Chapter 2

Aggregates

The Ideal Aggregate

- Strong and resists loads applied
- Chemically inert so it is not broken down by reactions with substances it comes in contact with
- Has a stable volume so that it does not shrink or swell
- Bonds tightly with asphalt
- Contains no impurities or weak particles
- Perfect size and gradation for the application intended
- Locally available and economical
Aggregate Types

- Coarse Aggregate
  - gravel or crushed stone
  - Particle sizes larger than No. 4 sieve (0.2 in.)
- Fine Aggregate
  - sand or washed screenings
  - Particle sizes between No. 200 and No. 4 sieve (0.003 and 0.2 in.)
- Filler
  - silt or clay
  - Particle sizes smaller than No. 200 sieve (0.003 in.)

Fine Aggregate Types

- Stone Screenings
- Creek Sand
- Natural Sand
- Processed Sand
Stone Screenings

- By-product of the crushing operation at the quarry.
- Regular Screenings
  - High dust content (generally >10%)
- Washed Screenings (also known as Manufactured Sand)
  - Low dust content (generally <5%)

Creek Sand

- Creek sand, or river sand, is dredged from creeks or rivers, screened, and used as is.
- More commonly used by concrete industry.
- Typically have a low dust content.
Natural Sand

- Sand that is common to a particular location.
- Typically found below the Fall Line. The Fall Line runs through Augusta, Columbia, and Florence.
- Generally have low dust contents.

Processed Sand

- Sands that go through some formal process (sieving or blending for example).
- Done to achieve a certain gradation.
Coarse Aggregate Types

- Crushed stone
- Gravel
- Marine limestone
- Slag
- RAM

Crushed Stone

- Most common type of CA
- Three types in SC
  - Granite
  - Granite Gneiss
  - Marble Schist
Crushed Stone

- Good stone at the location
- Site suitability
  - Transportation access
  - Overburden ratio
  - Drainage
  - Buffer zones
  - Water availability
  - Reclamation
- Undergoes crushing process (# and types of crushers, etc.)

Gravel

- Mined from the natural surroundings
- No blasting involved
- Can be crushed if so desired
- Screened, washed, and separated into various sizes
Marine Limestone

- Also called fossiliferous limestone
- Made from fossils of marine creatures
- One source in SC
- Production is similar to that of crushed stone
- Absorptive aggregate

Slag

- By-product of the steel industry
- When iron ore is heated to extreme temperatures, it becomes molten
- The heavy iron sinks to the bottom, while impurities rise to the top
- Impurities are poured off and quenched with water. This is slag
- Can then be crushed into various sizes
- Has a high specific gravity and high absorption
RAM

- RAM: Reprocessed Aggregate Material
- Aggregate portion of our RAP

Aggregate Troubleshooting

- Dirty stone
- Gradation changes
- Specific Gravity changes
- Material breakdown
- Mica
- Clay balls
- Roots
Aggregate Properties

- Size and Grading
  - Nominal Maximum Aggregate Size
  - Maximum Aggregate Size

Size and Grading

- Nominal Maximum Aggregate Size: The largest sieve to retain more than 10% of the material
  - We identify it by finding the sieve that is one size larger than the largest sieve with less than 90% passing
- Maximum Aggregate Size: One size larger than the nominal maximum aggregate size
Size and Grading

- Aggregate gradations are graphed on a 0.45 Power chart.
- Maximum Density Line (MDL) is also drawn on the 0.45 Power chart.
  - Drawn from (0,0) to 100% passing at the maximum aggregate size

Example Problem

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<th>% Passing</th>
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<td>3/8&quot;</td>
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<tr>
<td>#100</td>
<td>12</td>
</tr>
<tr>
<td>#200</td>
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Size and Grading

- Aggregates can be described based on their gradation.
  - Dense (well) graded
  - Open graded
  - Fine graded
  - Coarse graded
  - One size (uniformly) graded
  - Gap graded

Aggregate Properties

- Cleanliness
  - Want our aggregates to be washed.
  - Dust on aggregate surface can lead to stripping problems.
Aggregate Properties

- Cleanliness
- Toughness
  - Los Angeles Abrasion Test
  - Soundness Test (Sodium Sulfate or Magnesium Sulfate)

Aggregate Properties

- Cleanliness
- Toughness
- Particle Shape
  - Affects the strength of our HMA mix.
Particle Shape

- Irregular or angular shaped particles tend to interlock.
- Rounded particles do not tend to interlock.

Aggregate Properties

- Cleanliness
- Toughness
- Particle Shape
- Surface Texture
  - Surface texture influences both workability and strength.
Surface Texture

- A rough (like sandpaper) surface as opposed to a smooth surface tends to increase the HMA mix strength but decrease workability.
- A smooth, rounded surface (like gravel) tends to increase the workability of the HMA mix but decrease mix strength.

Aggregate Properties

- Cleanliness
- Toughness
- Particle Shape
- Surface Texture
- Absorption
  - Water and/or Asphalt Binder
**Absorption**

- An aggregate with 1% or less absorption is good for asphalt mixtures.
- All aggregates in SC except slag and marine limestone have absorption rates less than 1%.

**Aggregate Properties**

- Cleanliness
- Toughness
- Particle Shape
- Surface Texture
- Absorption
- Affinity for Asphalt
  - Lime and/or antistripping agents
Aggregate Properties

- Cleanliness
- Toughness
- Particle Shape
- Surface Texture
- Absorption
- Affinity for Asphalt
- Specific Gravity

Specific Gravity

- Specific Gravity is defined as the ratio of the mass (or weight) of a given volume of material to the mass (or weight) of an equal volume of water.
  - How much heavier is a given amount of material compared to an equal volume of water?
- Example: 1 ft³ of solid stone weighs 156 lbs. 1 ft³ of water weighs 62.4 lbs. The specific gravity is 156/62.4, or 2.500.
**Bulk Specific Gravity (BSG)**

- The ratio of the weight of dry aggregate to the weight of water having a volume equal to the volume of the aggregate including both its permeable and impermeable pores.
  - BSG includes the volume of the solid aggregate plus all of the aggregate pores (permeable and impermeable) and the weight of the solid aggregate
  - BSG is the “real” specific gravity

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**Apparent Specific Gravity (ASG)**

- The ratio of the weight of dry aggregate to the weight of water having a volume equal to the solid volume of the aggregate excluding its permeable pores.
  - ASG includes only the volume of the solid aggregate plus the impermeable pores and the weight of the solid aggregate
**Effective Specific Gravity (ESG)**

- The ratio of the weight of dry aggregate to the weight of water having a volume equal to the solid volume of the aggregate excluding both its permeable pores and its impermeable pores.
  - ESG includes only the volume of the solid aggregate (no pores) and the weight of the solid aggregate.

**Bulk Specific Gravity, Saturated Surface Dry (BSG\textsubscript{SSD})**

- The ratio of the weight of the aggregate, including the weight of water it contains when its permeable voids are saturated, to the weight of an equal volume of water.
  - BSG\textsubscript{SSD} includes the volume of the solid aggregate plus all of the aggregate pores (permeable and impermeable) and the weight of the solid aggregate plus the weight of water filling all of the permeable pores.
Aggregate Sampling

- We want to obtain a REPRESENTATIVE sample.
- Accuracy in sampling is just as important if not more so than testing.

Aggregate Sampling

- Stockpile sampling
- Belt sampling
- Must reduce these field samples to an appropriate testing size. There are two methods to do this:
  - Quartering
  - Sample splitter
Aggregate Gradations

- Main reason why we are sampling our aggregates.
- Sieve analysis gives us our gradation.
- Typically we are interested in the percent passing any given sieve.

Aggregate Gradations

- There are two types of sieve analysis:
  - Dry Sieve Analysis (ASTM C136 or AASHTO T27)
  - Wet Sieve Analysis (SC-T-5 + ASTM C136 or AASHTO T27)
Dry Sieve Analysis

- ASTM C136 or AASHTO T27
- Shake dried aggregate over desired nest of sieves for specified time
- Weigh material retained on each sieve
- Calculate % passing for each sieve (gradation)

Wet Sieve Analysis

- SC-T-5 + ASTM C136 or AASHTO T27
- The process is the same as for a dry sieve analysis except that before sieving, the sample is:
  - Weighed
  - Immersed in water plus a wetting agent
  - Washed/rinsed over a #200 sieve
  - Recombined with anything retained on the #200 sieve
  - Dried and weighed again
- This measures the amount of material passing the #200 sieve, which is used in the gradation calculations
Gradation Calculations

- To determine the % passing any given sieve, divide the weight passing by the total weight.
- For a wet sieve analysis, remember to add back weight lost from washing.
  - Weight passing: Add weight loss to all sieves.
  - Weight retained: Add weight loss only to the Pan.

Aggregate Blending

- Why is it necessary to blend aggregates?
Aggregate Blending

- For most HMA mixes, SCDOT requires at least 3 aggregate sources.
- RAP does count as an aggregate source.
- Ways to blend aggregates:
  - Graphical
  - Computer programs
  - Trial and error

Superpave Aggregate Testing

- Two types of aggregate testing were adopted during SHRP:
  1. Consensus Properties
     - Adopted by all DOT agencies
  2. Source Properties
     - Chosen by each state DOT
Consensus Properties

- The Consensus Properties are:
  - Coarse Aggregate Angularity
  - Fine Aggregate Angularity
  - Flat and Elongated Particles
  - Sand Equivalent/Clay Content

Source Properties

- The Source Properties for South Carolina are:
  - Toughness (Los Angeles Abrasion)
  - Soundness
  - Deleterious Materials
Coarse Aggregate Angularity

- Commonly known as “fractured faces” test
- Counting the number of fractured faces on each aggregate particle in a sample
- Measured on +#4 material
- Two groups:
  - 1 fractured face
  - 2 or more fractured faces
- SCDOT Requirements:
  - > 90% must have at least 2 fractured faces

Fine Aggregate Angularity

- Measuring air voids in an uncompacted sample of fine aggregate
- Measured on -#8 material
- Need to know the BSG of the fine aggregate
- SCDOT Requirements: none
Fine Aggregate Angularity

Comparing the largest to smallest dimension
Measured on +#4 material
SCDOT uses a 5:1 ratio
Test can be performed at a 3:1 or 2:1 ratio
Requirements: < 10% (5:1 ratio)

Flat and Elongated Particles

- SC-T-77
- Comparing the largest to smallest dimension
- Measured on +#4 material
- SCDOT uses a 5:1 ratio
- Test can be performed at a 3:1 or 2:1 ratio
- Requirements: < 10% (5:1 ratio)
Flat and Elongated Particles

Measuring the amount of "clay-like" material in the fine aggregate

Measured on -#4 material

Requirements:
- Regular Screenings: SE > 40
- Limestone Screenings and Crusher-Run fines: SE > 28

Sand Equivalent/Clay Content
Sand Equivalent/Clay Content

- Measuring resistance to abrasion by the Los Angeles Abrasion Test
- Measured on +3/8” material
- Proper size aggregate is placed in the drum along with appropriate number of steel “charges”
- Drum rotates 500 times at a speed of 30 rpm
- After test is completed, the percent passing the #12 sieve is considered to be the percent loss. This is the LA value.

Toughness
LA Abrasion Test

- Requirements:
  - Max. LA Value of 55 for Surface and Intermediate Mixes with Gyration Levels >= 75
  - Max. LA Value of 60 for Surface and Intermediate Mixes with Gyrations Level = 50
  - Max. LA Value of 60 for All Base Mixes

Los Angeles Abrasion Test
Soundness

- Measuring the chemical resistance of the aggregate
- Aggregate is placed in chemical bath for 5 cycles
- Chemicals used are Sodium Sulfate or Magnesium Sulfate

Deleterious Materials

- AASHTO T 112
- Determining the amount of clay lumps and friable particles.
End of Chapter 2

Any Questions?