Introduction to Asphalt Technology

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Objectives

- Understand the materials used for construction of flexible pavements
- Bituminous materials
- Aggregates
- Mix Design process
  - Marshall
  - Superpave
- Construction and inspection of asphalt concrete pavements

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Fundamentals of Bituminous Materials and Mixes

- Asphalt
  - hydrogen and carbon + minor elements
  - Bitumen
- Mineral Aggregate
  - coarse
  - fine
  - mineral filler
- Air
- Hot mix asphalt -
  - mixture of aggregate and asphalt
  - high quality road construction
- Cold mix
  - mixture of aggregate and emulsion
  - patching
- Spray applications

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Uses of Asphalt

- Hot mix pavement -
  - central mix in batch, continuous or drum plant
  - transported hot
  - placed with paver
  - compacted
- Cold mix
  - central plant
  - use emulsion or cutback
  - used for patching
- Surface treatment
  - application of asphalt
  - single sized aggregate
  - rolled to orient aggregate
- Tack coat
  - spray application of emulsion
  - bond surface with new paving mix

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Fundamentals of Asphalt

- Types of bituminous materials
- Types of aggregates
- Mix design
- Construction
- Performance

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Bituminous Materials

- Asphalt - distillation of petroleum products
  - natural
  - manufactured
- Tar
  - destructive distillation process
    - from production of coke for coal
    - resistant to gasoline

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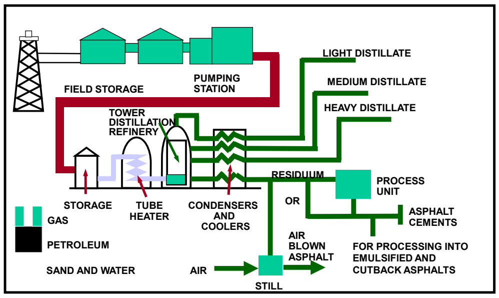
Asphalt Production



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Asphalt Properties

- Consistency or hardness
  - ability to flow
  - viscosity
- Effect of Heat
  - flows at high temperatures
  - stiff at low temperatures
  - ages when exposed to high temperature and air
- Adhesion
- Durability
- Handling

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Types of asphalt binders

- Binders
  - neat
  - modified
- Emulsions
  - suspension of asphalt in water
- Cutback
  - asphalt reduced in solvent
    - gasoline
    - naphtha
    - diesel

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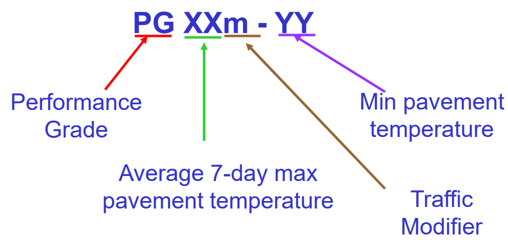
Binder Grades



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Grade Selection

- Primary selection based on temperature of the pavement about 1 inch below the surface
- Selection modified based on traffic
  - loads
  - speeds

WV grades

- Standard grade
  - PG 64S-22
- High volume roads
  - PG 64H-22
- Optional
  - PG 58S-28
  - PG 64E-22

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Aggregates Used in Asphalt

- 93 to 97 percent of weight of hot mix
- Types
  - Limestone
  - Gravel
  - Blast furnace slag
  - Sand
    - manufactured
    - natural
  - Mineral filler

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Properties of Aggregates

- Resistance to weathering
- Abrasion resistance
- Deleterious materials
- Unit weight - density
- Fractured faces
- Surface texture

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Asphalt Mix Design

- Determine the combination of aggregates and asphalt that provides mixes with required characteristics
- Mix design methods
  - Marshall
  - Superpave
- Technicians are required to obtain certification by completing an approved mix design class.

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Desired Characteristics

- Stability - ability to resist loads without excessive deformation
- Workability - ability to place and compact the mix
- Durability - ability to resist changes caused by traffic and environment

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Construction

- Surface preparation
- Mix production
- Transportation
- Placement
- Compaction

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Site preparation

New Construction
- Planning and communication
- Traffic control
- Grade preparation
  - Grade
  - Compaction

Rehabilitation
- Overlay
- Planning and communication
- Traffic control
- Surface preparation
  - Patching
  - Clean/sweep
  - Tack coat

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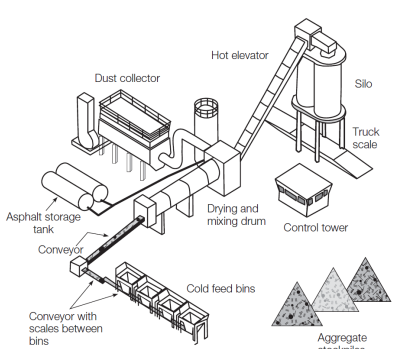
Hot Mix Production Drum Plant



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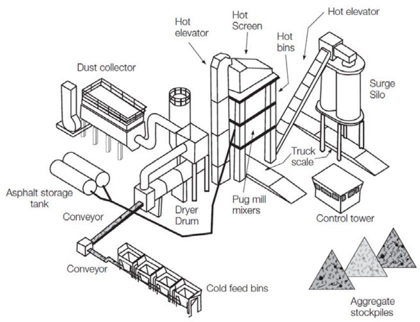
Hot Mix Production Batch Plant



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Asphalt Concrete Placement

- Continuous operation
  - Delivery
  - Loading paver
  - Constant head of material
  - No thickness adjustment

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Compaction

- Arrange aggregates into dense configuration
- Eliminate compaction by traffic
- Eliminate permeability

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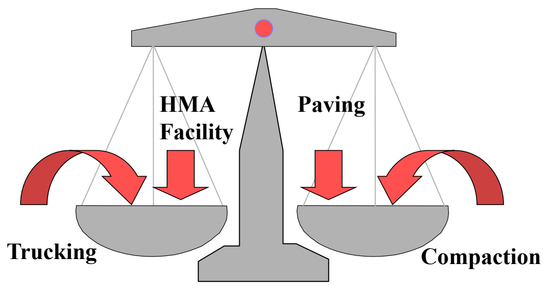
Balance



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HMA Performance

- Highways serve the user!!!!!!!!!
- Performance parameters
  - Skid resistance
  - Smoothness
  - Distress?????

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Summary

- Asphalt – refined material
  - Neat
  - Modified
- Aggregates
  - Natural
  - Crushed
  - Slags
- Air
- Mix design
  - Marshall
  - Superpave
- Production
  - Hot mix
  - Cold mix
- Construction
- Performance
- Maintenance

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Bituminous Materials

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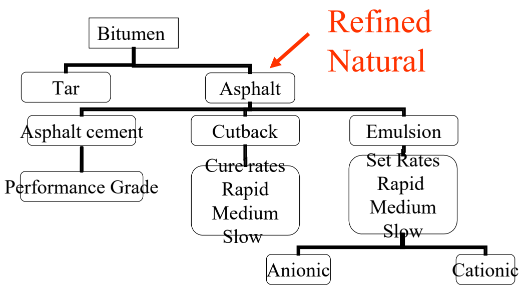
Bituminous material types



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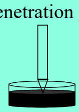
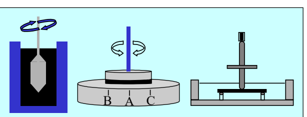
Asphalt Cement Grading

- Penetration grading



- Viscosity grading
  - without conditioning
  - with conditioning

- Performance grading
  - classification based on expected environmental exposure temperatures



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Limitations of Previous Methods

- Empirical
- Standard temperature
- No low temperature evaluation
- Short term aging only
- Grading method not sensitive enough
- Cannot consider modified asphalt

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SHRP Salient Features

- Include both modified and unmodified binders
- Constant criteria, vary test temperature
- Measure physical - engineering properties relate to performance
- Stages of asphalt
  - original
  - after mixing
  - long term behavior
- Entire temperature range
- Control distress
  - rutting
  - fatigue
  - thermal cracking
- SI units

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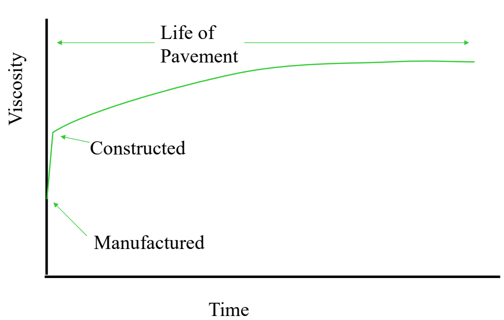
Changes in asphalt



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Aging

- Asphalt reacts with oxygen
  - "oxidative" or "age hardening"
- Short term
  - Volatilization of specific components
  - During construction process
- Long term
  - Over life of pavement (in-service)

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SHRP Temperatures

- High - highest seven-day moving average pavement temperature, as computed from air temperature and other environmental factors
- Low - lowest pavement temperature at the site, computed from air temperature and location
- Intermediate - average of high and low plus 4°C

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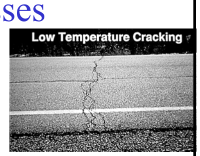
Pavement distresses



Rutting	Fatigue	Low temperature cracking
Low asphalt viscosity	Medium asphalt viscosity	High asphalt viscosity
High temperature	Intermediate temperature	Low temperature
Early in pavement life	Late in pavement life	Late in pavement life

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Superpave Binder Tests

Equipment	Purpose	Performance Parameter
Rolling thin film oven	Binder aging during production	Resistance to aging during construction
Pressure aging vessel	Aging during service life	Resistance to aging during service life
Rotational Viscometer	Binder properties at mix temperature	Handling and pumping
Dynamic Shear Rheometer	Rheology at high and intermediate temp.	Rutting and fatigue
Bending Beam Rheometer	Rheology at low temperatures	Thermal cracking
Direct Tension Tester	Low temperature properties	Thermal cracking
Cleveland Open Cup	Measure flash point	Safety

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Test Conditions

	Temperature			
Stage	Low	Inter-mediate	High	Quality
Original			DSR	Rotational Flash point Solubility
As constructed RTFO			DSR	
Long term aging RTFO + PAV	BBR DTT	DSR		

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Laboratory asphalt aging equipment

- **Rolling Thin Film Oven**

- **Pressure aging vessel**

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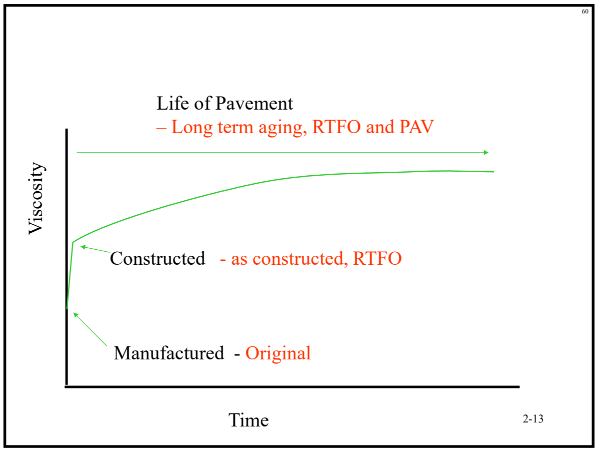
Life of Pavement
– Long term aging, RTFO and PAV
Viscosity
Constructed - as constructed, RTFO
Manufactured - Original
Time
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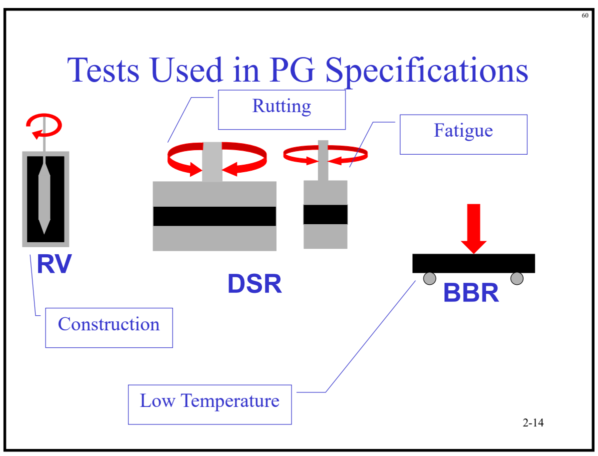
Tests Used in PG Specifications
Rutting
Fatigue
RV
DSR
BBR
Construction
Low Temperature
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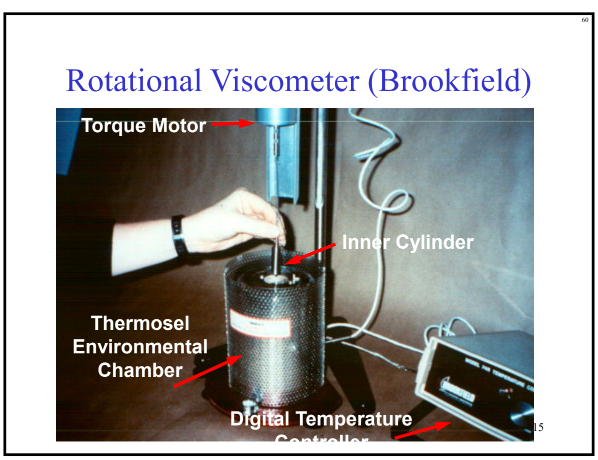
Rotational Viscometer (Brookfield)
Torque Motor
Inner Cylinder
Thermosel
Environmental
Chamber
Digital Temperature

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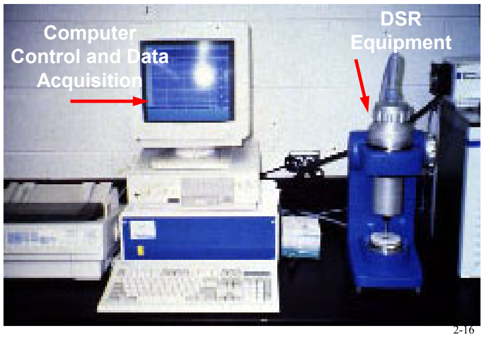
DSR Equipment



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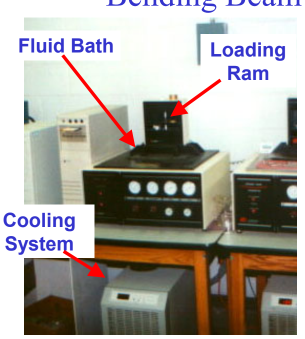
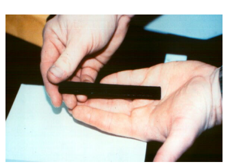
Bending Beam Rheometer





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PG Specifications

- Fundamental properties related to pavement performance
- Environmental factors
- In-service & construction temperatures
- Short and long term aging

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Performance Grade Binder Specification

The grading system is based on Climate

PG 64m - 22

Performance Grade

Average 7-day max pavement temperature

Min pavement temperature

Modify:
Traffic loads
Traffic speed
S = Standard
H = Heavy
E = Extreme

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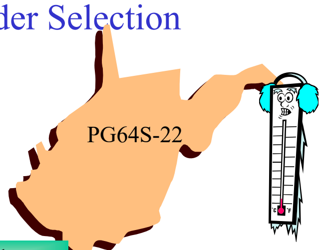
Binder Selection

Many agencies have established zones

WVDOH has a standard asphalt grade but …



For interstates and high volume increase high temperature one grade PG64H-22

PG64E-22
Heavy truck volume intersections

Some use
PG58S-28
Low temperature areas

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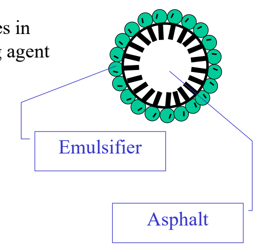
Emulsions

- Suspension of asphalt globules in water with use of emulsifying agent
- 60-70 % asphalt,
- remainder water
- trace emulsifier
- Uses
  - tack coat
  - chip seals (tar & chip)
  - cold mix

Globule



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Emulsion Types

- Emulsifier charge
  - Anionic
  - Cationic
  - Nonionic
- Curing rate
  - Rapid
  - Medium
  - Slow
  - Quick
- Viscosity of emulsion
  - Standard
  - High
- Viscosity of asphalt
  - Standard
  - Hard
  - Soft

x yS – n z

Asphalt viscosity
Standard blank
Hard – h
Soft - s

Emulsion viscosity
Standard – 1
High - 2

Set Rate
Slow – S
Medium – M
Rapid – R
Quick - Q

Charge
Anionic – blank
Cationic – C
Nonionic - N

2-23

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Example

- CSS-1h
  - C = Cationic
  - SS = Slow Set
  - 1 = Standard emulsion viscosity
  - h = Hard asphalt

x yS – n z

Asphalt viscosity
Standard bland
Hard – h
Soft - s

Emulsion viscosity
Standard – 1
High - 2

Set Rate
Slow – S
Medium – M
Rapid – R
Quick - Q

Charge
Anionic – blank
Cationic – C
Nonionic - N

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Tack Coat Application

Fresh emulsion
Brown color
Water still present

Breaking emulsion
Brown color
Black patches
Water still present

Set emulsion
Break complete
Ready for paving

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Tack Coat application rate

- 0.04 to 0.06 gallons / square yard
- Residual Asphalt Content
- Sometimes sprayed diluted 1:1
- Example
  - Emulsion with 65% asphalt content
  - Dilute 1:1
  - Application rate 0.05 gal/sy residual
  - Spray rate

=0.05/(0.65*0.5)= 0.15 g/sy

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TABLE 408.11		
Condition of Existing Pavement	Application Rate (gal/yd^2) / (L/m^2) (Note-2)	
	Undiluted	Diluted (1:1) (Note-3)
New HMA (Note-4)	0.04 – 0.05 / (0.18 – 0.23)	0.08 to 0.10 / (0.36 – 0.45)
Oxidized HMA	0.07 – 0.10 / (0.32 – 0.45)	0.13 – 0.20 / (0.59 – 0.90)
Milled Surface	0.10 – 0.13 / (0.45 – 0.49)	0.20 – 0.27 / (0.90 – 1.22)
PC Concrete	0.07 – 0.10 / (0.32 – 0.45)	0.13 – 0.20 / (0.59 – 0.90)

Note 3: Dilution rate only applies to SS and CSS grades.

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Asphalt Cutbacks

- Cutback asphalt a combination of asphalt cement and petroleum solvent.
- Reduce asphalt viscosity for lower temperature uses
  - Prime coat, Tack coat, Fog seal, Slurry seal
  - After applied the petroleum solvent evaporates leaving behind asphalt cement residue
  - Cutback asphalt is said to "cure" as the petroleum solvent evaporates away.
- Use of cutback asphalts is decreasing
  - *Environmental regulations.*
  - *Loss of high energy products.*
- Use in WV for winter patch mix

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Summary

- Asphalt
  - Cement
  - Emulsion
  - Cutback
- Refined from petroleum
- Performance Grade Specifications
  - Extensive testing
  - Grade based on climate
  - Modify for traffic

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Aggregates Description and Types

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Objective

- Aggregate production
- Aggregate testing and specifications

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Aggregate Production

- Excavation
- Transportation
- Crushing
- Sizing
- Washing

- Natural
  - aggregates
  - sands
- Crushed stone and rock
  - coarse
  - fines

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Natural sand and gravel

- Underwater sources
  - + Rivers & lakes
  - + Barge-mounted dredges, draglines, scoop, conveyors, or pumps
  - + Relatively clean
- Land sources
  - + Gravel or sand pits
  - + Bucket loader

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Crushed Stone and Rock

Rock depths < 50 ft., overburden washed out during processing

Rock depths > 50 ft., remove overburden

- Soil stripped with bulldozers and scrapers
- Tunnel mines

Blasting required

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Crushing

River Gravel | Partially Crushed River Gravel

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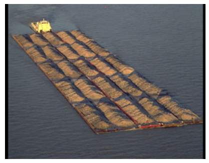
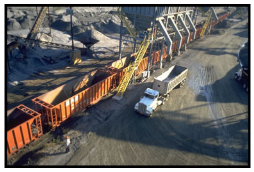
Transportation





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Sizing

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Stockpiling

* Prevent segregation and contamination
* Good stockpiling = uniform gradations

- Short drop distances
- Minimize moving
- Don't use "single cone" method
- Separate stockpiles

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Sampling

- Why Sampling Is Important
  - To evaluate the potential quality of a proposed aggregate source.
    - Does new source meet aggregate specifications?
  - To determine compliance with project specification requirements.
    - Do current aggregates meet specifications?

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Required Aggregate Properties

- Coarse Aggregate 703.1 - 703.3
- Fine Aggregate 702.3
- Mineral Filler 702.4

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Definitions

* Coarse Aggregate
  - Retained on 4.75 mm (No. 4) ASTM D692
* Fine Aggregate
  - Passing 4.75 mm (No. 4) ASTM D1073
* Mineral Filler
  - At least 70% Pass. 0.075 mm ASTM D242

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Coarse Aggregate

WV DOH Requirements 703.1 to 703.3

- Crushed Stone
  - Deleterious Substances
    - Thin or elongated pieces
    - Shale
    - Coal and other lightweight deleterious materials
    - Friable particles
  - Percent wear
  - Soundness
- Gravel
  - same as crushed stone, plus
  - fractured face requirement

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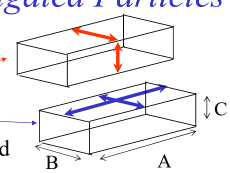
Coarse Aggregate

Flat and Elongated Particles

- ASTM D4791
  - Flat (Thin) B:C
  - Elongated A:B
  - Total flat and elongated
- WVDOH
  - MP 703.00.25
  - 4:1 ratio
  - Max. 5% thin and elongated.



$$P = \frac{w_1 + w_2}{w_3} 100$$

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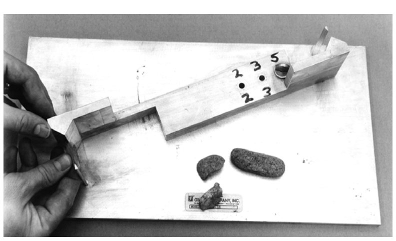
Coarse Aggregate

Flat and Elongated



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Coarse Aggregate

Shale Content

- WVDOH
- MP 703.00.27

$$S = \frac{w_1}{w_2}100$$

w_1 = weight of shale in sample
w_2 = sample weight

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Coarse Aggregate

Coal and Other Lightweight Deleterious Materials

- WVDOH
- MP 702.01.20

$$L = \frac{w_1}{w_2}100 \quad Fine\ aggregate$$

$$L = \frac{w_1}{w_3}100 \quad Coarse\ aggregate$$

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Coarse Aggregate

Clay Lumps and Friable Particles ASTM C 142

Dries a given mass of agg., then soaks for 24 hr., and each particle is rubbed. A washed sieve is then performed over several screens, the aggregate dried, and the percent loss is reported as the % clay or friable particles.

WVDOH
MP 703.00.20

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Current WVDOH

- Maximum of 3% deleterious materials

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Coarse Aggregate

Percentage of Wear
Toughness

*** Los Angeles Abrasion (AASHTO T96, ASTM C131 C535):**

Resistance of coarse aggregate to abrasion and mechanical degradation during handling, construction and use

* Aggregate at standard gradation subjected to damage by rolling with prescribed number of steel balls in large drum for a given number of rotations
* Result expressed as % changes in original weight

* WVDOH - maximum weight loss of 40%
test material retained on 4.75 mm sieve

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Coarse Aggregate

Soundness

*** Resistance to weathering .**
*** Simulates freeze/thaw**
*** Successive wetting and drying in sodium sulfate or magnesium sulfate**
*** Result is total percent loss over various sieve intervals for a prescribed number of cycles**
*** Max. loss values typically range from 10 to 20% per 5 cycles**

WVDOH
MP 703.00.22
Material retained on 9.5 mm sieve
Five cycles
Sodium sulfate
No more than 12% weight loss

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Coarse Aggregate

Percent Crushed Fragments in Gravel

- Quarried materials always 100% crushed
- Defined as % mass with one or more fractured faces
- WVDOH
  - MP 703.00.21
  - Retained on No. 4 (4.75mm)
  - Requirements
    - Base 1 - min. 80% one face
    - All other mixes - min 80% two faces

$$C_1 = \frac{w_1}{w_3}100$$

$$C_{1+} = \frac{w_1 + w_2}{w_3}100$$

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Coarse Aggregate

Percent Crushed Fragments in Gravel

0% Crushed | **100% with 2 or More Crushed Faces**

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WVDOH Fine Aggregate Requirements

- 702.3
  - Meet requirements of ASTM D 1073
  - Wave gradation requirements

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WVDOH Mineral Filler Requirements

- 702.4
  - Meet requirements of ASTM D 242
  - Wave gradation requirements
  - Free from organic impurities

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Gradation Analysis

Washed sieve

- Dry aggregate and determine mass
  - Wash and decant water through 0.075 mm sieve until water is clear
  - Dry aggregate to a constant mass
  - Determine mass of 0.075 material removed by washing

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Gradation Analysis

Mechanical sieve analysis

- Place dry aggregate in standard stack of sieves
- Place sieve stack in mechanical shaker
- Determine mass of aggregate retained on each sieve

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Aggregate Size Definitions

100
100
90
72
65
48
36
22
15
9
4

- *Maximum* Aggregate Size
  - the smallest sieve through which 100% of the aggregate sample passes
- *Nominal Maximum* Aggregate Size
  - the largest sieve that retains some material, generally less than 10%

100
99
89
72
65
48
36
22
15
9
4

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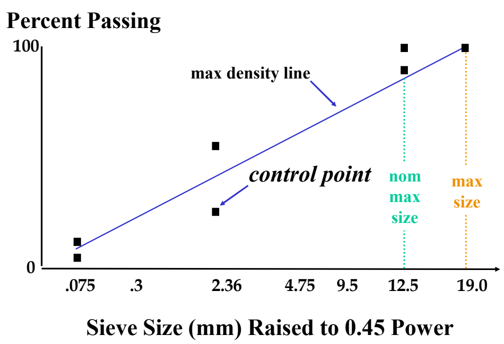
Gradation Chart



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Marshall Gradation Requirements

Standard Sieve		Percent Passing Criteria (Control Points)				
US Cust.	mm	Base I 1 1/2"	Base II 3/4"	Wearing IV 3/4"	Wearing I (scratch) 3/8"	Wearing III No. 4
2"	50	100				
1 1/2"	37.5	90-100				
1"	25	90 max	100	100		
3/4"	19		90-100	90-100		
1/2"	12.5		90 max	90 max	100	
3/8"	9.5				85-100	100
#4	4.75			47 min	80 max	90-100
#8	2.36	15-36	20-50	20-50	30-55	90 max
#16	1.18					40-65
#200	0.075	1.0-6.0	2.0-8.0	2.0-8.0	2.0-9.0	3.0-11.0

1-30

30

Superpave Gradation Requirements

Standard Sieve (mm)	Percent Passing Criteria (Control Points) Nominal Maximum Sieve Size					
	4.75 Wearing III	9.5 mm Wearing I (Scratch)	12.5 mm	19 mm Base II Wearing-IV	25 mm	37.5 mm Base I
50						100
37.5					100	90-100
25				100	90-100	90.0 max.
19			100	90-100	90.0 max.	
12.5	100	100	90-100	90.0 max.		
9.5	95-100	90-100	90.0 max.			47
4.75	90-100	90.0 max.		47	40	
2.36		32-67 47	28-58 39	23-49	19-45	15-41
1.18	30-60					
0.075	6-12	2.0-10.0	2.0-10.0	2.0-8.0	1.0-7.0	0.0-6.0

Mix Designations

Maximum aggregate size

Nominal Maximum aggregate size

Primary Control Sieve

Gradations which fall below the primary control sieve are classified as coarse gradations

3-31

31

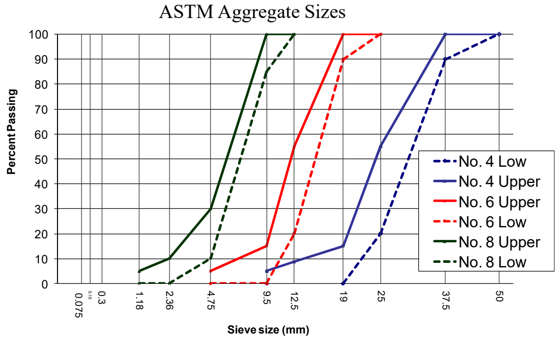
Aggregates placed in multiple stockpiles to manage **segregation**

Stockpiles are generally produced to meet ASTM size specifications

3-32

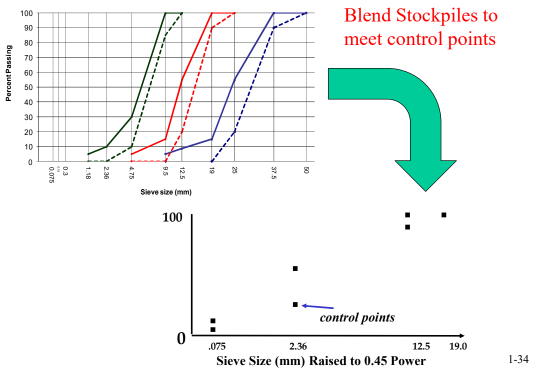
32

ASTM Aggregate Sizes



1-33

33



1-34

34

Blended gradations for multiple stockpiles

Material	Agg. #1		Agg. #2		Blend	Target
% Used						
U.S. Sieve	% Passing	% Batch	% Passing	% Batch		
3/8 “	100		100			100
No. 4	90		100			80 - 100
No. 8	40		100			65 - 100
No. 16	15		78			40 - 80
No. 30	3		52			20 - 65
No. 50	1		29			7 - 40
No. 100	0		16			3 - 20
No. 200	0		12			2 - 10

3-35

35

Blended Aggregate Specific Gravities

- Once the percentages of the stockpiles have been established, the combined aggregate specific gravity is calculated
- Specific gravity is a measure of the mass/volume characteristics of a material

3-36

36

Combined Specific Gravities

$$G = \frac{100}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \ldots\ldots\ldots \frac{P_n}{G_n}}$$

G = Blended Specific Gravity

P_i = Percent of stockpile i in the blend

G_i = Specific gravity of stockpile i

3-37

37

Summary

- Quality HMA cannot be produced without quality aggregates
- Source and production determines the quality of the aggregates
- Sampling ensures quality of aggregates are properly evaluated

- Crushed Stone
  - Deleterious Substances
    - Thin or elongated pieces
    - Shale
    - Coal and other lightweight deleterious materials
    - Friable particles
  - Percent wear
  - Soundness
- Gravel
  - Fractured faces

3-44

44

Mix Design

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4-1

1

Methods

Marshall

- Traditional method
- Uses volumetric analysis and stability and flow
- Mix types
  - Wearing I
  - Wearing III
  - Wearing IV
  - Base I
  - Base II

Superpave

- "New" method 1997
- Volumetric analysis only
- Mix types (NMAS mm)
  - 4.75
  - 9.5
  - 12.5
  - 19
  - 25
  - 37.5

Wearing III ~ SuperPave 4.75

4-2

2

Process

- Select Aggregates
- Select Binder
- Prepare samples
- Test samples
- Select asphalt content

4-3

3

Select aggregates

Marshall

- Deleterious materials
- Wear resistance
- Soundness
- Fractured faces
- Flat and elongated
- Blend for gradation
- Determine specific gravity

Superpave

- Source properties
  - Deleterious materials
  - Wear resistance
  - Soundness
- Consensus properties
  - Coarse aggregate angularity
  - Flat and elongated
  - Fine aggregate angularity
  - Sand equivalency
- Gradation
- Specific gravity

4-4

4

Select binder

- Marshall and Superpave are the same
- Normal roads PG 64S-22
- High volume roads PG 64H-22

- Other grades by special provision
  - PG 64E-22 high traffic volume slow moving
  - PG 58S-28 high elevation areas

4-5

5

Prepare samples

Marshall

- Compacted samples
  - Bulk specific gravity
  - Stability and Flow
  - Three samples at five binder contents
- Uncompacted samples
  - Maximum theoretical specific gravity
  - Two samples at one binder content

Superpave

- Compacted samples
  - Bulk specific gravity
  - Two samples at four binder contents
- Uncompacted samples
  - Maximum theoretical specific gravity
  - Two samples at four binder contents

4-6

6

Marshall Automatic Hammer

Superpave Gyratory Compactor

4-7

7

Marshall Stability and Flow

4-8

8

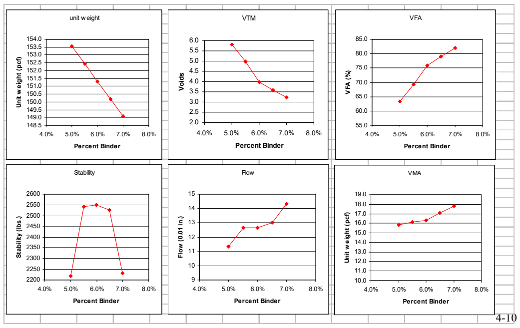
Volumetric Analysis

- Use specific gravity for to determine volumetric properties
  - Air voids
  - Voids in Mineral Aggregate
  - Voids Filled with Asphalt
  - Dust to Binder Ratio
    - Marshall Dust to Total binder ratio
    - Superpave Dust to Effective binder content

4-9

9

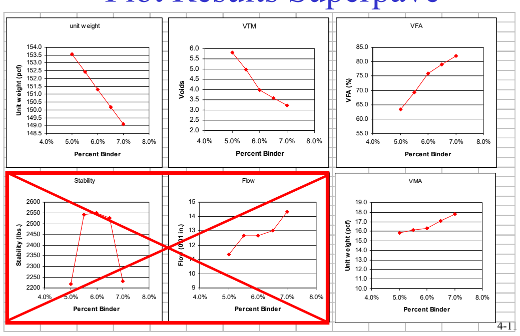
Plot Results Marshall



4-10

10

Plot Results Superpave



4-1

11

Select binder content

- Percent binder that corresponds to 4% asphalt content
- Meets all other criteria

4-12

12

60

Summary

- Two methods of mix design
  - Marshall
  - SuperPave

- Methods are similar but:
  - Marshall
    - Stability and Flow
  - SuperPave
    - Fine aggregate angularity
  - Compaction equipment
  - Number of samples

4-16

16