD Relative Density

$$RD_{SSD} = \frac{M_{sand}^{SSD}}{M_{water} + M_{sand}^{SSD} - M_{blend}}$$



Bulk volume

Example

A pycnometer filled with 500 ml of clean water has a mass of 660 g. After adding 495 g of SSD sand and refilling it to the 500-ml mark, it has a mass of 965 g. After oven drying overnight, the sand has a mass of 489 g.

Find RD_A, RD_B and RD_{SSD}