
بسم الله الرحمن الرحيم

Lecture # 3

Civil Engineering Material

Fine and Coarse aggregates

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Aggregates:

- **Aggregates make up 60-75% of total volume of concrete.**
- **Aggregate: the inert filler materials, such as sand or stone, used in making concrete.**
  - **Coarse Aggregates**
  - **Fine aggregates**

Aggregates in Composites

- 60-70% of Concrete Volume
- 80-90% of Asphalt Volume
- Control Low-Strength Fill Material
- 95% of Polymer Concrete

Aggregate Production

- Crushed Stone:
  - Quarried from a ledge rock

- Gravel:
  - Mined or dredged from natural deposits

Processing

- Mining
- Crushing
  - Primary
  - Secondary
- Sizing
  - Gradation
  - Fines
- Testing (QC/QA)

Other Aggregate Sources

- Recycled Concrete:
  – Quarried from pavements or other sources

- Slag or Foundry Sand:
  - Mined from industrial stockpiles

Natural (mineral) Aggregates

- Sources
  - 50% Gravel
  - 50% Crushed
- Gravel
  - River Run
  - Glacial Deposits
- Crushed Stone
  - 65% Carbonates
  - 35% Other
    - Sandstone
    - Granite
    - basalt.....

Definitions

- Aggregate:
  - Granular material of mineral composition such as sand, gravel, shale, slag or crushed stone.

- Coarse Aggregate:
  - Predominantly retained on the 4.75mm (#4) sieve

- Fine Aggregate:
  - Completely passing through the 9.5mm (3/8”) sieve

Definitions

- Maximum size:
  - Smallest sieve opening through which the entire amount is required to pass.
- Nominal Max. size:
  - Largest sieve opening through which a specified quantity may be retained
- Dense Graded
  - Aggregate that has a particle size distribution such that, when compacted, the voids (as a % of volume) are relatively small.
- Gap Graded
  - Aggregate that has a particle size distribution such that, when compacted, the voids (as a % of volume) are relatively large.

Basic Geology

- Bedrock
  - Igneous (solidification of molten material
  - Sedimentary (consolidated transported material)
  - Metamorphic (preexisting rock changed by temperature or pressure over time)
- Mantle
  - Material that covers the bedrock which may be cm or km in thickness
  - Boulders, cobbles, gravel, sand, silt, clay

Mineral Identification

- Crystal Structure
- Optical Properties
- Hardness
- Color
- React with Acids
- Luster (dull, glassy)
- Fracture

- Group I –Glassy
  - Quartz, Obsidian
- Group II – Dull, Fine Grain
  - Scratch with a knife
    - Shale, limestone
  - Hard - Chert, Basalt
- Group III - Granular
  - Scratch with a knife
    - Limestone, dolomite
  - Hard
    - Granite, Gabbro

Mineral Identification

- Field Tests
  - Hardness
    Mohs Hardness
    - Talc - 1
      fingernail
      Gypsum - 2
      penny
      - Calcite - 3
        Dolomite - 4
        Apatite - 5
        knife
        - glass
          Orthoclase - 6
          file
          Quartz, Chert - 7
          - Topaz - 8
            Corundum - 9
            Diamond - 10
  - HCl Reactivity
    0.1N HCl
    - Carbonates
      Calcite
      Powdered Dolomite
    - Non-Carbonates
  - Cleavage
    - Planer
      Fracture
      - Single Plane
        Mica, etc.
        - Double Plane
          Feldspars
    - Conchoidal
      Fracture
      - Concave Surface
        quartz, chert

Minerals in Aggregates

- Silica and Silicates
  - Quartz SiO_2
    - hard, strong, insoluble
    - ussually igneous
  - Opal
    - poor crystallinity
    - hydrous silicate (3-9%)
  - Feldspar
    - hard, strong, variable composition
- Carbonates
  - Calcite $CaCO_3$
    - limestone
    - softer, strength variable
  - Dolomite
    - dolomitic limestone
    - $1CaCO_3 + 1MgCO_3$
    - softer, strength variable

Aggregates

- Silicious Gravels
  - excellent strength and hardness
  - avoid contamination with silts, shale and clay
- Sandstone
  - variable strength and durability with porosity, absorption
- Chert
  - dense strong aggregate
  - many types are reactive with alkalies
- Limestone + Dolomite
  - Lower modulus than silicates (softer)
  - porosity and absorption vary considerably
  - good aggregate source

Types of Aggregate

- Lightweight (ASTM C330)
  - Pumice,
  - Expanded shale and Clay
  - 3M microspheres, cenospheres...
  - Uses: filler or low modulus applications
    - Geo Fills, Structural Slabs

Types of Aggregate

- Heavyweight (ASTM C637)
  - Steel slag
  - Shot,
  - Ores
  - BSG= 3.5-5.2
  - Uses: ballast & radiation shielding

Weight	Examples of Aggregates Used	Uses for the Concrete
ultra-lightweight	vermiculite, ceramic	can be sawed or nailed, also used for its insulating properties
lightweight	expanded clay, shale or slate, crushed brick	used primarily for making lightweight concrete for structures, also used for its insulating properties
normal weight	crushed limestone, sand, river gravel, crushed recycled concrete	used for normal concrete projects
heavyweight	steel or iron shot; steel or iron pellets	used for making high density concrete for shielding against nuclear radiation

Physical Properties

- Shape(angular, aspect)
- Size (maximum, distribution)
- Texture (smooth, porous)
- Specific Gravity
- Absorption
- Soundness
- Freeze thaw stability
- Thermal stability
- Deleterious constituents
- Unit weight
  - Compacted
  - Loose
- Integrity during heating

Unit Weight

(unit mass or bulk density)

-The weight of the aggregate required to fill a container of a specified unit volume.

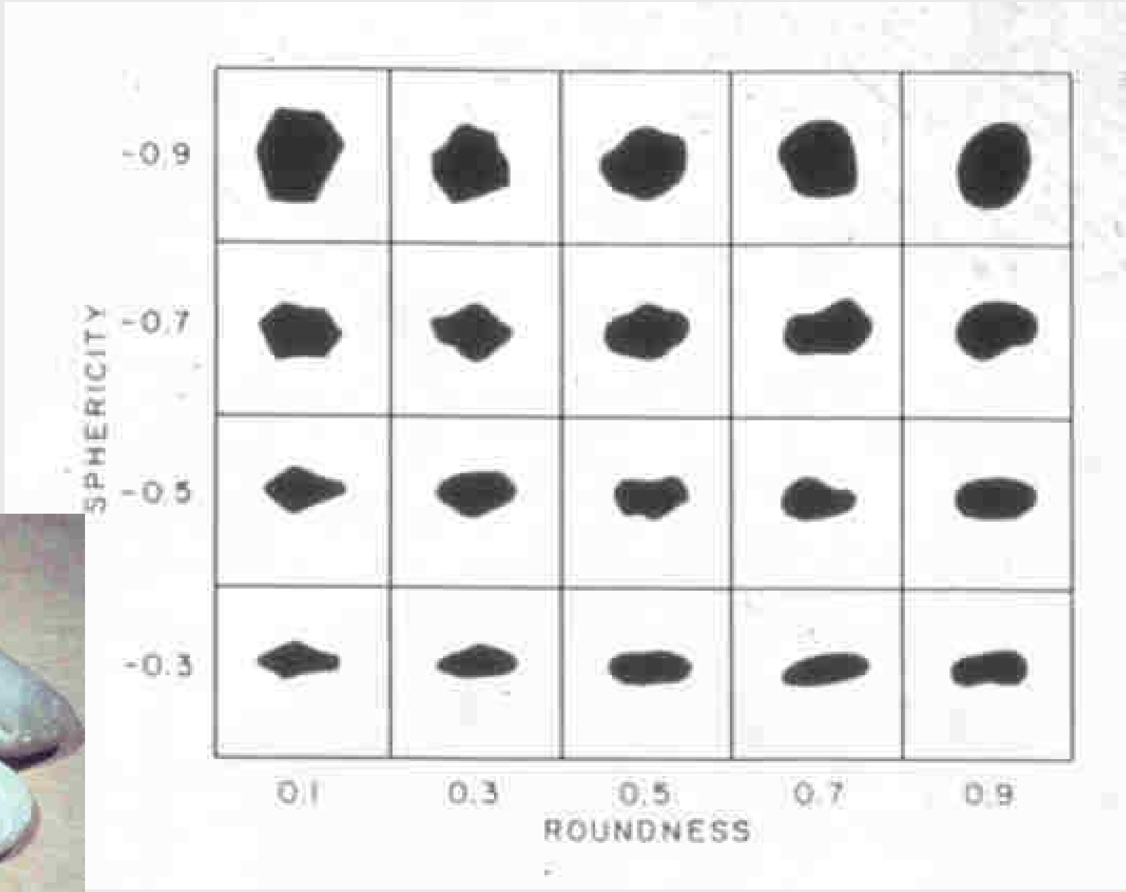
-Volume is occupied by both the aggregates and the voids between the aggregate particles.

-Depends on size distribution and shape of particles and how densely the aggregate is packed

- -Loose bulk density
- -Rodded or compact bulk density

Normal-weight concrete... bulk density of aggregate is approximately 75-110 lb per cubic foot.

Particle Shape



Voids

- Void content affects mortar requirements in mix design; water and mortar requirement tend to increase as aggregate void content increases.

- Void content between aggregate particles increases with increasing aggregate angularity.

- Void contents range from 30-45% for coarse aggregates to about 40-50% for fine aggregates.

- Total volume of voids can be reduced by using a collection of aggregate sizes.

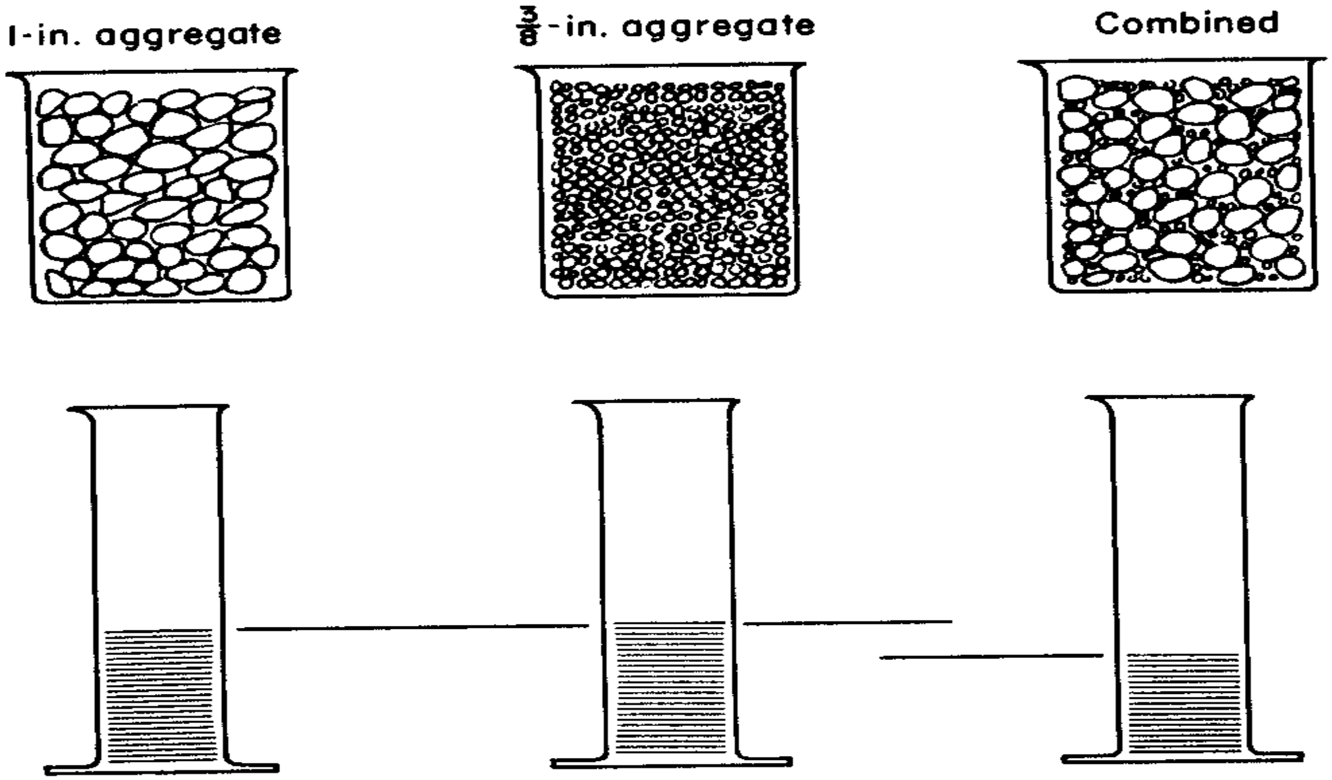


Fig. 4-4. The level of liquid in the graduates, representing voids, is constant for equal absolute volumes of aggregates of uniform but different size. When different sizes are combined, the void-content decreases. The illustration is not to scale.

The cement paste requirement for concrete is proportional to the void content of the combined aggregate.

Specific Gravity (Relative density)

Absolute: the ratio of the weight of the solid to the weight of an equal volume of water (both at a stated temperature)

- Refers to volume of the material excluding all pores

Apparent: ratio of the weight of the aggregate (dried in an oven at 212- 230ºF for 24 hours) to the weight of water occupying volume equal to that of the solid including the impermeable pores

- Volume of solid includes impermeable pores (but not capillary pores)

Used for calculating yield of concrete or the quantity of aggregate required for a given volume of concrete.

Particle Shape and Surface Texture

- Rough textured, angular, elongated particles require more water to produce workable concrete than do smooth, rounded, compact aggregates.
  - Aggregates should be relatively free of flat and elongated particles (limit to 15% by weight of total aggregate).

- Important for coarse and crushed fine aggregate - these require an increase in mixing water and may affect the strength of the concrete, if cement water ratio is not maintained.

Shrinkage of Aggregates:

Large Shrinkage = fine grained sandstones, slate, basalt, trap rock, clay-containing

Low Shrinkage = quartz, limestone, granite, feldspar

What happens if abnormal aggregate shrinkage occurs?

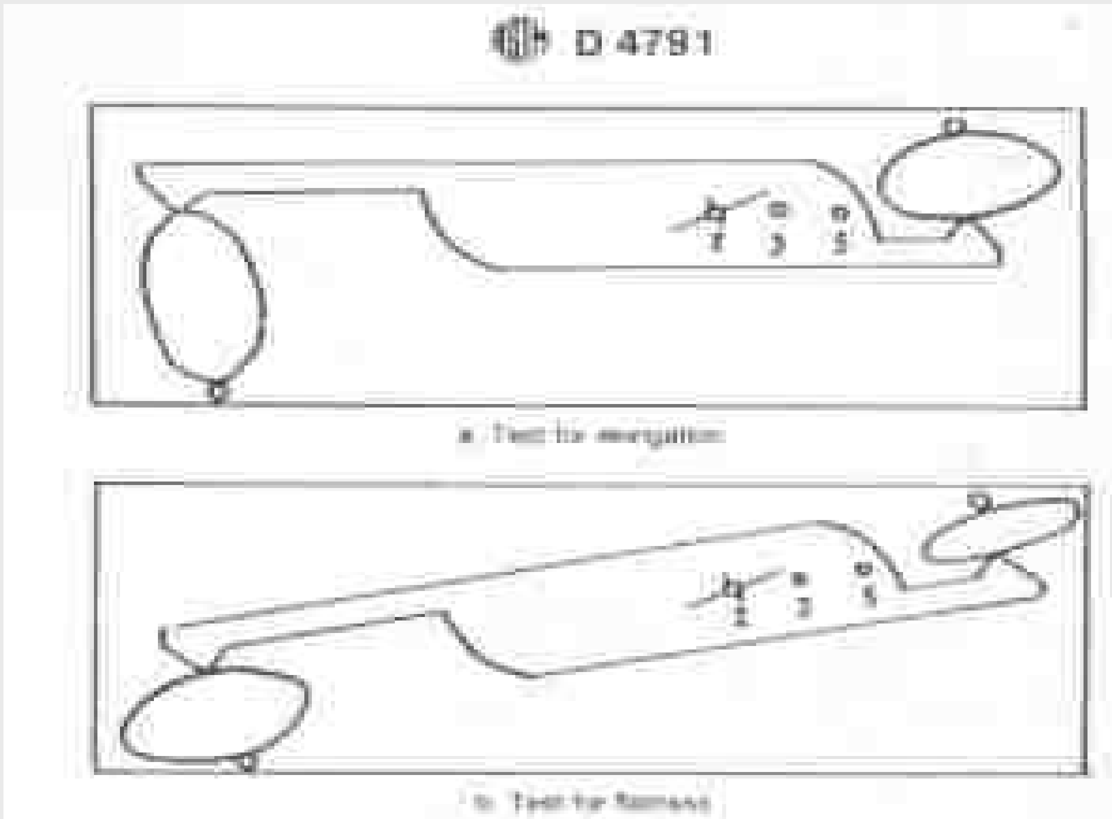
- Excessive cracking
- Large deflection of reinforced beams and slabs
- Some spalling (chipping or crumbling)

If more than 0.08 percent shrinkage occurs, the aggregate is considered undesirable.

Absorption and Surface Moisture

If water content of the concrete mixture is not kept constant, the compressive strength, workability, and other properties will vary from batch to batch.

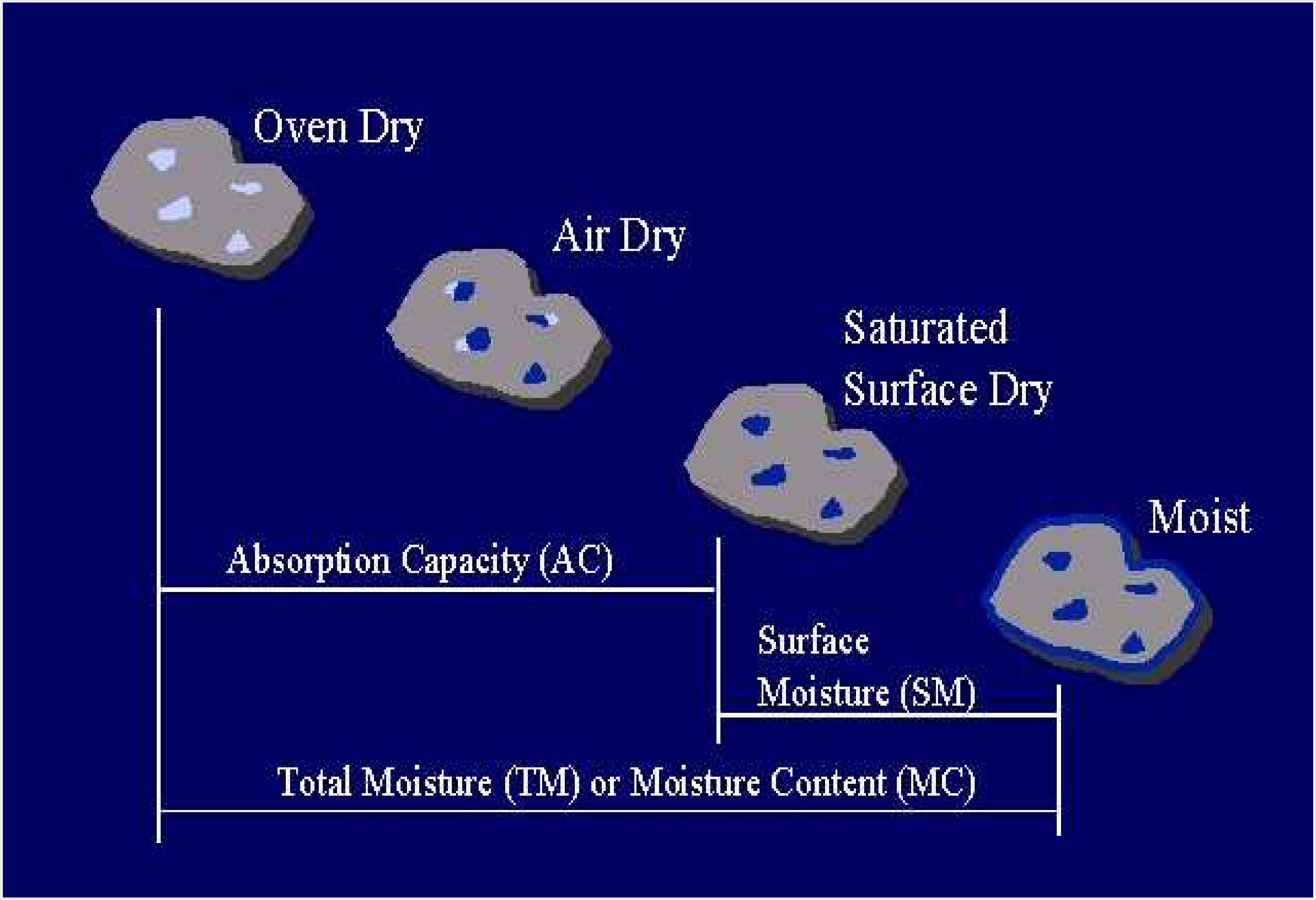
Elongation/Flatness



- D 4791 Elongation test

Moisture Conditions of Aggregates:

1. Oven dry- fully absorbent
2. Air dry- dry at the particle surface but containing some interior moisture
3. Saturated surface dry (SSD) –neither absorbing water nor contributing water to the concrete mixture.
4. Wet or moist- containing an excess of moisture on the surface


Oven Dry
Air Dry
Saturated
Surface Dry
Moist
Absorption Capacity (AC)
Surface
Moisture (SM)
Total Moisture (TM) or Moisture Content (MC)

Absorption Capacity: maximum amount of water aggregate can absorb

- Absorption Capacity (%) = $[(W_{SSD} - W_{OD})/W_{OD}] \times 100$

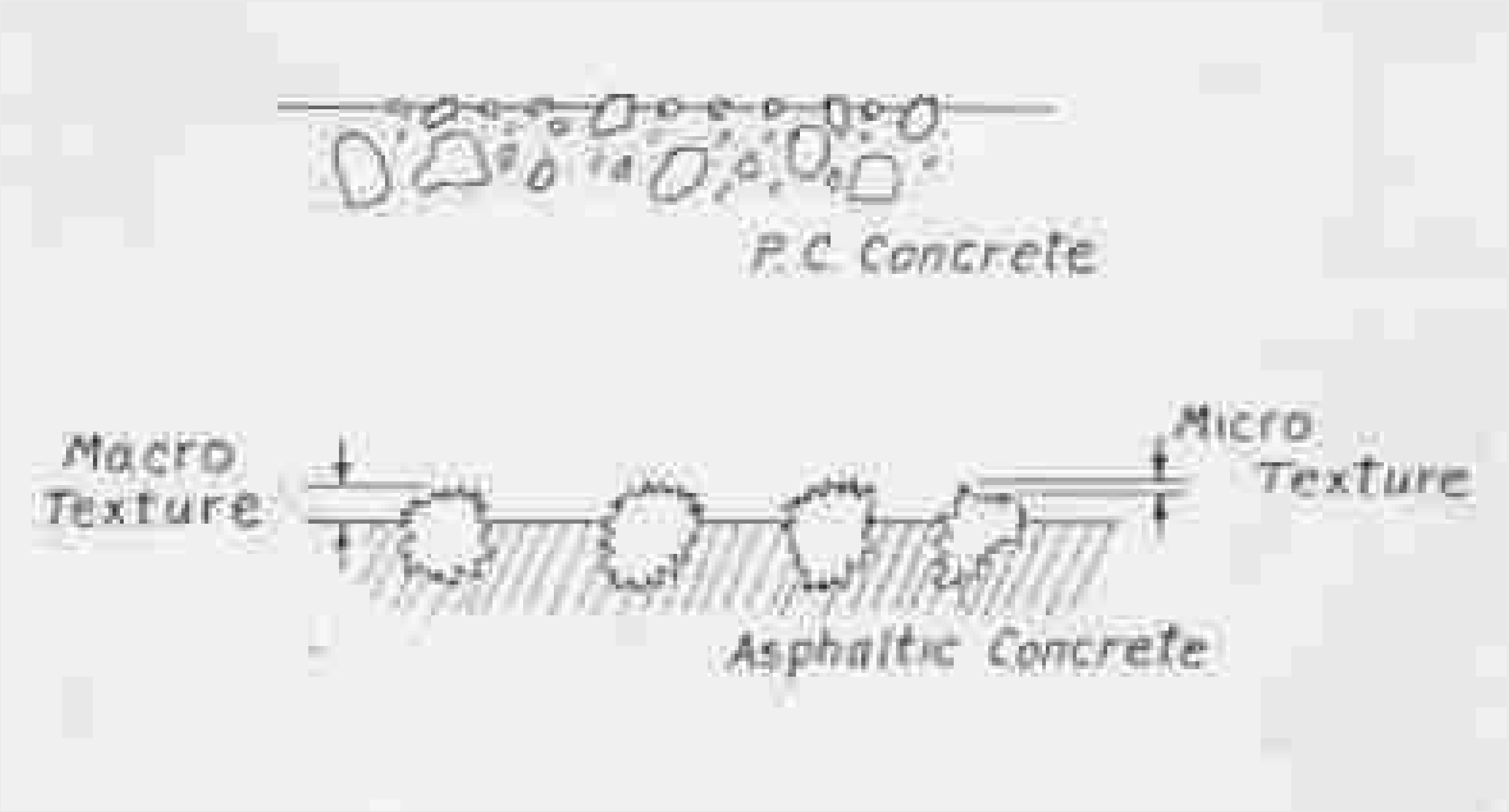
Surface Moisture: water on surface of aggregate particles

- Surface Moisture (%) = $[(W_{WET} - W_{SSD})/W_{SSD}] \times 100$

Moisture Content: of an aggregate in any state

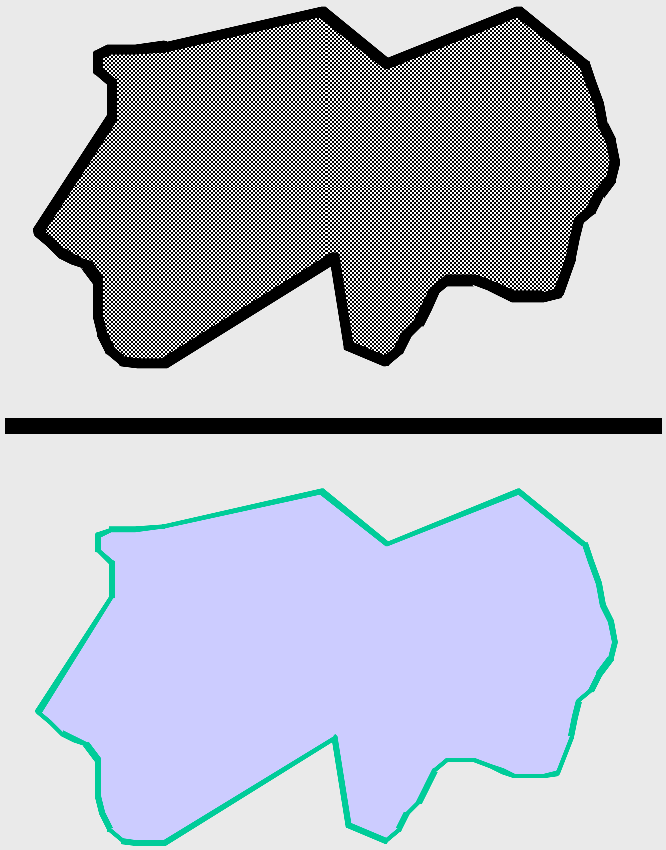
- Moisture Content (%) = $[(W_{AGG} - W_{OD})/W_{OD}] \times 100$

Texture


P.C Concrete
Macro
Texture
Micro
Texture
Asphaltic Concrete

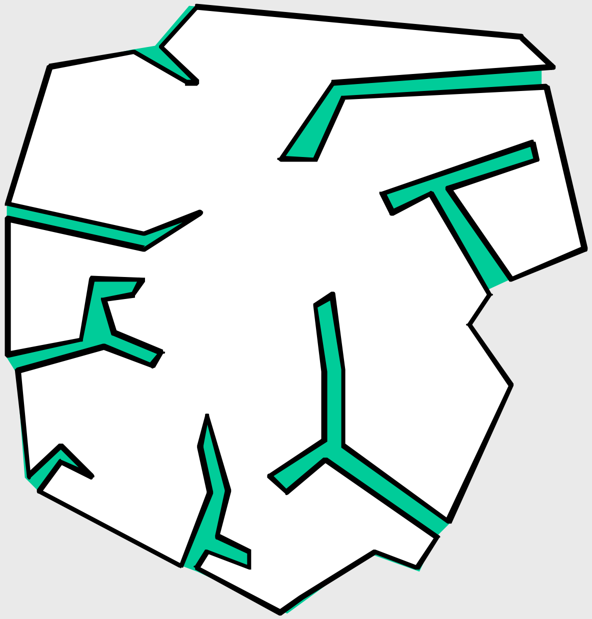
Specific Gravity

- Ratio of the weight of an object to the weight of an equal volume of water (at std. temp. & pressure).



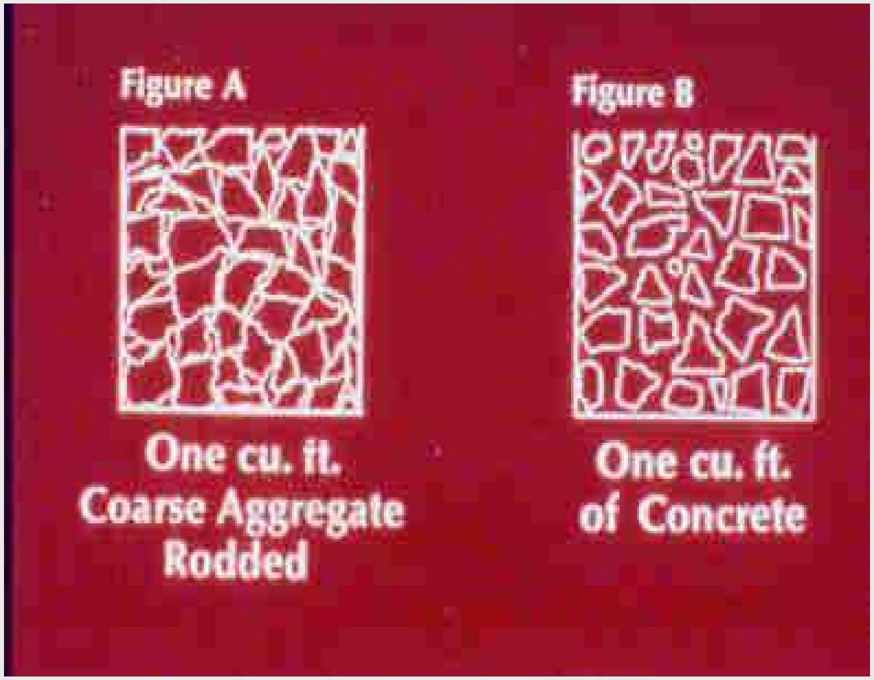
Absorption

- Absorption is the moisture content in the SSD state
- Moisture content when permeable voids just filled with water



Abs. = $(W_{SSD} - W_{OD}) / W_{OD} \times 100\%$

Dry Rodded Unit Weight, DRUW



- Compacted density of coarse aggregate
- Denser gradations have higher relative DRUW values

Voids Analysis

- Interparticle voids can be minimized by using a more uniform gradation.
- Void can be calculated using S.G. and DRUW of the aggregate.

Gradation (C117, C136)

- Particle size distribution
  - Standard - best compaction
  - Max size vs. Nominal max size
  - Gap Graded (some sizes missing)
  - Single Size

Fineness Modulus (ASTM C136)

		%Ret.	%Cum. Ret.
9.5mm	*3/8”*	*0*	*0*
4.75mm	*# 4*	*2*	*2*
2.36mm	*# 8*	*13*	*15*
1.18 mm	*# 16*	*20*	*35*
600μm	*# 30*	*20*	*55*
300μm	*# 50*	*24*	*79*
150μm	*#100*	*18*	*97*
	Pan	*3*	Σ *283/100*

Gradation of Aggregates

- Too many fines contribute to problems
- Organic impurities
- Compaction,
- Water demand in concrete
- Shoving in asphalt
- Dust control

Deleterious Aggregates

Chemical Properties

- Solubility
- Electrical conductivity
- Asphalt affinity
- Reactivity to alkalies
- Reactivity to CO_2
- Chemical stability

Soundness Testing

- Na or Mg sulfate saturated solutions are used to test aggregate friability
- 5 cycles of saturation and drying
- Sulfates hydrate and expand to fracture weak planes
- ASTM C88
  - Specific gradations
  - Loss is determined by mass
  - 12% max loss w/ Na
  - 18% max loss w/ Mg
- Precision is very poor

Mechanical Properties

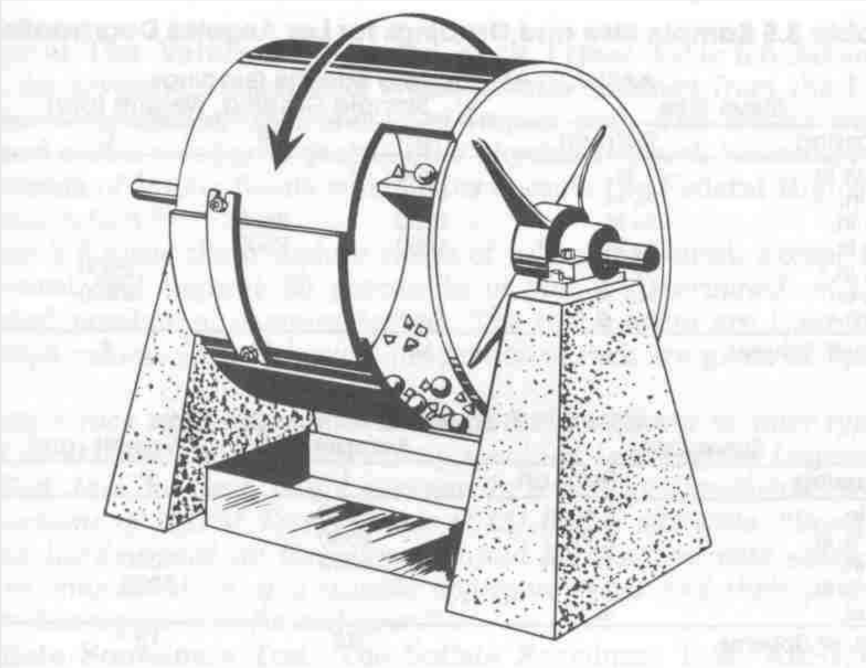
- Compressive strength
- Tensile strength
- Toughness
- Abrasion resistance
  - Powder or fracture
- Modulus
- Coefficient of thermal expansion

Strength of Aggregates

- Shale and Sandstone: 35-90 MPa (5-13 ksi)
- Limestone: 48-270 MPa (7-39 ksi)
- Granite: 27-275 MPa (4-40 ksi)
- Pumice: 2 MPa (300 psi)
- Traprock: 105-235 MPa (15-34 ksi)

Abrasion Resistance

- ASTM C131
- Special gradation of material is used
- 445g spheres added
- 500 revolutions
- Sieve and wash to determine material greater than No. 12 sieve.



$$\%\ \text{Loss} = \frac{W_{>\text{No.12 sieve after test}}}{W_{\text{Original sample}}}$$

Abrasion Results

Typical results of losses between 10 and 40%.

40% is the max. limit

- Coefficient of Variation

  Single Operator – 2%

  Multilab – 4.5%

Two tests by the same operator on the same sample should not vary by more than 2.83*2.0=5.7% on the % loss (the 2.83 represents 1 in 20 samples outside the range coefficient).

Storage and Transportation

- Segregation
  - mostly a problem in Coarse Aggregate
  - dry fine aggregate may lose fines
- Moisture content
  - mostly a problem in Fine Aggregate
  - M.C. of stockpiles should be stabilize
- Contamination
  - avoid silts, clay, carbon contamination

Storage and Transportation

- Trucks, conveyors, barges, rail,
- Cleanliness
- Covered
- Paved area for storage