TACERA Annual Conference

Seal Coat Material Selection and Rate Design

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Outline

- Binder
- Aggregate
- Rate Design

Material Selection - Binder

What is Asphalt?

Types of Bitumen

Tar

(from Coal)

- Coal Tar
- Road Tar

Asphalt

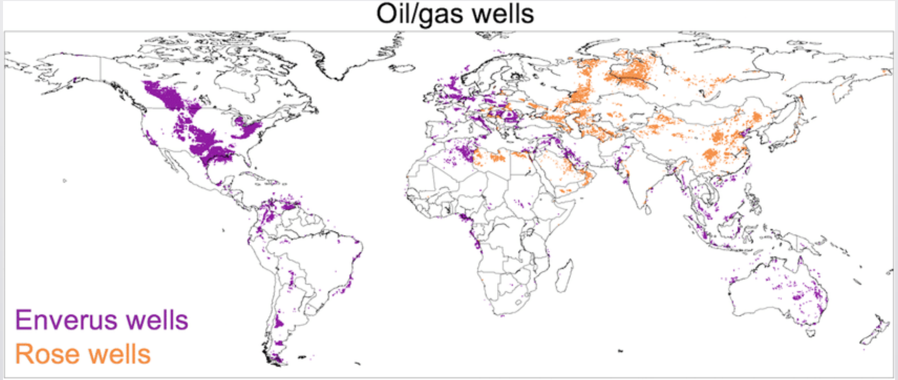
(from Petroleum)

- Asphaltic Bitumen
- Paving Grade Asphalt

Asphalt

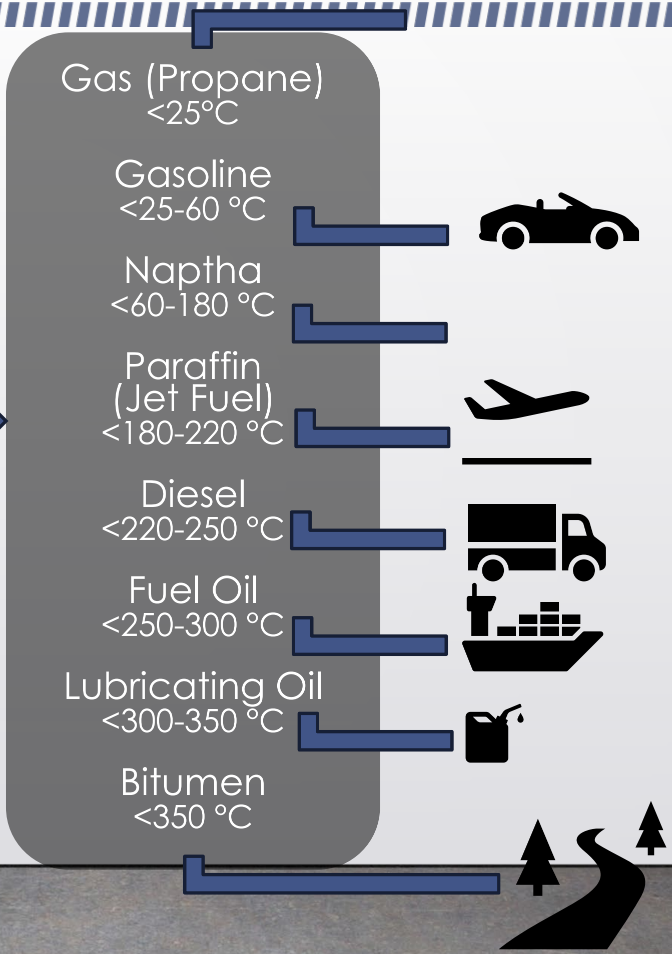
- Asphalt binder is a by-product from refinery processing of crude oil
  - Sometimes called the "bottom of the barrel"
- Properties depend on:
  - Refinery operations (distillation, PDA, ROSE, coker, cracker)
  - Composition crude-source dependent

Domestic & Foreign Crude Sources



Oil/Gas Wells Image from: Scarpelli, T., et al. (2020). "A global gridded (0.1° × 0.1°) inventory of methane emissions from oil, gas, and coal exploitation based on national reports to the United Nations Framework Convention on Climate Change." Earth System Science Data **12**: 563-575.

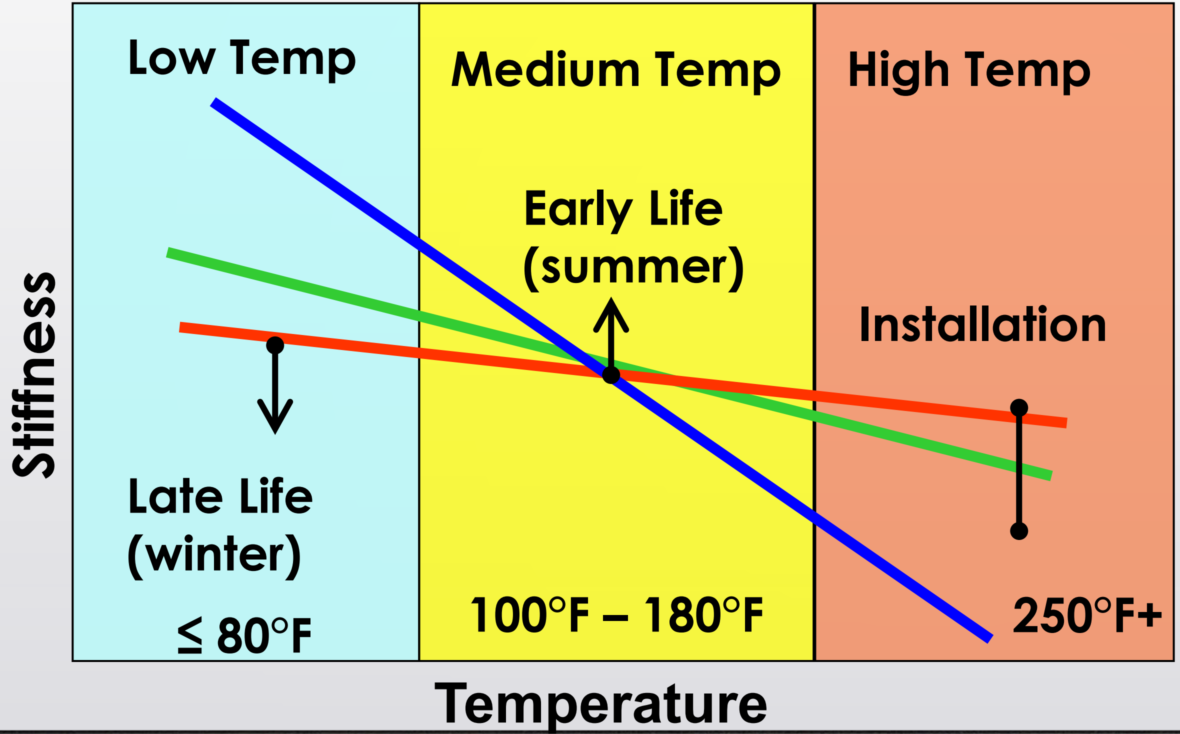
Basics of Refining Crude Oil



Purchasing of Asphalt Binders

- The key to binder specs:
  - Temperature Susceptibility
    - Or "How do the properties change with temperature?"
    - Main property is stiffness, of some type.

How Specifications Work



- When applied, the binder should be fluid enough to spray and cover the surface uniformly, yet viscous enough to remain in a uniform layer and not puddle in depressions or run off the pavement;
- After application, it should retain the required consistency to wet the applied aggregate;
- It should develop adhesion quickly;
- After rolling and curing, it should hold the aggregate tightly to the roadway surface to prevent dislodging by traffic; and
- When applied in the proper amount, it should not bleed or strip with changing weather conditions.

Types of Asphalt Binders

- Asphalt Cement
  - Hot applied asphalt binder
  - Generally graded by viscosity
  - Typically modified with polymer or tire rubber to improve qualities.
- Cutback Asphalt
  - Applied at lower temperatures
- Emulsified Asphalt
  - Applied at lower temperatures
  - Typically modified with polymer or tire rubber to improve qualities.

Typical Asphalt Cement Nomenclature

AC-##YY

Type

Viscosity

Modifier

AC-15P
AC-20-5TR
AC-20-XP

Emulsion (X)YS-#Z

Ionicity & Special Properties

Type

Overall Viscosity

Modifier

CRS-2P
HFRS-2P

Cutback RC-##

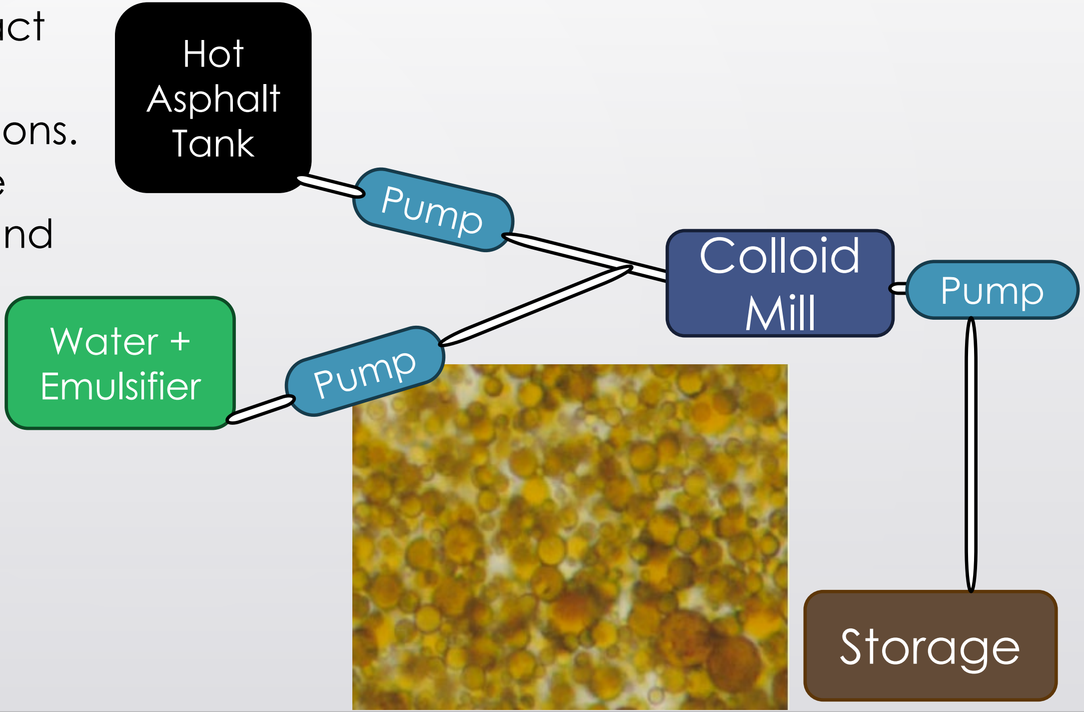
Rapid Curing (RC)

Asphalt + Naphtha

RC - 250

Basic Emulsion Classifications

- **RS emulsions** are the least stable.
- They *break rapidly* when in contact with aggregates.
- They are used for spray applications.
- Polymers may be added to these emulsions to increase adhesion and shorten return-to-traffic times.
- Anionic
  - Negatively Charged Asphalt Particles.
- Cationic
  - Positively Charged Asphalt Particles.



Benefits/Utility of Emulsions

- Can use at lower temperatures than AC
- No petroleum solvents
  - no danger of fire / explosion
  - little or no hydrocarbon emissions (good for non-attainment areas)
- Can readily coat damp aggregate surfaces
- Can customize emulsion chemistry to maximize adhesion to different aggregate mineralogy
- Aggregates for use with emulsions should not be precoated because the precoating inhibits the chemical break, absorption, and adhesion of the emulsion to the rock.
- In general, cationic emulsions will break and set more quickly than anionic emulsions. Setting rate of cationic is affected less by weather.

Material Selection - Aggregate

Desirable Aggregate Properties for Seal Coats

- Properties
  - Resistance to wheel load abrasion
  - Resistant to environment
  - Provide a skid resistant surface
  - Provide different texture or color
  - Cubical shape
  - Single size aggregate
- Specify:
  - Aggregate type
  - Aggregate gradation
  - Precoating requirements

Aggregate Factors Affecting Performance

- Size
  - Larger rock – more binder
  - Larger rock more noise – more vehicle damage.
- Shape
  - As near Cubical as possible
  - Flakiness test
- Toughness
  - LA Abrasion and Mag Sulfate Soundness
- Cleanliness
  - Limit dust and dirt to improve adhesion
  - Deleterious Materials and Decantation Test
- Aggregate Absorption (lightweight only)
- Pre-coated
  - AC binder - pre-coating recommended
  - Emulsion - Pre-coating not recommended

Aggregate Factors Affecting Performance, cont.

- Other
  - Vehicle damage can be reduced by using smaller aggregate or using lightweight aggregates.
  - Larger aggregate seal coats provide a better sealing capabilities
    - Larger aggregates generate complaints of noise from motorists/residents.
  - Double application seal coats using a smaller aggregate for the top layer produce less tire noise.

Aggregate

- Types
  - Natural Aggregates
    - Crushed Gravel
    - Crushed Stone
    - Natural Limestone Rock Asphalt
  - Synthetic Aggregates
    - Lightweight Aggregates
    - Crushed Slag
- Terminology
  - Coarse Aggregate
  - Fine Aggregate
  - Nominal Max. Size
    - One size larger than the first sieve to retain more than 10%
  - Maximum Size
    - One size larger than nominal maximum size

Seal Coat Rates

The Texas Seal Coat Design Method was developed through TxDOT research project 0-6989, "Update Seal Coat Application Rate Design Method". The research reports can be found at the following websites:

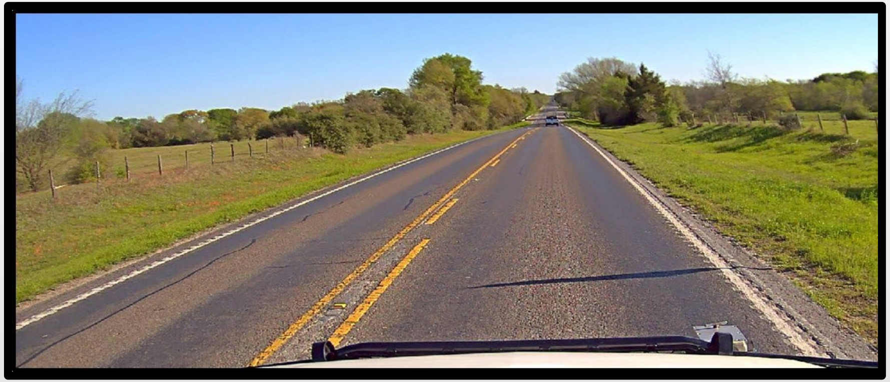
https://static.tti.tamu.edu/tti.tamu.edu/documents/0-6989-R1.pdf

Example

If you use AC 20-5TR and Precoated Grade 4 rock,

1. **Will the rock rate change?**
2. **Will the asphalt rate change?**

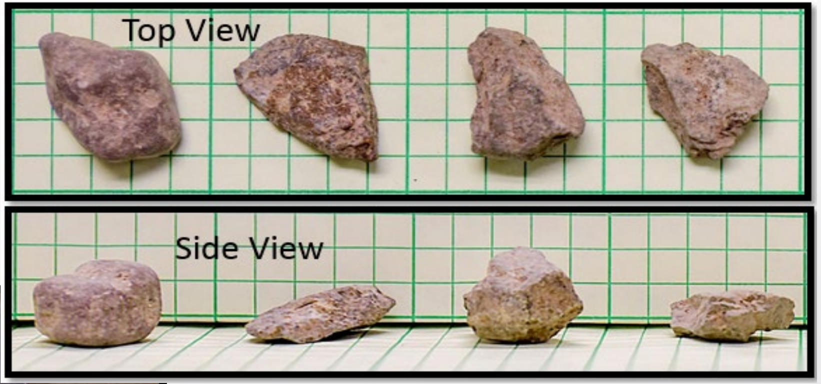
- Conditions:
  - Dry hot mix with cracks
  - 3200 ADT
  - 28 % Trucks

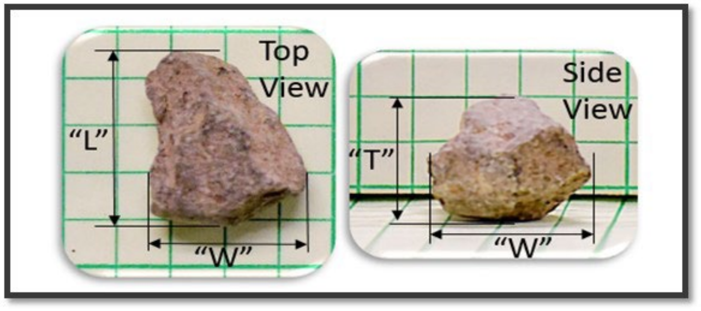


- Conditions:
  - Seal Coat with wheelpath flushing
  - 810 ADT
  - 32 % Trucks

Rock Rate – Determined by Size and Shape of Rock

- What can I measure?
  - Loose Unit Weight
    - Approximately the condition in the haul truck
    - Rock + air(void space) in bucket
  - Size of the Rock
    - Determine the average height
  - Shape of the Rock
    - Flakiness Index





Rock Rate

Theoretical Spread Rate | Typical Visual Spread Rate | Light Spread Rate

- Which one is correct and how do I determine the rate?

Rock Rate

$$S = \frac{36}{T_m}$$

Where:

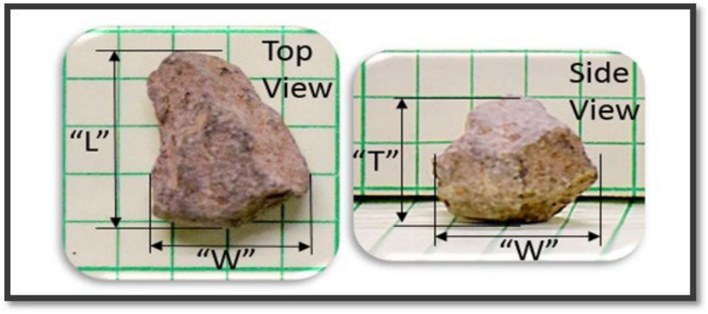
S = Theoretical Spread Rate, sq. yd. per cu. yd.

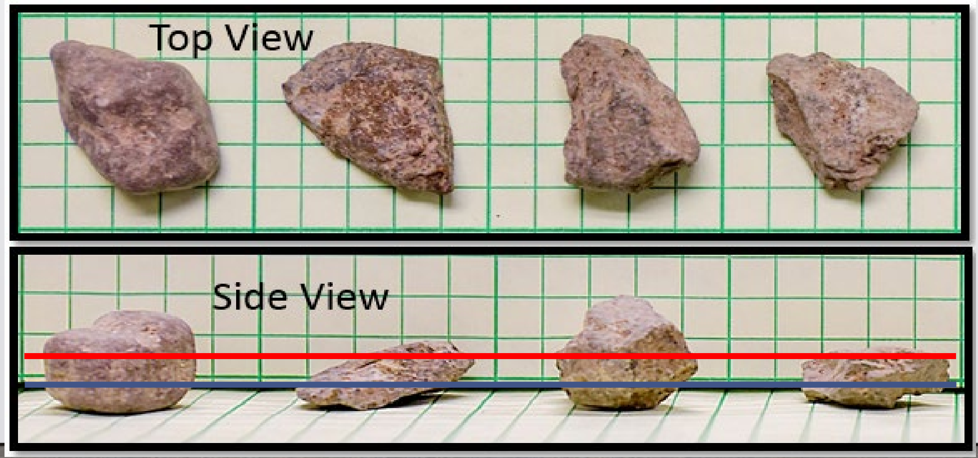
T_m = Average Mat Thickness, in.

Description	Symbol	Example	Units	Comments/Formula
Average Mat Thickness	T_m	0.285	in	Measured
Theoretical Spread Rate	S	126	sy/cy	$= 36 \div 0.285$

Asphalt Rate – Controlled by Size and Shape of Rock

- Binder depth should be minimum of 30% of aggregate thickness to avoid aggregate loss
- Binder depth should be maximum of ~65% of aggregate thickness to avoid flushing





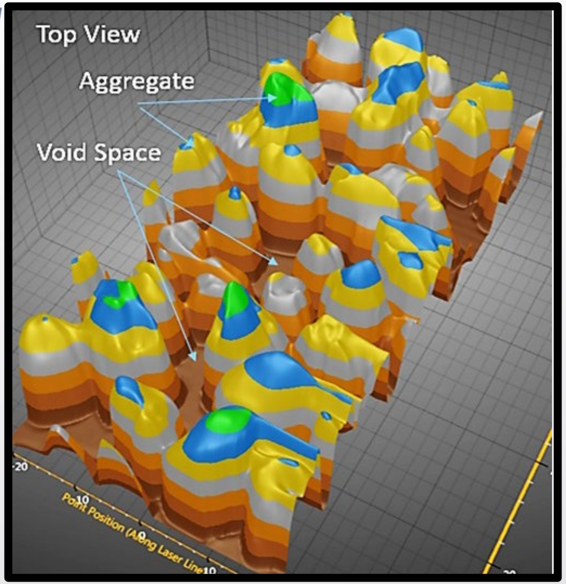
Embedment

Table 1: Design Embedment												
FI	≤8%						>8%					
Aggr. Grade	Gr 3		Gr 4		Gr 5		Gr 3		Gr 4		Gr 5	
Binder	B	A-R	B	A-R	B	A-R	B	A-R	B	A-R	B	A-R
Traffic (v/d/l)	De (%)	De (%)	De (%)	De (%)	De (%)	De (%)	De (%)	De (%)	De (%)	De (%)	De (%)	De (%)
0–50 SHLD	41	52.5	40.5	51.5	40.5	51.5	37	47	36.5	46.5	36	46
51–100	40	52	39.5	51	39.5	51	36	46.5	35.5	46	35	45.5
101–250	39.5	51.5	39	50.5	39	50.5	35.5	46	35	45.5	34.5	45
251–400	39	50.5	38.5	49.5	38.5	49.5	35	45	34.5	44.5	34	44
401–600	38	49.5	37.5	48.5	37.5	48.5	34	44	33.5	43.5	33	43
601–800	37.5	49	37	48	37	48	33.5	43.5	33	43	32.5	42.5
801–1000	37	48	36.5	47	36.5	47	33	42.5	32.5	42	32	41.5
1001–1500	36.5	47.5	36	46.5	36	46.5	32.5	42	32	41.5	31.5	41
1501–2000	36	47	35.5	46	35.5	46	32	41.5	31.5	41	31	40.5
2001–3000	35.5	46	35	45	35	45	31.5	40.5	31	40	30.5	39.5
>3000	35	45.5	34.5	44.5	34.5	44.5	31	40	30.5	39.5	30	39

B = AC, Modified AC, Emulsion and Cutback, A-R = Asphalt Rubber

Asphalt Rate

- What can we measure?
  - Size of the road – length x width
  - Size of the rock to estimate the thickness of asphalt.
    - This gives us a length x width x height --- convert volume to gallons per sy
- What happens when we add rock?
  - Can rock and asphalt occupy the same space?
  - How much space on the road is for the asphalt and how much for the rock?



Level Rises when rock pushes into asphalt

Asphalt sprayed on pavement before add rock

Asphalt Rate

$$R = 5.61 \times V \times D_e \times T_m \times (1 + C_r)$$

Area or Length X Width (V)

Height ($D_e \times T_m$)

Only needed for A-R binders

Where:

5.61 = conversion factor

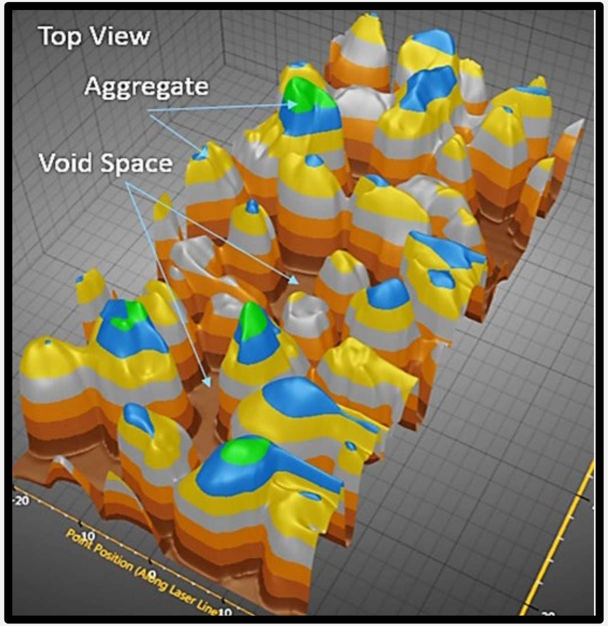
R = Residual Binder at 60°F in gal. per sq. yd.

V = Volume of Voids, percent (expressed as decimal)

For usual spread rate, use V=0.55 (55%)

De = Design Embedment, percent (expressed as decimal)

Cr = Crumb Rubber content, percent (expressed as decimal)



Example 1

Binder	**AC 20-5TR**
Aggregate	GR 4
Application Temp ˚F	375
Traffic Data (Vehicles/Day/Lane)	3200
Trucks, %	28
Time of Year	Summer

Determine the Void Space				
[1]Volume of Voids	V	55%	%	
Determine the Design Embedment				
Current Traffic		3200	veh/day/ lane	Measured
Flakiness Index	FI	5%	%	Measured
Aggregate Grade		4	Grade	Specified
Design Embedment	D_e	34.5%	%	Table
Determine Binder Application Rate based on Aggregate Size and Shape				
Crumb Rubber Content	W_a	0	%	A-R Mixture Design
Average Mat Thickness	T_m	0.285	in	Measured
Residual Binder at **60°F**	R	0.30	gal/sy	5.61 x 0.55 x 0.345 x 0.285

Example 1 – Application Temperature Adjustment

$$A = \frac{R}{Ft}$$

Where:

A = Binder application rate adjusted for application temperature, gal. per sq. yd.

F_t = Temperature correction factor from in Table 3, Table 4, and Table 5 or TxDOT's "Asphalt Binder Temperature-Volume Corrections."

Binder	App. Temp.	Vol. Correction Factor to
	[°F]	[60°F]
Cutbacks	150	0.96891
Emulsions	**150**	0.97750
Asphalt Cements and Asphalt-Rubber	375	0.89437

Application Temperature Adjustment				
Application Temperature		375	°F	Contractor Provides
Temperature Correction Factor	Ft	0.89437		Table
Binder Rate at Application Temperature	A	0.34	gal/sy	=0.30/0.89437

Asphalt Rate

Do we need to adjust for road condition?

Description	Example 1
Binder	AC 20-5TR
Aggregate	GR 4
Application Temp ˚F	375
Traffic Data (Vehicles/Day/Lane)	3200
Trucks, %	28
Time of Year	Summer
Based on Aggregate Size and Shape at **60°F**	**0.30 gal/sy**
Adjusted for Application Temperature at **375 °F**	**0.34 gal/sy**

Design Procedure - Adjustments

- Adjust Application Rate

$$B = A + P + T_V + TH$$

Where:

B = Temperature Adjusted Binder Rate, gal. per sq. yd.

P = Pavement adjustment factor, gal. per sq. yd., Refer to Table

T_V = Traffic adjustment factor, gal. per sq. yd., Refer to Table

T_H = Heavy Traffic adjustment factor, gal. per sq. yd., Refer to Table

Example Road Condition Adjustment Chart

Binder Rate Adjustment Factors for Pavement Surface Condition (existing or new pavement-wheel path conditions)				
Surface Type	**Surface Condition**	**Aggregate Grade**		
		Gr 3 gal/sy	**Gr 4 gal/sy**	**Gr 5 gal/sy**
Asphaltic Concrete Pavement (ACP)	Very dry ACP with many cracks	0.08	0.06	0.05
	Dry ACP with some cracks	0.05	0.04	0.03
	Good condition ACP with few cracks	0.02	0.02	0.01
Seal	Very dry with many cracks	0.06	0.06	0.04
	Very Coarse Texture and Dry with few cracks	0.04	0.04	0.03
	Dry seal with few cracks	0.03	0.03	0.02
	Good seal with few cracks	0.00	0.00	0.00
	Flushed seal	−0.02	−0.02	−0.01
	Bleeding seal	−0.04	−0.04	−0.02
Patches	Dry or fresh patch	0.03	0.03	0.02
	Fogged patch	0.00	0.00	0.00
	Flushed patch	−0.03	−0.03	−0.03
Base	Flex Base	0.04	0.03	0.02
	Stabilized Base	0.02	0.01	0
	Asphalt Stabilized Base	0.01	0	−0.01

Example 1

Binder Rate Adjustment Factors for Pavement Surface Condition (existing or new pavement-wheel path conditions)

Surface Type	Surface Condition	Aggregate Grade		
		Gr 3	Gr 4	Gr 5
		gal./sq. yd.	gal./sq. yd.	gal./sq. yd.
Asphaltic Concrete Pavement	Very dry ACP with many cracks	0.08	0.06	0.05
	Dry ACP with some cracks	0.05	0.04	0.03
	Good condition ACP with few cracks	0.02	0.02	0.01

Binder Rate at Application Temperature	A	0.34	gal/sy	
Adjustments based on Field Conditions				
Pavement Condition Adj. Factor	P	0.06	gal/sy	Visual
Traffic Volume Adj. Factor	T_V	-0.03	gal/sy	Measured
Heavy Traffic Adj. Factor	T_H	-0.01	gal/sy	Measured
Binder Rate at Application Temperature	B	0.36	gal/sy	$= 0.34 + 0.06 - .03 - 0.01$

Traffic Volume Adjustments

Binder Rate Adjustment Factors for Traffic Volume

Current Traffic	Aggregate Grade		
	Gr 3	Gr 4	Gr 5
v/d/l	gal/sy	gal/sy	gal/sy
0–50 (SHLD)	0.05	0.05	0.02
50–100	0.05	0.05	0.02
101–250	0.04	0.04	0.01
251–400	0.03	0.03	0.00
401–500	0.02	0.02	0.00
501–650	0.01	0.01	0.00
651–900	0.00	0.00	0.00
901–1100	−0.01	−0.01	−0.01
1101–1500	−0.01	−0.01	−0.01
1501–2000	−0.02	−0.02	−0.01
>2000	−0.03	−0.03	−0.01

Heavy Truck Traffic Adjustments

Binder Rate Adjustment Factors for Truck Traffic

	Aggregate Grade		
% Trucks	Gr 3	Gr 4	Gr 5
	gal/sy	gal/sy	gal/sy
≤ 15%	0.00	0.00	0.00
15.1%–30%	−0.01	−0.01	0.00
>30%	−0.02	−0.02	0.00

Example 1- Binder Application Rate

Description	Example 1
Binder	AC 20-5TR
Aggregate	GR 4
Application Temp ˚F	375
Traffic Data (Vehicles/Day/Lane)	3200
Trucks, %	28
Time of Year	Summer

Description	Example 1
Binder	AC 20-5TR
Aggregate	GR 4
Application Temp ˚F	375
Traffic Data (Vehicles/Day/Lane)	3200
Trucks, %	28
Time of Year	Summer
Based on Aggregate Size and Shape at **60°F**	0.30 gal/sy
Adjusted for Application Temperature at **375 °F**	0.34 gal/sy
Distributor	**0.36 gal/sy**

Example 2 - Emulsion

Description	Example 1	Example 2
Binder	AC 20-5TR	CRS-2P
Aggregate	GR 4	
Application Temp ˚F	375	150
Traffic Data (Vehicles/Day/Lane)	3200	
Trucks, %	28	
Time of Year	Summer	Fall
Residual Asphalt	100%	68%

Example 2

Description	Example 1	Example 2
Binder	AC 20-5TR	CRS-2P
Aggregate	GR 4	
Application Temp ˚F	375	150
Traffic Data (Vehicles/Day/Lane)	3200	
Trucks, %	28	
Time of Year	Summer	Fall
Residual Asphalt	100%	68%

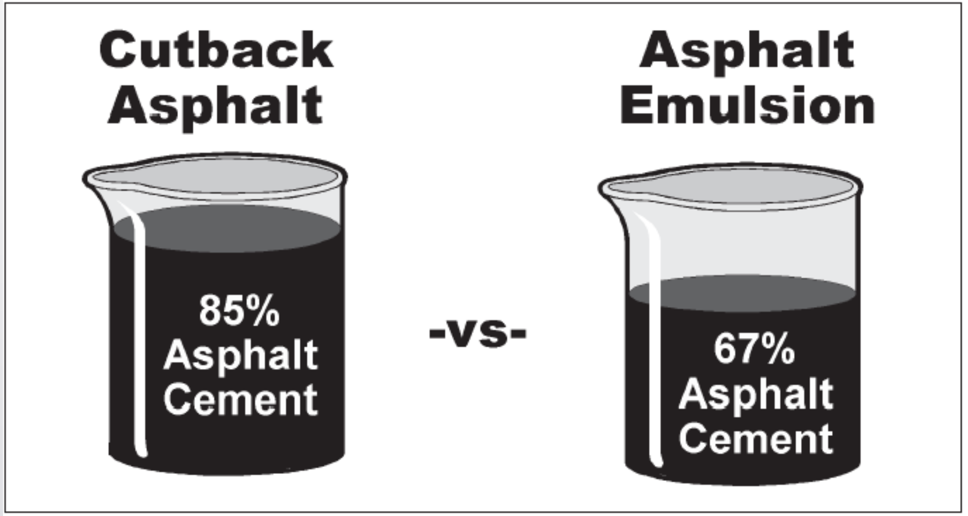
Application Temperature Adjustment				
Application Temperature		150	°F	Contractor Provides
Temperature Correction Factor	Ft	**0.97750**		Table
Binder Rate at Application Temperature	A	0.31	gal/sy	$= 0.30 \div 0.97750$
Adjustments based on Field Conditions				
Pavement Condition Adj. Factor	P	0.06	gal/sy	Visual
Traffic Volume Adj. Factor	T_V	-0.03	gal/sy	Measured
Heavy Traffic Adj. Factor	T_H	-0.01	gal/sy	Measured
Binder Rate Adjusted	B	0.33	gal/sy	$= 0.31 + 0.06 - .03 - 0.01$

Binder Application Rate

Description	Example 1	Example 2
Binder	AC 20-5TR	CRS-2P
Aggregate	GR 4	
Application Temp ˚F	375	150
Traffic Data (Vehicles/Day/Lane)	3200	
Trucks, %	28	
Time of Year	Summer	Fall
Residual Asphalt	100%	68%
Based on Aggregate Size and Shape at **60°F**	0.30 gal/sy	0.30 gal/sy
Adjusted for Application Temperature at **375 °F**	0.34 gal/sy	0.31 gal/sy
Field Condition Adjusted Rate	0.36 gal/sy	0.33 gal/sy
Adjusted Rate for Distributor	0.36 gal/sy	**?**

Design Procedure – Cutbacks and Emulsions

Remember to Adjust Application Rates!



Design Procedure – Cutbacks and Emulsions

Time of Year and Residual Asphalt Adjustment

$$B_{ec} = B + K \times \left(\frac{B}{R_a} - B\right)$$

Where:

B_{ec} = recommended application rate of either emulsion or cutback, gal. per sq. yd.

K = seasonal adjustment factor from Table

R_a = percent residual asphalt in emulsion or cutback expressed as a decimal

Binder Type	Minimum Residue from distillation Ra
Emulsion	65%
Cutback	70%

Construction Time	Seasonal Adjustment Factor (K)	
	Emulsion	Cutback
Spring	0.60	0.70
Summer	0.40	0.60
Fall	0.70	0.80
Winter	0.90	0.90

Example 2

Description	Example 1	Example 2
Binder	AC 20-5TR	CRS-2P
Aggregate	GR 4	
Application Temp ˚F	375	150
Traffic Data (Vehicles/Day/Lane)	3200	
Trucks, %	28	
Time of Year	Summer	Fall
Residual Asphalt	100%	68%

Construction Time	Seasonal Adjustment Factor (K)	
	Emulsion	Cutback
Spring	0.60	0.70
Summer	0.40	0.60
Fall	0.70	0.80
Winter	0.90	0.90

Application Temperature and Field Condition Adjustments				
Binder Rate at Application Temperature	B	0.33	gal/sy	
Adjustments based on Binder Type and Time of Year				
Seasonal Adjustment Factor	K	0.7		Table
Residual Asphalt	R_a	68%	Percent	Measured
Binder Rate	B_{ec}	0.44	Gal/sy	$= 0.33 + 0.7 \times (\frac{0.33}{0.68} - 0.33)$

Binder Application Rate

Description	Example 1	Example 2
Binder	AC 20-5TR	CRS-2P
Aggregate	GR 4	
Application Temp ˚F	375	150
Traffic Data (Vehicles/Day/Lane)	3200	
Trucks, %	28	
Time of Year	Summer	
Residual Asphalt	100%	68%
Based on Aggregate Size and Shape at **60°F**	0.30 gal/sy	0.30 gal/sy
Adjusted for Application Temperature at **375 °F**	0.34 gal/sy	0.31 gal/sy
Field Condition Adjusted Rate	0.36 gal/sy	0.33 gal/sy
Distributor	**0.36 gal/sy**	**0.44 gal/sy**

Questions?

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