# Bulk Density and Void Content

# Bulk Density

**Bulk density** (*n*.) the mass of a unit volume of bulk aggregate including the volume of the individual particles and the volume of the voids between them.

$$\text{bulk density} = \frac{m_{agg}}{V_{bucket}} = \frac{kg}{m^3}$$

# Unit Weight

**Unit weight** (*n*.) the weight of a unit volume of bulk aggregate including the volume of the individual particles and the volume of the voids between them.

$$\text{unit weight} = \frac{W_{agg}}{V_{bucket}} = \frac{\text{lb}}{\text{ft}^3}$$

Designation: C29/C29M – 17a

American Association of State
Highway and Transportation Officials Standard
AASHTO No.: T19/T19M

# Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate[1]

This standard is issued under the fixed designation C29/C29M; 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 U.S. Department of Defense.*

## 1. Scope*

1.1 This test method covers the determination of bulk density ("unit weight") of aggregate in a compacted or loose condition, and calculated voids between particles in fine, coarse, or mixed aggregates based on the same determination. This test method is applicable to aggregates not exceeding 125 mm [5 in.] in nominal maximum size.

NOTE 1—Unit weight is the traditional terminology used to describe the property determined by this test method, which is weight per unit volume (more correctly, mass per unit volume or density).

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard, as appropriate for a specification with which this test method is used. An exception is with regard to sieve sizes and nominal size of aggregate, in which the SI values are the standard as stated in Specification

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

C125 Terminology Relating to Concrete and Concrete Aggregates

C127 Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate

C128 Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C702/C702M Practice for Reducing Samples of Aggregate to Testing Size

C1077 Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation

# Dry-Rodded Unit Weight

1. DRY the aggregate overnight in the oven
2. Select a metal mold of known volume
3. Fill the mold in three ***lifts*** (layers)
4. ROD each lift 25 times with a tamping rod
5. Strike off the surface level with the mold
6. Weigh the mold and the aggregate
7. Subtract the weight of the empty mold

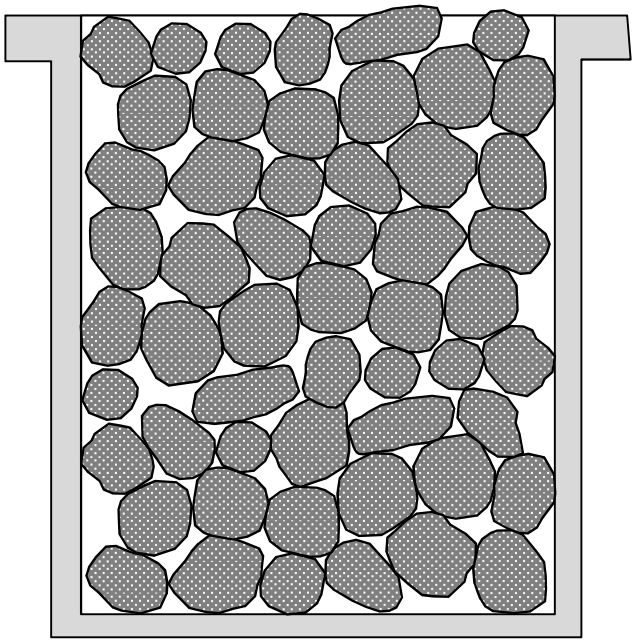
# Equipment

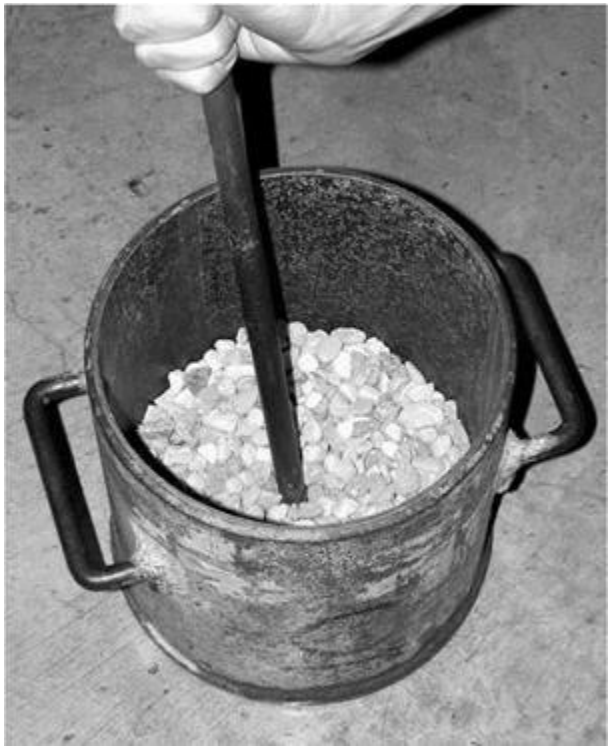
## TABLE 1 Capacity of Measures

| Nominal Maximum Size of Aggregate | | Capacity of Measure[A] | |
|---|---|---|---|
| mm | in. | $m^3$ [L] | $ft^3$ |
| 12.5 | ½ | 0.0028[2.8] | 1/10 |
| 25.0 | 1 | 0.0093 [9.3] | ⅓ |
| 37.5 | 1½ | 0.014 [14] | ½ |
| 75 | 3 | 0.028 [28] | 1 |
| 100 | 4 | 0.070 [70] | 2½ |
| 125 | 5 | 0.100 [100] | 3½ |

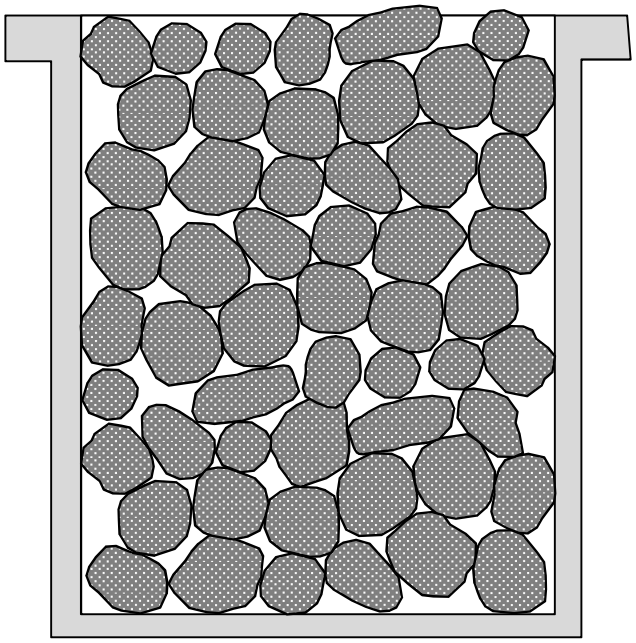
[A] The indicated size of measure shall be used to test aggregates of a nominal maximum size equal to or smaller than that listed. The actual volume of the measure shall be at least 95 % of the nominal volume listed.

# Dry-Rodded Unit Weight





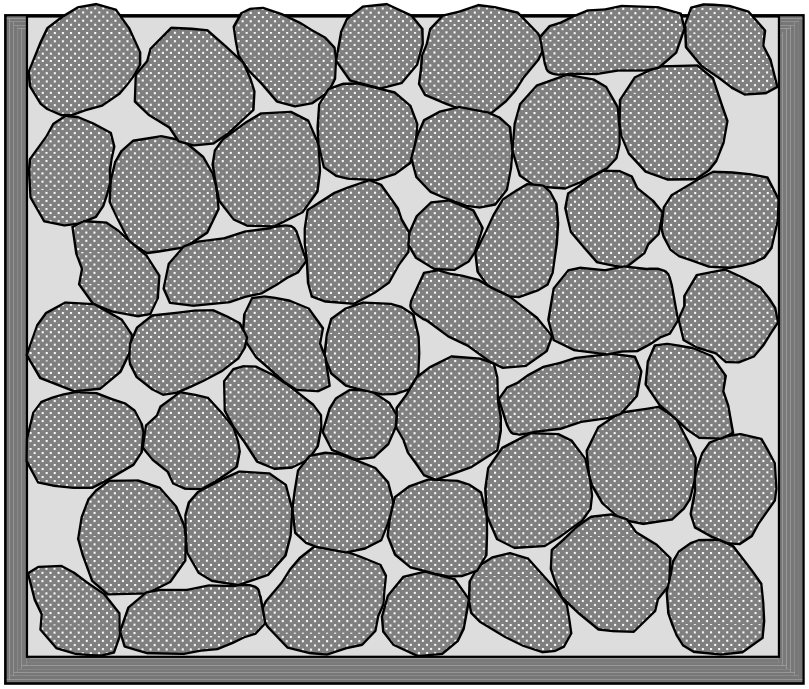
# Dry-Rodded Unit Weight



# Question

A ½-$ft^3$ bucket filled in three lifts holds 50 lb of dry aggregate.

What is the dry-rodded unit weight?



# Void Content

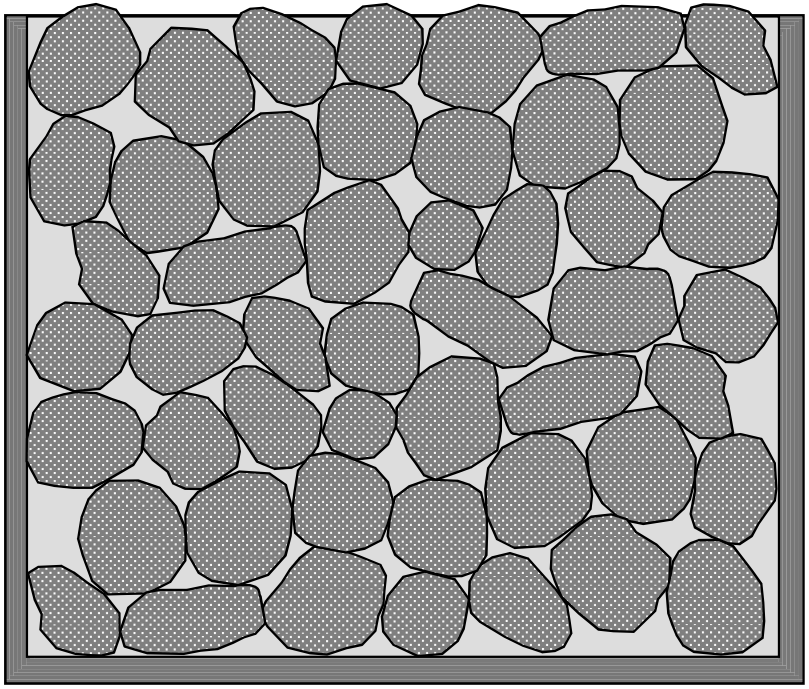
**Void Content** (*n*.) the volume of void spaces between particles expressed as a percentage of the volume needed to contain all of the particles.

$$\text{void content} = \frac{V_{voids}}{V_{bucket}} \times 100\%$$

# Question

A ½-$ft^3$ bucket filled in three lifts holds 50 lb of dry aggregate.

What is the void content of the aggregate?

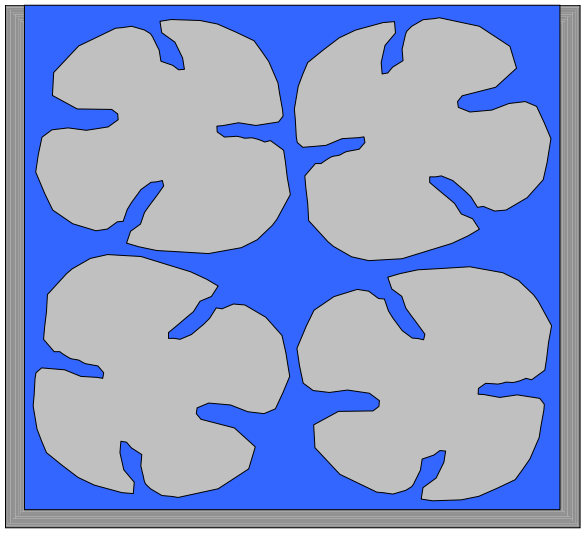


# Volume of Voids

$$V_{agg} = \frac{W_{agg}}{RD\,\gamma_w} = \frac{m_{agg}}{RD\,\rho_w}$$

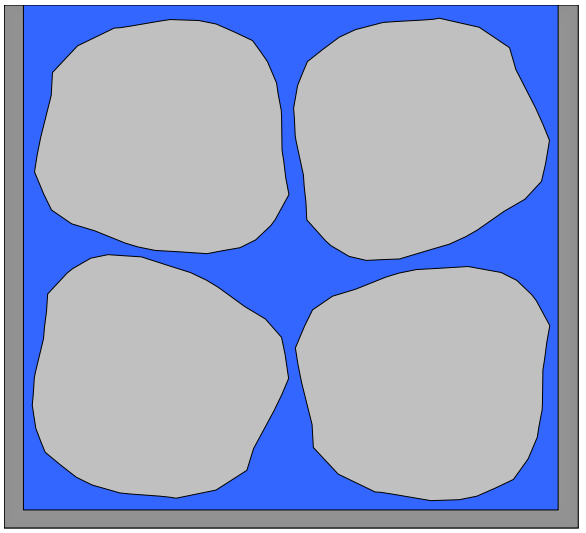
$$V_{voids} = V_{bucket} - V_{agg}$$

# Which Aggregate Volume?



Voids + Pores

(Net Volume)



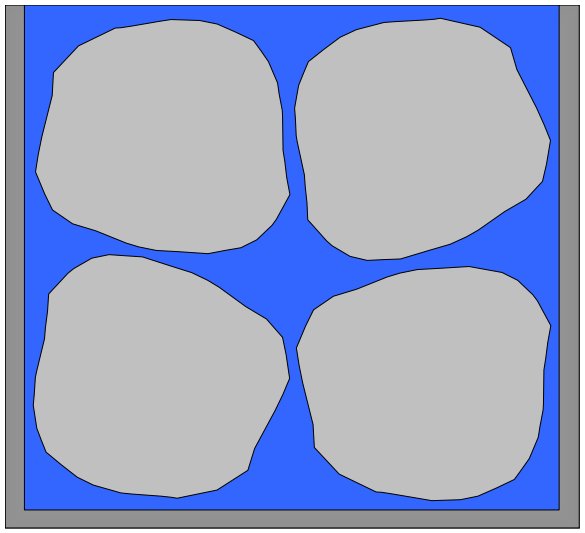
Voids Alone

(Bulk Volume)

# Volume of Voids

$$V_{agg} = \frac{W_{agg}}{RD_B \gamma_w}$$

$$V_{agg} = \frac{m_{agg}}{RD_B \rho_w}$$

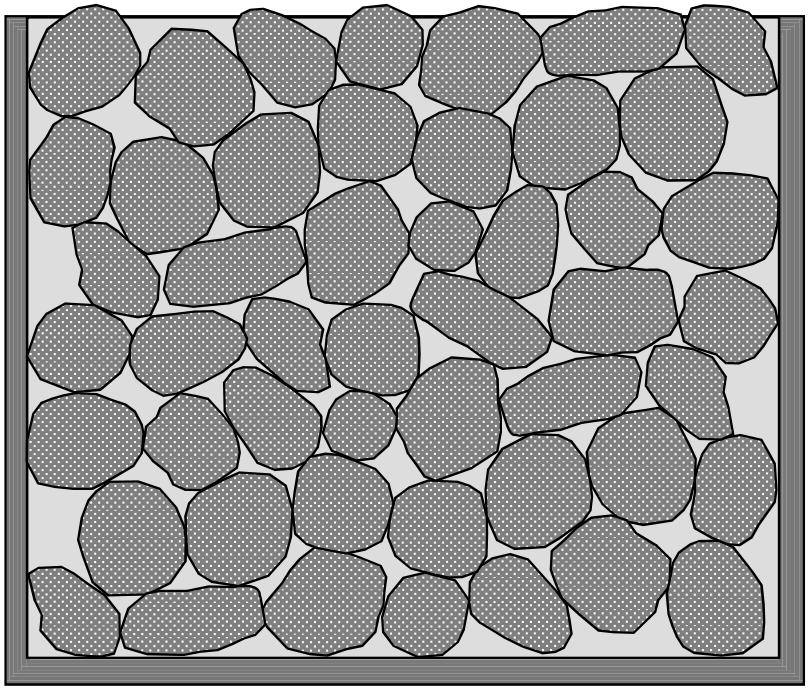


Voids Alone

(Bulk Volume)

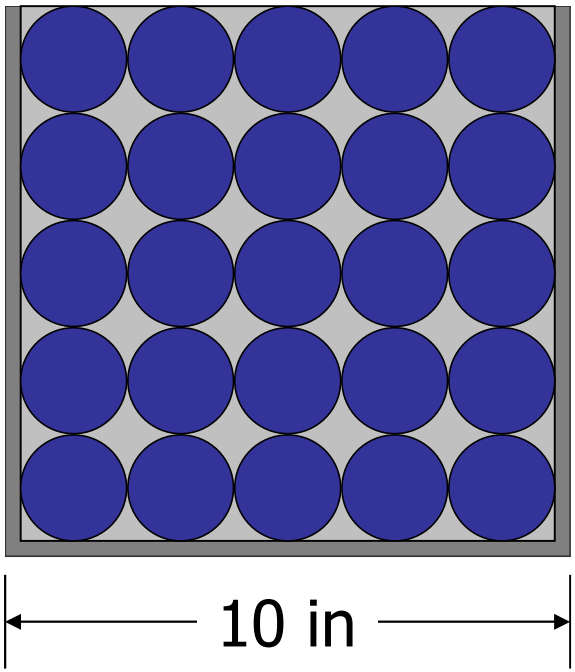
# Question

What determines the void content of a given aggregate sample?

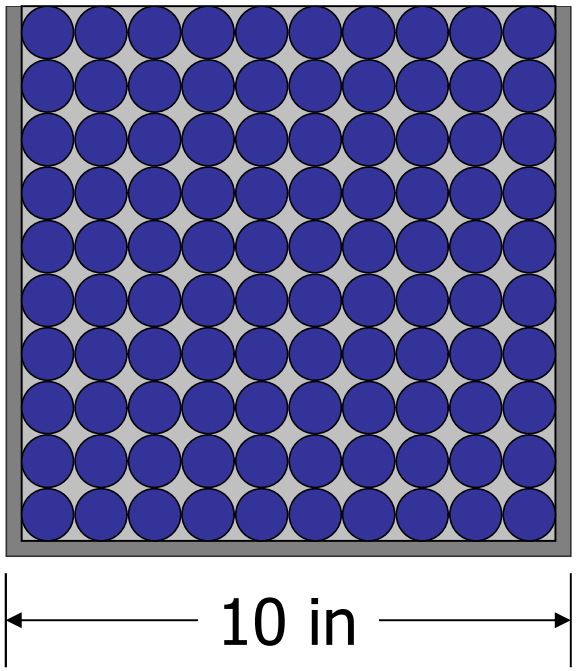


# Effects of Particle Size

5 × 5 × 5 =125 balls




10 × 10 × 10 =1000 balls



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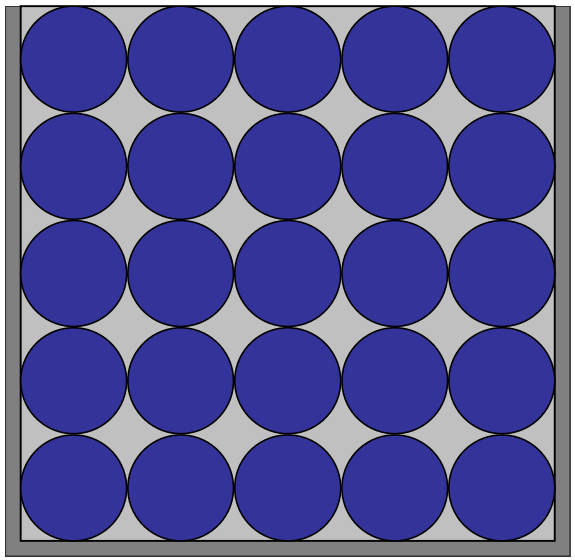
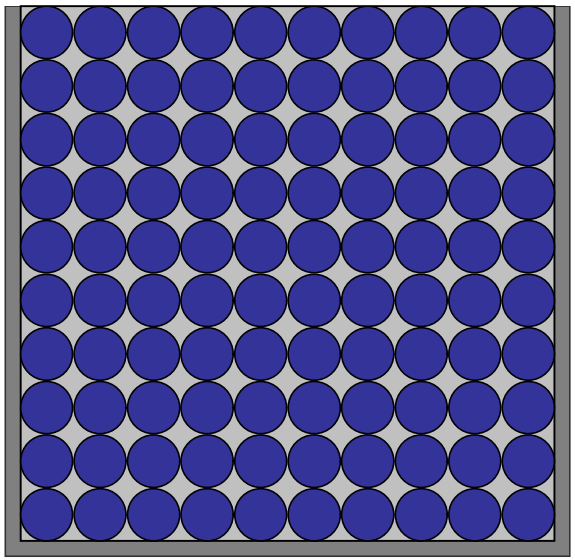


Void content = 48%

10 × 10 × 10 =1000 balls

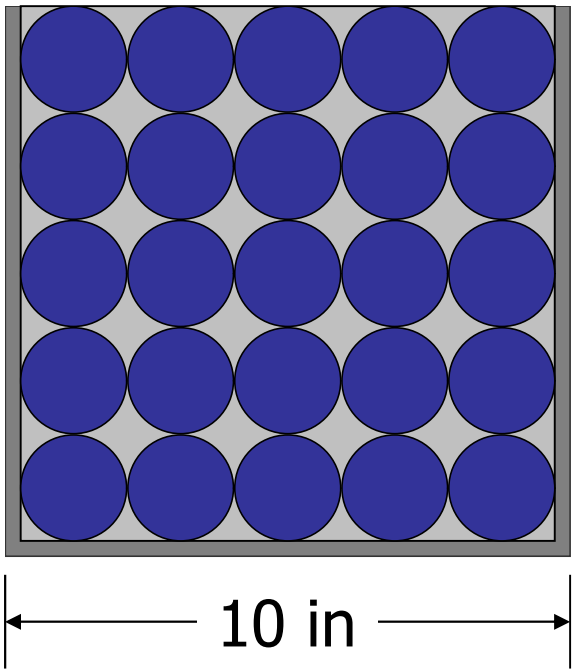


Void content = 48%

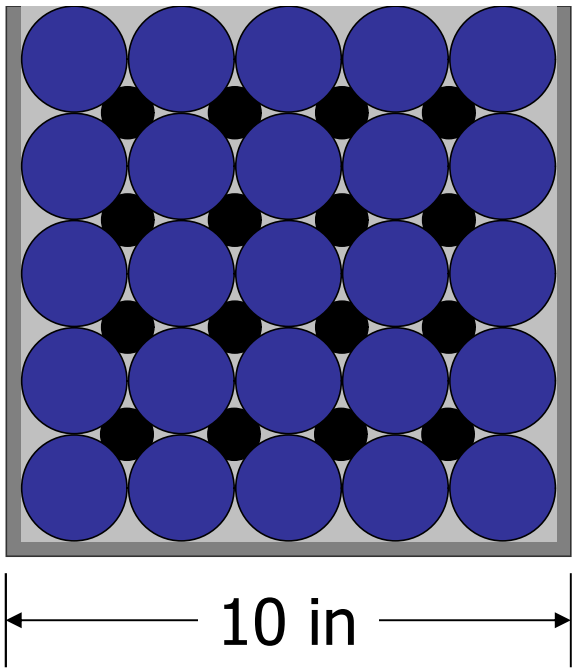
$$V_{sphere} = \frac{4}{3}\pi r^3$$

# Effects of Particle Gradation

125 large balls



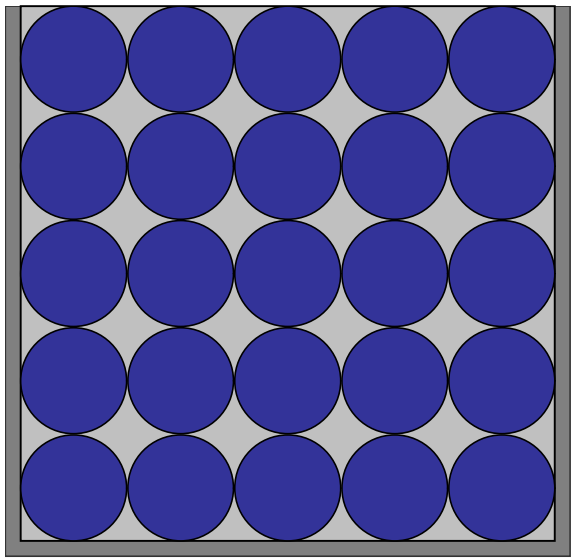

125 large + 125 small balls




$$V_{sphere} = \frac{4}{3}\pi r^3$$

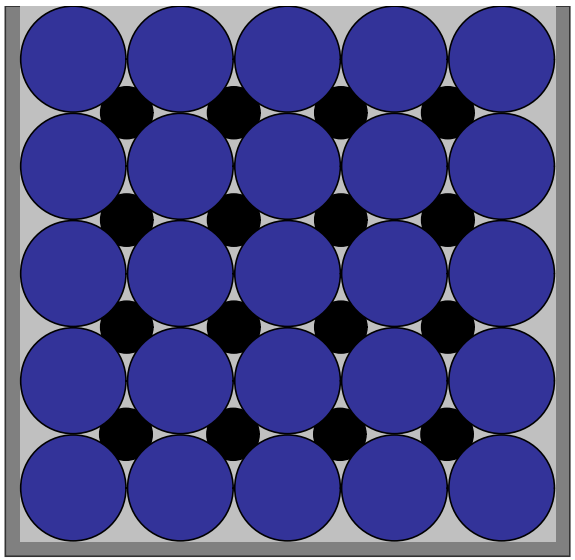
# Effects of Particle Gradation

125 large balls



Void content = 48%

125 large + 125 small balls

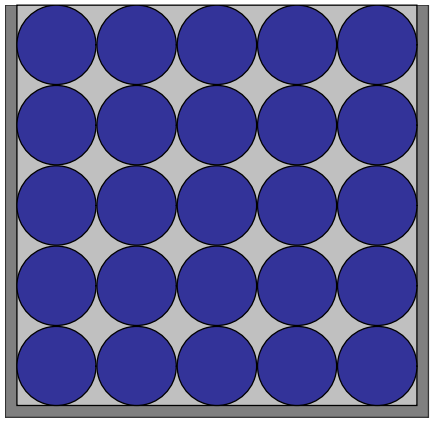


Void content = 41%

$$V_{sphere} = \frac{4}{3}\pi r^3$$

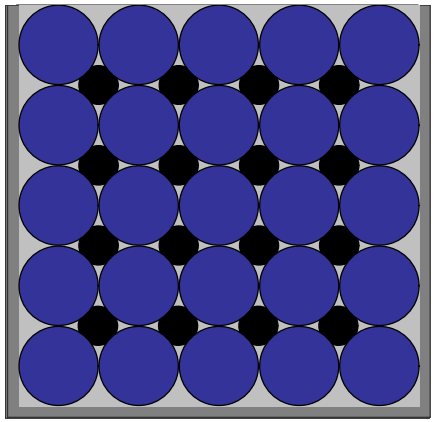
# Effects of Particle Gradation

100% CA



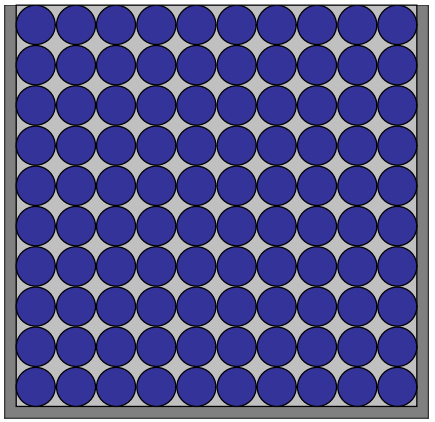
Void content = 48%

CA:FA Blend



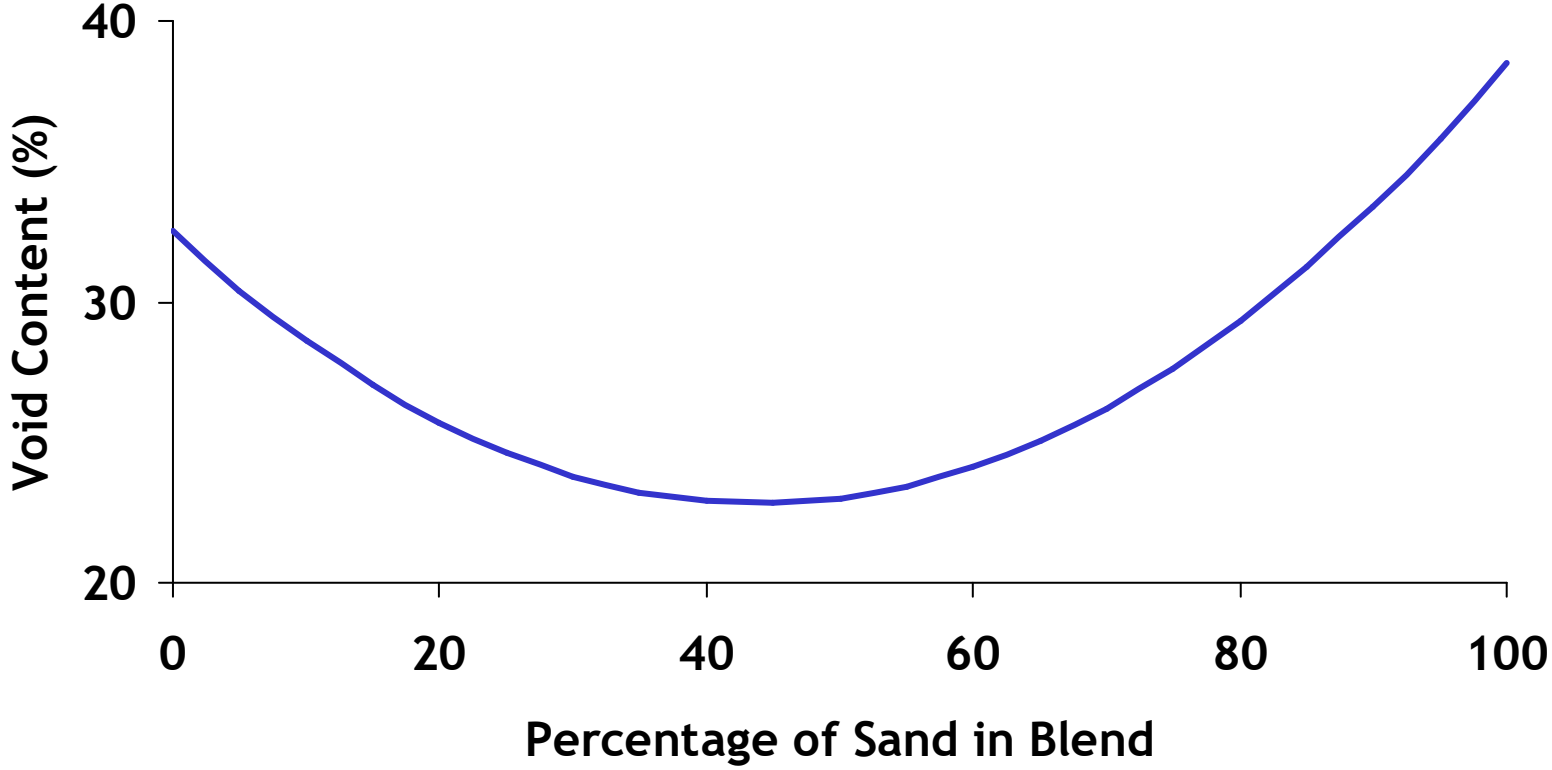
Void content = 41%

100% FA



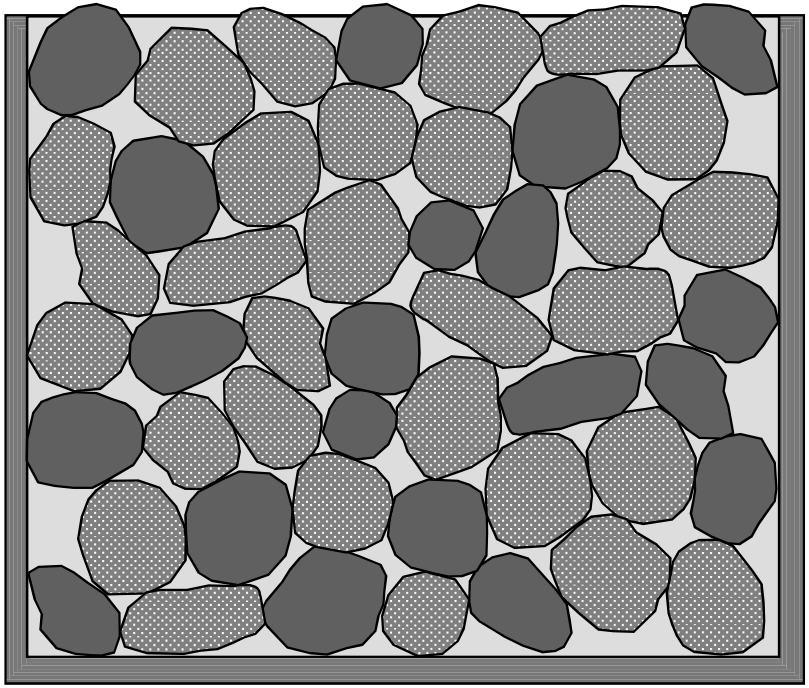
Void content = 48%

# Gravel-Sand Blend



# Question

A 1-$ft^3$ bucket holds a blend of aggregates. How much volume is occupied by the air and how much by the aggregate particles?



# Volume of Voids

$$V_{agg} = \left( \frac{W_{agg}}{RD_B \, \gamma_w} \right)_A + \left( \frac{W_{agg}}{RD_B \, \gamma_w} \right)_B + \cdots$$

$$V_{voids} = V_{bucket} - V_{agg}$$

# Volume of Voids

$$V_{agg} = \left( \frac{m_{agg}}{RD_B \, \rho_w} \right)_A + \left( \frac{m_{agg}}{RD_B \, \rho_w} \right)_B + \cdots$$

$$V_{voids} = V_{bucket} - V_{agg}$$

# Example

An aggregate blend of 30% sand and 70% gravel has a dry-rodded unit weight of 125.5 lb/ft$^3$.

If the sand has a bulk specific gravity of 2.57 and the gravel has a bulk specific gravity of 2.69 what is the void content of the blend?

# Volume of Voids

Assume a volume of 1 $ft^3$

$$W_{sand} = 0.3\left(125.5\ lb/ft^3\right) = 37.65\ lb/ft^3$$

$$W_{gravel} = 0.7\left(125.5\ lb/ft^3\right) = 87.85\ lb/ft^3$$

# Volume of Voids

$$V_{sand} = \frac{37.65\ \text{lb}}{2.57\left(62.24\ \text{lb}/\text{ft}^3\right)} = 0.235\ \text{ft}^3$$

$$V_{gravel} = \frac{87.85\ \text{lb}}{2.69\left(62.24\ \text{lb}/\text{ft}^3\right)} = 0.525\ \text{ft}^3$$

# Volume of Voids

$$V_{voids} = 1\ ft^3 - 0.235\ ft^3 - 0.525\ ft^3 = 0.24\ ft^3$$

$$\%voids = \frac{0.24\ ft^3}{1\ ft^3} \times 100\% = 24\%$$

# Gravel-Sand Blend