Highway & Traffic Engineering

HIGHWAY MATERIAL - AGGREGATE

by

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Chapter Description

- Aims
  - Understand the fundamental and criteria of aggregate as the most important road elements and the calculation of aggregate of properties.

- Expected Outcomes
  - Students should be able to understand source and definition of aggregate used in road's construction
  - Students should be able to identify basic properties of aggregate and tests related to evaluating aggregate strength.
  - Students will be able to calculate the properties of aggregates and designing how to blend correct aggregate size together.

- References
  - Highway Engineering, Paul H. Wright / Karen K. Dixon
  - Images are taken from other related websites.

Aggregate

- Granular mineral particles that can be combined with bitumen to form HMA or alone as road bases and/or sub bases.
- Typical uses of aggregate :
  - PCC
  - HMA
  - Road Bases
  - Sub-Bases
  - Concrete Blocks etc.

Aggregate Sources

- Aggregate obtained from quarry were produced from bedrock.
- Bedrock were blasted off using dynamite to break the rock into sizes that can be transported.
- Rocks will be crushed into desired sizes according to client requirement.

- Slag : waste material from treatment plant during process of producing iron, steel, nickels, copper etc.
- Blast furnace slag is a common aggregate uses on construction of base courses and concrete blocks.

Images from http://www.nationalslag.org/steel-furnace-slag

Aggregate Terms and Types

- Fine Aggregate: 4.75mm – 75µm in sizes
- Coarse Aggregate: Larger that 4.75mm sizes.
- Fines: silt, clay or dust particles smaller than 75µm sizes (passed No.200)
- By volume, aggregate generally accounts for
  - 92 to 96 percent of HMA
  - 70 to 80 percent of portland cement concrete.

Aggregate Physical Properties

- Aggregate physical properties have the most direct effect on how an aggregate performs either as pavement material (HMA or PCC) or by itself as a base or sub-base material.
  - Gradation and size
  - Toughness and abrasion/wear resistance
  - Durability and soundness/resistance to weathering
  - Particle shape and surface texture
  - Specific gravity
  - Cleanliness and deleterious materials
  - Chemical Stability

Gradation and size

- The particle size distribution or gradation is one of the most influential aggregate characteristics in determining how it will perform as a pavement material.
- Gradation properties are :-
  - stability
  - permeability
  - workability
  - fatigue resistance
  - frictional resistance
  - resistance to moisture damage
- Gradation affects density, strength and economy of pavement structure.

Gradation Test Method

Images from http://www.pavementinteractive.org/gradation-test/

Grain-size analysis

- Used to determine sizes of aggregate in a mix.
- Dried aggregate is shaken over a square openings.
- Largest openings on top
- Smallest opening at the bottom
- Weight of aggregate is represent in percentage (%) material retained.

Aggregate Requirement

- Toughness and abrasion resistance :
  - Hard – resistance of wear and polishing due to traffic.
  - Premature structural failure and/or a loss of skid resistance.
- Durability and soundness :
  - Aggregate's weathering resistance characteristic.
- Particle shape and surface texture :
  - Particle shape, Flat or elongated particles, Smooth-surfaced particles.
  - Cubical – thin, elongated particles break easily.
- Specific gravity :
  - Hydrophobic – water hating
  - Aggregate can be in Dry or Saturated Surface Dry or Wet Condition
- Cleanliness and deleterious materials
  - Free from deleterious substances such as clay, dirt and dust.

Abrasions Resistance Test

- Clean sample is placed in cylinder
- Drum is rotated for 500 revolutions and samples sieved on No.12 sieve (1.70mm)
- Difference between original weight and final weight is reported as percentage of wear.

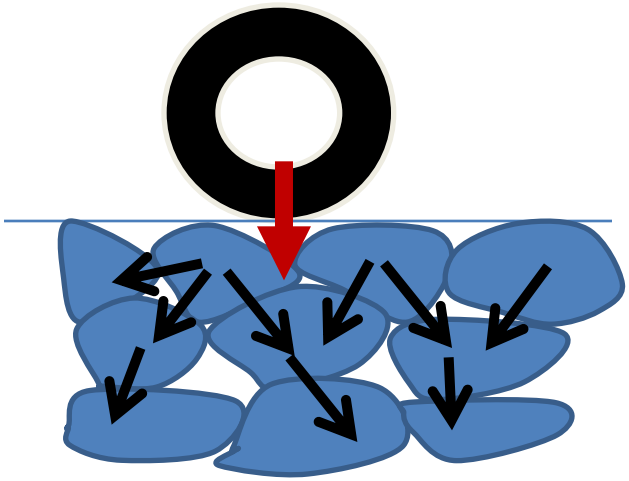
http://www.pavementinteractive.org/los-angeles-abrasion/

Aggregate Strength

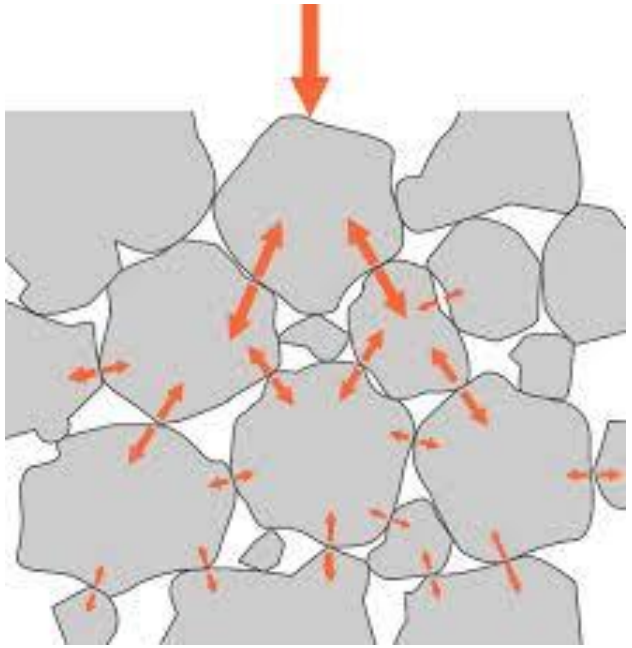
- Aggregate are used to distributes an imposed loads over the surface of layers.
- Mostly affected by its shape and texture
- Called load carrying capacity in base course.
- Strength property:
  - Able to carry loads without sliding over each other.

Aggregate Interlocking Behavior

Wheel Loads



Granular Structure



Aggregate Formations

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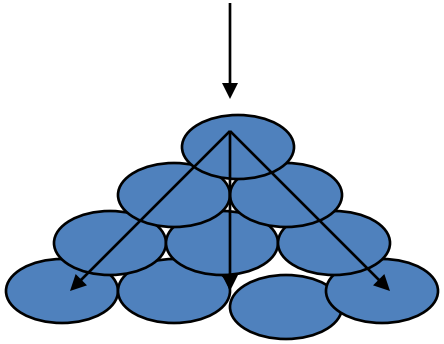

Contact points = low

Strength of Mix = low

Aggregate will slide with each other (smooth surface)

Base/Sub-base will fail

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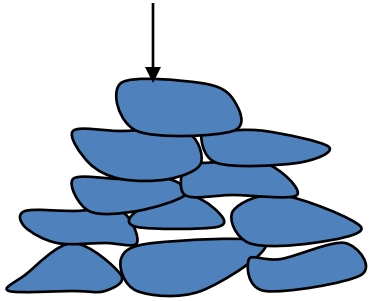


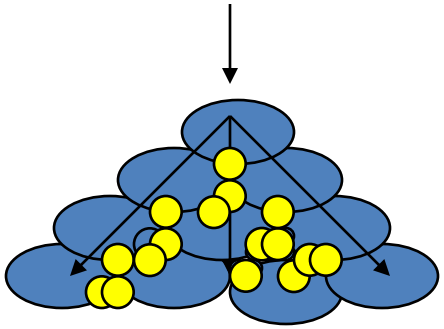
Particles will not slide. Friction between particles increased

Strength of Mix = Average

Contact points = average

Aggregate breaks easily

LOADS



Interlocking effects.

Strength of mix = good

Contact point = good

Frictional resistance to shearing is reduced.

Hot Mix Asphalt (HMA)

- Hot mix asphalt is known by many different names such as hot mix, asphalt concrete (AC or ACP), asphalt, blacktop or bitumen.
- HMA is known by its design and production methods and it includes
  - dense-graded mixes
  - stone matrix asphalt (SMA)
  - open-graded HMAs.

- It is a well-graded HMA intended for general use.
- When properly designed and constructed, a dense-graded mix is relatively impermeable.
- They can be further classified as:-
  - Fine-graded mixes
  - Coarse-graded mixes.

Dense-Graded Mix

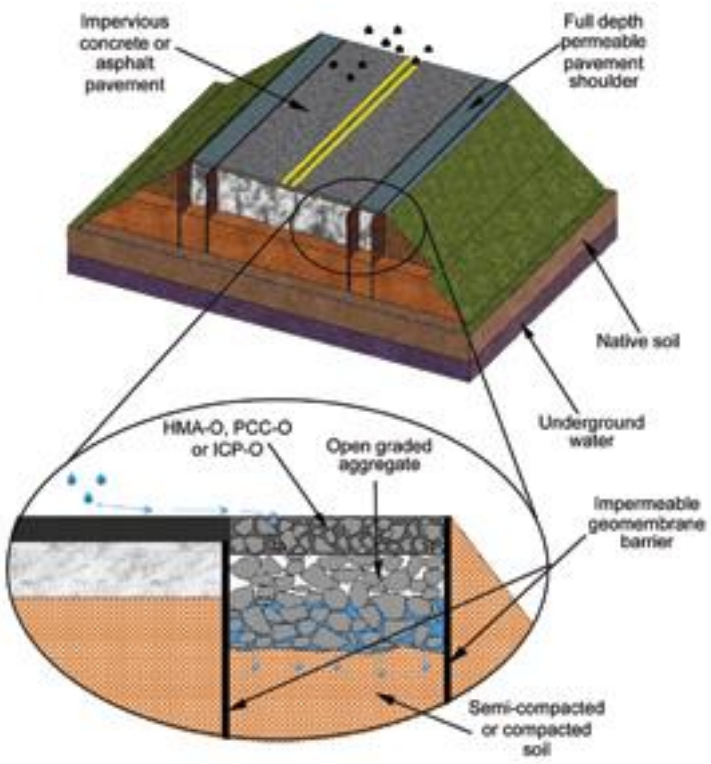
http://www.pavementinteractive.org/pavement-typesmix-types/

Open-Graded Mixes

- An open-graded HMA mixture is designed to be water permeable.
- Open-graded mixes use only crushed stone (or gravel) and a small percentage of manufactured sands.
- The two most typical open-graded mixes are:
  - *Open-graded friction course (OGFC)*. Typically 15 percent air voids and no maximum air voids specified.
  - *Asphalt treated permeable bases (ATPB)*. It is used only under dense-graded HMA, SMA or PCC for drainage.

Open Graded Mix

Image : https://nbwest.com/porous-pavement/



Importance of Well- Graded Mixes

- Particles are locked up, tightly bound together in a greater degree due to interlocking effects of smaller particles.
- Aiding in the development of frictional resistance to shearing failure.
- Significant increased in number of transfer point for distributions of imposed loads.

Disadvantages of well-graded mixes

- An excessive amount of finer materials are not effective in distributing loads.
- Will keep larger particles separate to a greater degree (water cohesion between aggregate).
- Less efficient loads transfer between grains.

Specific Gravity and Absorption

- Specific gravity of a solid is the ratio of its mass to that of an equal volume of distilled water at specified temperature.
- Specific Gravity :-
  - Apparent Specific Gravity, G_A
  - Bulk Specific Gravity, G_B

G_A, G_B and Percentage Absorption

- $$G_A = \frac{M_D / V_N}{w}$$

$$G_B = \frac{M_D / V_B}{w}$$

Percentage Absorption = $(M_w / M_D) * 100$

Example

- The dry mass of a sample aggregate is 1982.0 g. The mass in saturated, surface dry condition is 2006.7g. The net volume of the aggregate is 734.4cm^3. Find apparent specific gravity, bulk specific gravity and percentage of absorptions.

Specifications requirements

- Gradation Requirements
- Passing 25 mm = 100%
- 19 mm = 90-100%
- 9.5 mm = 50-75%
- 4.75 mm = 45-55%
- 1.18 mm = 15-40%
- 300 µm = 5-22%
- 75 µm = 2-8%

Physical Properties

- Abrasion loss (LA Test) = max. allowable = 40%
- Soundness loss = max. allowable = 18%

Aggregate evaluations

Example 1.0

- This aggregates are to be used as base course for highway connecting Kuantan to Kemaman. Check whether this aggregate mix meets the aggregate requirements for :
- 1. Gradation Requirements
- 2. Abrasion Loss
- 3. Soundness Loss

- Gradation Test Results :
- 1. Passing 25mm 100%
- 19mm 98%
- 12.5mm 81%
- 9.5mm 63%
- 4.75mm 48%
- 1.18mm 35%
- 300µm 24%
- 75µm 11%

- 2. Abrasion Test
- Original Mass = 2649gm
- Final Mass = 2267gm
- 3. Soundness Test
- Original Mass = 2649gm
- Final Mass = 2115gm

Solution

1. Check the percentage passing of each aggregate size.
2. Compare the percentage passing with gradation requirements.
3. Evaluate the results
4. Calculate the percentage of loss for Abrasion test
5. Check the acquired results with requirements
6. Calculate the percentage of loss for Soundness Test
7. Compare the acquired results with requirements for Soundness Test.
8. Conclude the results by examining whether this mix is suitable to be used as base or not. Explain why.

Aggregate Blending

- The ability to blend aggregates to meet a specified target is a must.
- Asphalt concrete requires the combination of two or more aggregates, having different gradations to produce an aggregate blend that meets gradation specifications for a particular asphalt mix.
- Trial and error method is simpler yet effective in defining good aggregate mixture.

Aggregate Blending.

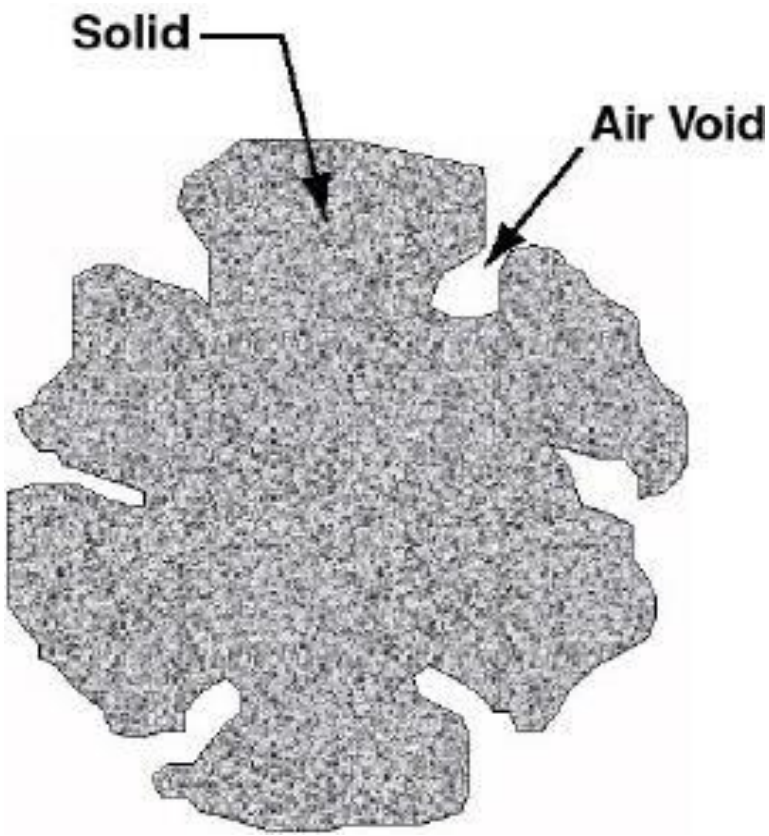
- Example 1.

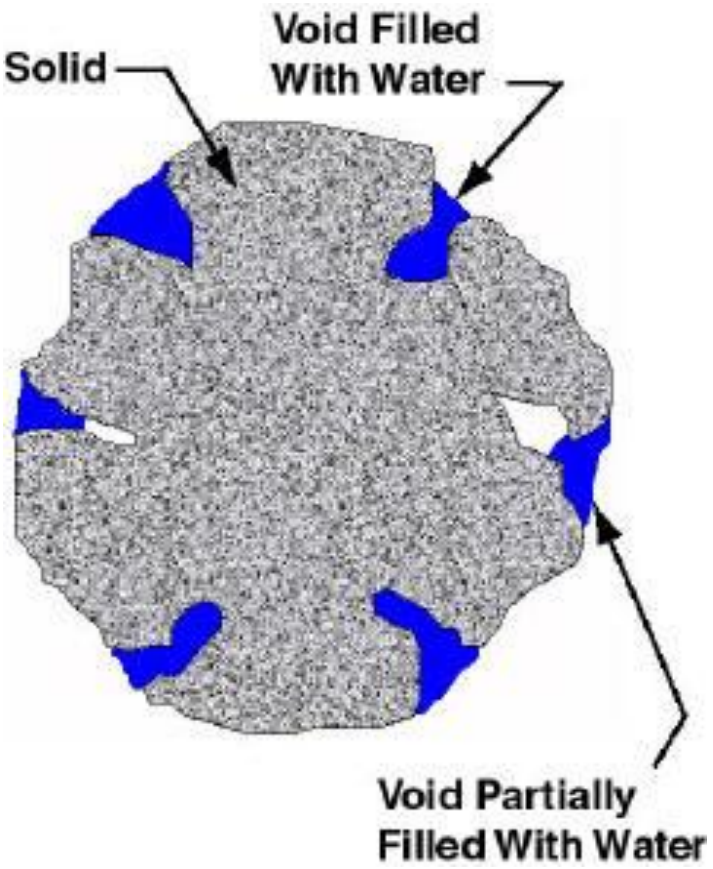
Passing	Agg A	Agg B	Agg C	Specification
12.5 mm	100%			100%
9.5 mm	62%		100%	72 – 88%
4.75 mm	8%	100%	78%	45 – 65%
2.36 mm	2%	91%	52%	30 – 60%
1.18 mm	0%	73%	36%	25 – 55%
600 µm		51%	29%	16 – 40%
300 µm		24%	24%	8 – 25%
150 µm		4%	20%	4 – 12%
75 µm		1%	18%	3 – 6%

Solutions

1. Check which aggregate group have the most coarse aggregate and fines.
2. Specifications for combinations of coarse, fine and fines are:
    1. Coarse Aggregate = 45-55%
    2. Fines = 3 – 6%
    3. Fine = 100 – (coarse + fines)
3. Use first trial and error by indicating desired coarse, fines and fine.
4. Calculate % of each aggregate size in each aggregate group according to chosen coarse, fine and fines.
5. Calculate combined gradations with gradation requirements
6. Evaluate whether the selected percentage of gradation meet the requirements or not
7. If not, repeat the entire process by changing the percentage of coarse, fine and fines.

Aggregate Particle Structure





- Chapter 15 : Highway Materials. Highway Engineering, Seventh Edition. Paul H.Wright & Karen Dixon. ISBN 0-471-26461-X. John Wiley & Sons.
  - 15.8 : Aggregates
  - 15.4 : Soil Classification for Highway Purpose

Conclusion of The Chapter

- Conclusion #1
  - Aggregate may comes from different sources.
- Conclusion #2
  - Different sizes of aggregates are combine with each other where the properties of aggregate must be well understand.
- Conclusion #3
  - Several types of aggregate/asphalt mix are used to construct a good road for different purposes.
- Conclusions #4
  - The calculation of aggregate properties and aggregate blending are very critical in producing good aggregate/asphalt mix.

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