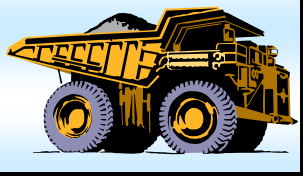
Volumetric Tests

Qualified Aggregate Technician



Overview

- Volumetrics
- Specific Gravity
  - Different types
  - Uses
- Density
  - Why density?
- Unit Weight

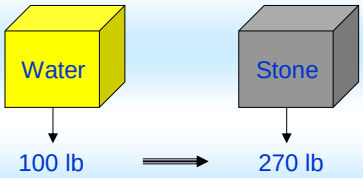
What are Volumetrics?

- All matter has weight and occupies space
- Volumetrics are the relationships between weight and volume
- Asphalt and concrete mix designs are based on aggregate and mixture volumetrics

Specific Gravity

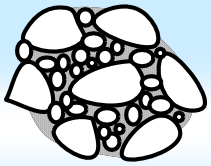
- **Ratio of aggregate weight to the weight of an equal volume of water**
  - **Dimensionless number (no units attached)**

Specific Gravity = 2.70 means that the rock weighs 2.70 times an equal volume of water

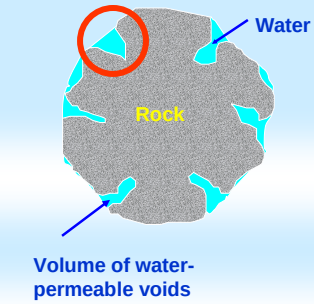


Uses of Specific Gravity

- Weight - Volume Conversions
- Hot Mix Asphalt Designs (BOD)
- Portland Cement Concrete Designs (SSD)
- Identifying Deleterious Materials (e.g. shale or chert)
- Mining Operations / Planning
- Quantity Calculations
- Void Calculations
- Float / Separation Systems



Rock and Water



Considerations:

1) Rock has weight
2) Rock takes up space (volume)
3) Absorbed Water has weight
4) Absorbed Water takes up space (volume)

Specific Gravity

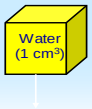
$$Specific\,Gravity = \frac{Weight}{Volume * (Unit\,Weight\,of\ Water)}$$

$$G = \frac{W}{V\gamma}$$

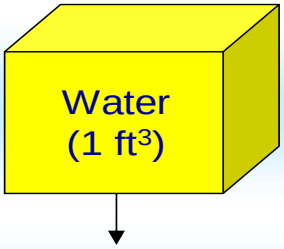
G=Specific Gravity
W = Weight
V=Volume
γ = Unit Wt. Of Water

Unit Weight of Water

γ_w = 1.000 g/cm³



1.000 g/cm³



γ_w = 62.4 lb/ft³

62.4 lb/ft³

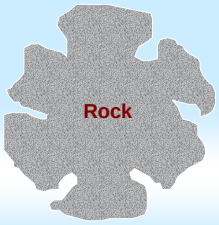
Types of Specific Gravity

- Apparent
- Bulk Oven Dry (BOD)
- Bulk Saturated Surface Dry (SSD)

Apparent Specific Gravity

Considerations:

1) Mass of Oven Dry Rock
2) Volume of Solid Rock Only

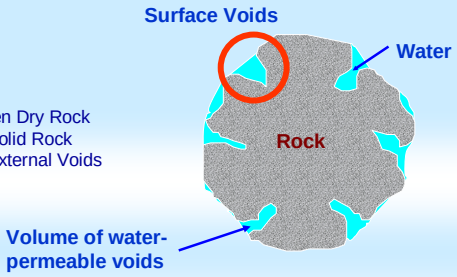


$$G_{sa} = \frac{Mass\ of\ Oven\ Dry\ Aggregate}{(Volume\ of\ Oven\ Dry\ Aggregate)\ x\ (Unit\ Weight\ of\ Water)}$$

BOD Specific Gravity

Considerations:

1) Mass of Oven Dry Rock
2) Volume of Solid Rock
3) Volume of External Voids

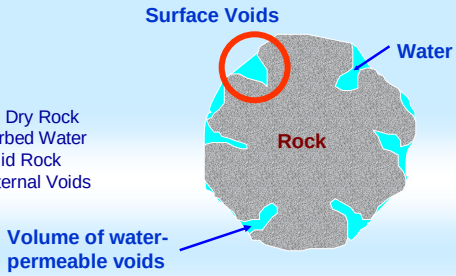


$$G_{sb} = \frac{Mass\ of\ Oven\ Dry\ Aggregate}{(Volume\ of\ Aggregate + Volume\ of\ Voids)\ x\ (Unit\ Weight\ of\ Water)}$$

SSD Specific Gravity

Considerations:

1) Mass of Oven Dry Rock
2) Mass of Absorbed Water
3) Volume of Solid Rock
4) Volume of External Voids



$$G_{SSD} = \frac{Mass\ of\ Oven\ Dry\ Aggregate + Mass\ of\ Absorbed\ Water}{(Volume\ of\ Aggregate + Volume\ of\ Voids)\ x\ (Unit\ Weight\ of\ Water)}$$

Specific Gravity Relationships

It is Always True that

Apparent > SSD > BOD

Unless

Absorption = 0

Specific Gravity Relationships

Apparent = SSD = BOD

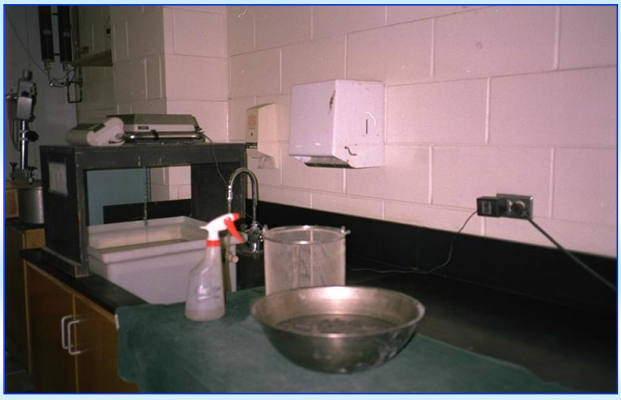
Only When

Absorption = 0

Coarse Agg Specific Gravity

- AASHTO T85
  - Dry aggregate
  - Soak in water for 15-19 hours
  - Decant water
  - Use towel to get SSD condition
  - Determine mass of SSD aggregate in bucket
  - Determine mass of aggregate under water
  - Dry to constant mass
  - Determine oven dry mass

Soaking, Submerging Bucket, and Scale



Achieve SSD Condition

Calculate 3 Gravities From 1 Test

- A = mass oven dry
- B = mass SSD
- C = mass under water

Apparent = G_{sa} = A / (A - C)

BOD = G_{sb} = A / (B - C)

SSD = G_{SSD} = B / (B - C)

Absorption % = [(B - A) / A] * 100

Fine Agg. Specific Gravity

- KM 64-605
  - Wash sample over a #200 sieve
  - Dry aggregate
  - Soak in water for 15 - 24 hours
  - Decant water over a #200 sieve
  - Spread out on plastic and dry to SSD with fan
  - Add 500 grams of SSD aggregate to pycnometer and 500 grams of SSD aggregate to a pan to be placed in an oven
  - Add water to 90 percent of pycnometer capacity and place on Gilson SS-28 vibrator for 4 minutes at high setting
  - Top off pycnometer with a bead of water and determine the mass of the pycnometer, aggregate and water
  - Determine mass of oven dry portion

Fine Agg. Specific Gravity

SSD Condition

Pycnometer & Vibrator

Calculate 3 Gravities From 1 Test

- A = mass oven dry
- B = mass of pycnometer filled with water
- C = mass pycnometer, SSD aggregate and water
- S = mass SSD aggregate

Apparent = G_{sa} = A / (B + A - C)
BOD = G_{sb} = A / (B + S - C)
SSD = G_{SSD} = S / (B + S - C)

Absorption % = [(S - A) / A] * 100

Specific Gravity Review

- Commonly Used for Weight-Volume Conversions
- Essential in HMA and PCC Mix Designs
- 3 Gravities discussed
  - Apparent, BOD, SSD
  - 3 Gravities Calculated From 1 Test Procedure
- Apparent > SSD > BOD, except when Absorption=0
  Absorption of 0 is very rare

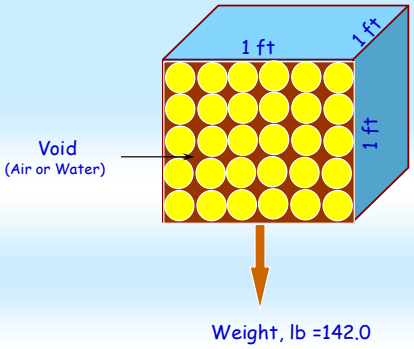
Density

- Density of an Aggregate is Defined as Weight per Unit Volume
  - Pounds per Cubic Foot = pcf = lb / ft^3
  - Grams per Cubic Centimeter = gm / cc = gm / cm^3
  - Tons/yd^3, N/m^3, lb/yd^3, lb/in^3, oz/in^3, gm/mm^3

Volume

- Volume is the Space Occupied by a substance
- 3-Dimensional Calculation
  - length x width x depth
- Unit Volume is the Space where length=width=depth=1 Unit

Density



Weight =142.0 lb
Volume = 1 ft^3

Density = 142.0 pcf

Why Density?

- The purpose of Aggregate Base is to Provide Adequate Support
- Support is Measured by Strength and Stiffness
- Strength and Stiffness are Derived from Stone-to-Stone Contact in an Aggregate Support Layer
- Stone-to-Stone Contact Provides Internal Friction to Resist Particles Sliding Across Each Other
- Dry Density is a Measure of the Amount of Solid Particles (Weight) in a Unit Volume

Why Density?

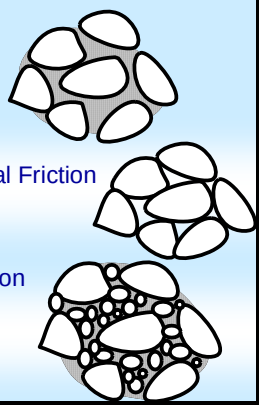
- Higher Density Indicates more stone-to-stone contact…
  - (except with high fines contents)
- More Stone-to-Stone Contact Means Greater Internal Friction...
- Greater Internal Friction Increases the Stiffness and Strength...
- *Increased Stiffness & Strength Provide Greater Structural Support in a Pavement System!!!*

What Influences Density?

- Gradation
- Moisture
- Compactive Effort
- Particle Shape and Others...

Gradation Influence

- Too Fine
  - Coarse Particles Float in Fines
- Too Coarse
  - Excessive Voids & Lower Internal Friction
- Just Right
  - Well-proportioned Size Distribution



Moisture Influences

- Too Wet
  - Base is “Soupy” & Water Pushes Particles Apart
- Too Dry
  - No Lubrication to Enhance Compaction
- Just Right
  - Particles Move Easier and Voids Replaced with Solid Particles

Compactive Effort

- Too Little
  - Particles aren't Tightly Packed
- Too Much
  - Breakdown Particles, Generate Fines, Coarse Float in Fines Matrix

GOOD COMPACTION LEADS TO GOOD PERFORMANCE

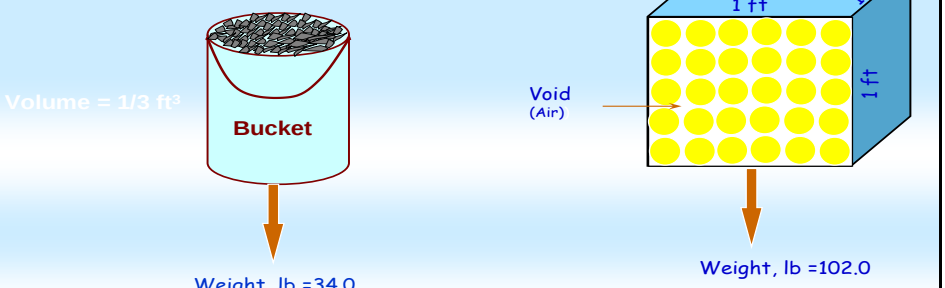
Others...

- Particle Shape
- Plasticity
- Construction Foundation

Unit Weight

- What is Unit Weight?
  - Density of material determined according to specified procedures
- Used for Concrete Mix Designs, Yields, Stockpile Inventories
- AASHTO T19
  - Dry Loose or Dry Rodded
  - 1/10-, 1/3-, 1/2-, 1-, 2 1/2-, or 3 1/2- ft^3 Bucket

Unit Weight



$$Unit\ Weight = \frac{34\ lb}{1/3\ ft^3} = 102.0\ pcf$$

Voids Calculations

- Void space can be calculated from the unit weight value if the bulk specific gravity is known

$$\%\,Voids = \frac{(G_{sb} * \gamma_w) - \gamma_s}{G_{sb} * \gamma_w} * 100$$

G_{sb} = BOD Gravity
γ_w = Unit Weight of Water = 1 g/cm^3 = 62.4 lb/ft^3
γ_s = Unit Weight of Solid (stone)

Voids Calculations

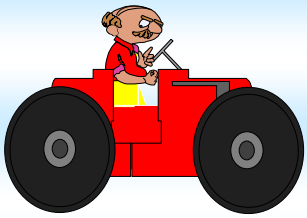
$$\%\,Voids = \frac{(G_{sb} * \gamma_w) - \gamma_s}{G_{sb} * \gamma_w} * 100$$

G_{sb} = 2.70
γ_w = Unit Weight of Water = 62.4 pcf
γ_s = Unit Weight of Stone = 102.0 pcf

$$\%\,Voids = \frac{(2.70\ x\ 62.4) - 102.0}{2.70\ x\ 62.4}\ x\ 100 = 39.5\%$$

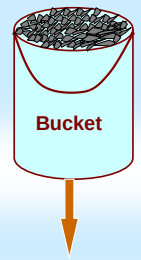
Review - Density

- Higher Density Indicates more stone-to-stone contact…which leads to improved performance
- Factors influencing density
  - Gradation
  - Moisture Content
  - Compactive Effort
  - Construction Foundation
  - Particle Shape
  - Plasticity



Review – Unit Weight

- Unit weight is a density measurement
- Unit Weight used in concrete mix designs, yield calculations, stockpile inventories…
- Voids can be calculated knowing unit weight and specific gravity of a material



Weight, lb =34.0

Summary

- Specific Gravity
  - Apparent, BOD, SSD
- Density
  - Factors influencing density
- Unit Weight