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ASPHALT PRODUCTS 101 & ALTERNATIVES FOR PAVEMENT MAINTENANCE ON TOWN & COUNTY ROADS

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MEIGS
Paving Asphalts & Emulsions

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First, some terminology:

"Asphalt Binder" or "Asphalt" or "Hot Oil"
(PG 58-28 S, PG 58-34 S, PG 64-22 S... and more)

"Paving Grade" or "Oil"
(Production of HMA/WMA)

"Cutbacks" or "Road Oil"
(Asphalt binder + solvent)
(Ex.: SC-800, MAC-5, MS-5)

"Asphalt Emulsion" or "Emulsion"
(CRS-2, HFRS-2, EM-8)

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Why are we here?

2017 INFRASTRUCTURE REPORT CARD

ASCE

This map shows the miles of public roads and percentage in poor condition, and the cost per year and per motorist of driving on roads in need of repair. More than two out of every five miles of America's urban interstates are congested.

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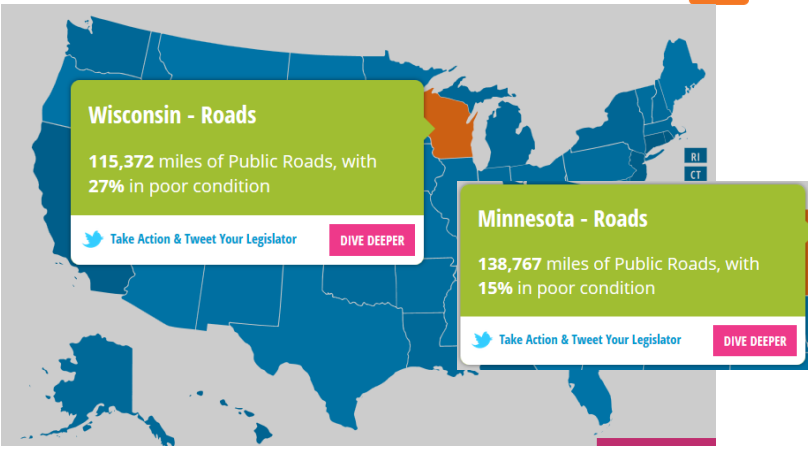

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How did we get here?

U.S. Department of Transportation Federal Highway Administration

MAP-21

FUNDING & FUTURE NEED

The U.S. has been underfunding its highway system for years, resulting in a $836 billion backlog of highway and bridge capital needs. The bulk of the backlog ($420 billion) is in repairing existing highways, while $123 billion is needed for bridge repair, $167 billion for system expansion, and $126 for system enhancement (which includes safety enhancements, operational improvements, and environmental projects). The Federal Highway Administration estimates that each dollar spent on road, highway, and bridge improvements returns $5.20 in the form of lower vehicle maintenance costs, decreased delays, reduced fuel consumption, improved safety, lower road and bridge maintenance costs, and reduced emissions as a result of improved traffic flow.

Adapted from: Nestler, J. "WisDOT Asset Management" WAPA 2017 & 2017 ASCE Infrastructure Report Card

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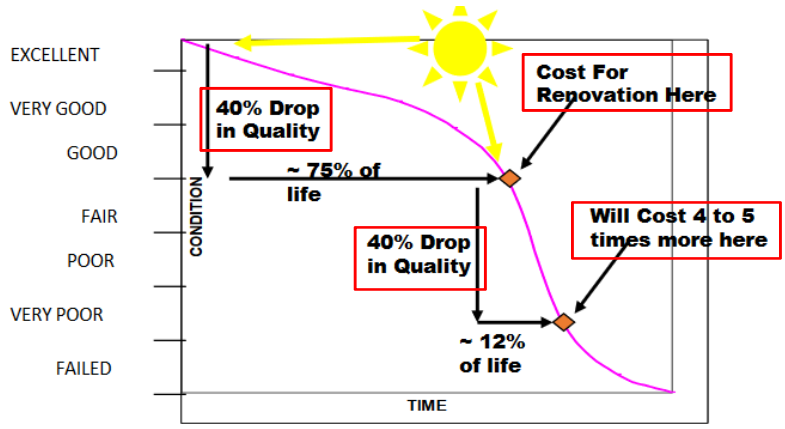
Some theory: Why the "Worst-First" approach is ineffective:



Adapted from: Nestler, J. "WisDOT Asset Management" WAPA 2017

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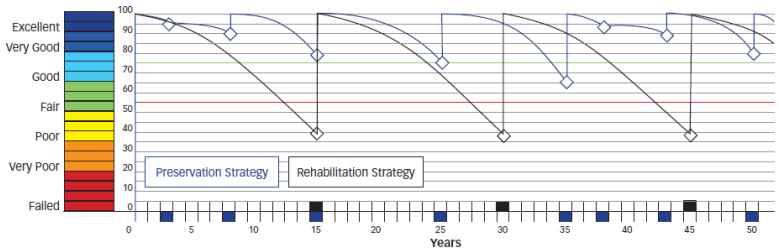
Worst-First vs. Preservation

Preservation vs. Rehabilitation



Preservation Strategy	Rehabilitation Strategy
Years 3 & 38: Rejuvenation Years 8 & 43: Microsurfacing (single) Years 15 & 50: Microsurfacing (double) Year 25: Cape seal Year 35: 1¾-in. hot-mix overlay	Year 15: CIPR with 2-in. HMA overlay Year 30: CIPR with 2-in. HMA overlay Year 45: CIPR with 2-in. HMA overlay
Total cost/SY over 50 years = $28.65	**Total cost/SY over 50 years = $48.00**

Adapted from: Ford, D. "Calculation is Correct" Roads & Bridges, April, 2013

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So, I should just chip seal, chip seal, chip seal then, right?

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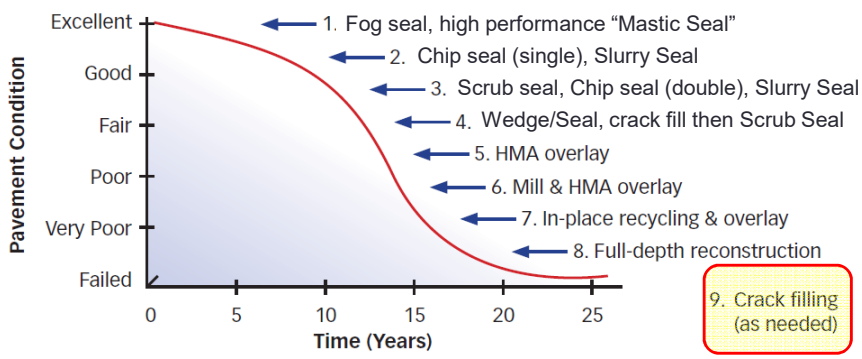
"The right treatment on the right road"



Two takeaways:

1. ***Timing is everything (Equivalent Annual Cost); a chip seal might last 2 years or 7 years depending on condition of existing surface, but upfront cost is the same.***
2. ***Assign actual numbers based on your network (Cost-Benefit-Value) to determine timing (Do NOT ignore bad roads, single-use roads, etc., prioritize them!)***

Adapted from: Nestler, J. "WisDOT Asset Management" WAPA 2017

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Shameless Plug…

MEIGSTECHBulletin No. 8a

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Pavement Preservation Principles

Pavement Preservation Strategy Example

The three metrics used in this example are defined below:

- ✓ **Equivalent Annual Cost (EAC):** The unit cost of a treatment divided by the expected service life of that treatment; EAC has units of $/yd²/yr. This metric is useful for two reasons: (1) EAC normalizes treatments to create an even comparison between treatments and amortizes costs, and (2) if a given treatment is used on the wrong road (e.g. a surface treatment on an old, beat up road that instead needs reconstruction; see table below), the expected life of the treatment is reduced and the EAC thereby increases, making a surface treatment *more costly* on that road even if unit cost is unchanged. EAC relies on pavement owners working with material suppliers to make an unbiased estimate of the expected service life of a treatment. For example:

Treatment	Unit Cost/yd²	Est. Service Life (yr.)*	EAC
Surface Treatment (hypothetical, properly timed)	$2.00	5	$0.40
Surface Treatment (hypothetical, poorly timed)	$2.00	2	$1.00
Mill-and-Fill	$12.00	12	$1.00
Reconstruction	$25.00	20	$1.25

*Assumes treatment is properly selected and constructed

- ✓ **Remaining Service Life (RSL):** Every pavement has a quantifiable RSL; for each year one lane-mile of road is allowed to deteriorate with no maintenance, the pavement will lose one lane-mile-year. Reconstruction and preventative surface treatments add life expectancy to a pavement, so they add lane-mile-years. Using a simple 'check-and-balance', two or more scenarios can be compared objectively. By comparing 'worst-first' with a more proactive management strategy, the proactive approach will usually add more service to the system in a given year (Example below).
- ✓ **Cost-Benefit Value (CBV):** CBV helps you choose the right projects to work on given a fixed budget accounting for current pavement condition and traffic level. It is calculated as:

$$CBV = \frac{Traffic\ Level\ (AADT) * Est.serivce\ Life\ of\ Treatment}{Unit\ Cost\ of\ Treatment * Pavement\ Condition\ Index\ (PCI)}$$

How to use these metrics:

***Example:** A 500 lane-mile network has a budget of $3.0 million available.*

"Worst First" with No Preservation

Network Trend:

Programmed Activity	Lane-Mile-Years	Total Budget
Reconstruction	200	$1,760,000
Rehabilitation	168	$1,239,040
Preservation	0	$0
Totals:	**368**	**$2,999,040**

Added Service Summary:

Programmed Activity	
(Lane-Mile-Years) =	**368**
Total Network	-
(Lane-Mile-Years) =	500
Gain (+) / Deficit (-) =	**-132**

Preservation Focused

Network Trend:

Programmed Activity	Lane-Mile-Years	Total Budget
Reconstruction	100	$880,000
Rehabilitation	120	$901,120
Preservation	424	$1,214,400
Totals:	**644**	**$2,995,520**

Added Service Summary:

Programmed Activity	
(Lane-Mile-Years) =	644
Total Network	-
(Lane-Mile-Years) =	500
Gain (+) / Deficit (-) =	**+144**

Using the same total budget and not ignoring the reconstruction/rehabilitation needs of the network, the ***preservation focused strategy added 144 lane-mile-years to the system***, while the ***"worst-first" method actually produced a deficit!*** Obviously a

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Asphalt 101 – Why is my road gray?

- Co-product of refinery operations:
  - Crude source (naturally occurring material)
  - Distillation (refinery) practices, advances
  - Now additives…polymers, oils, acids,….
- Asphalt is "graded" based on the local climate **and** traffic conditions for a given project.
  - The asphalt we use to pave I-94 is the same climate grade (PG 58-28) as what is used to pave CTH B, **but** I94 requires a higher traffic grade, 'H' or 'V' instead of 'S'.

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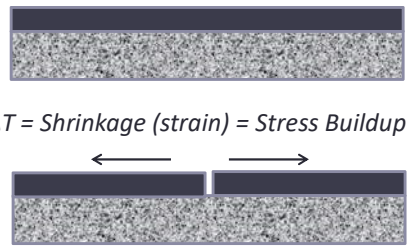
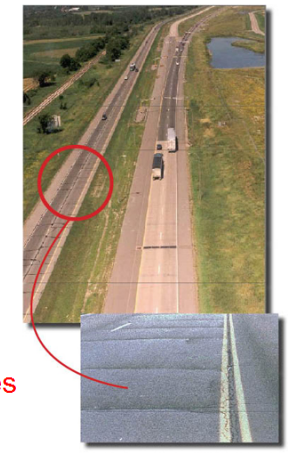
A quick applied engineering example:

Low temperature thermal cracking doesn't usually appear in asphalt pavements until several years after placement. Why is this true?



Ability to relax stresses decreases



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Superpave Performance Grading (PG), M332 Method

- Binder is assigned a "Performance Grade":

PG HT – LT T (PG 58-28 S, for example)

PG = Performance Grade

HT* = 7-day average maximum pavement temperature for which this binder is certified for use. (52, 58 typical in WI, MN), considering reliability

T = Traffic level designation (S, H, V, E)

LT* = single minimum pavement temperature for which this binder is certified for use. (-28 or -34 typical for WI, MN), considering reliability

**We also use LT, MT, and HT to describe ESALs for WisDOT mix designs, but for this slide we're talking temperature….*

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Guidance:

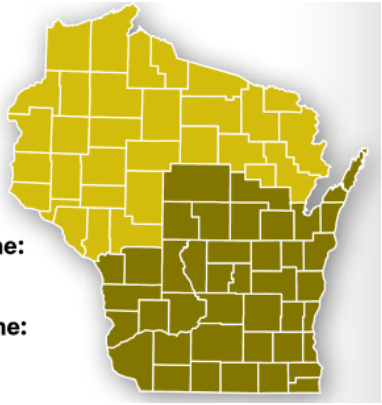
- Wisconsin Asphalt Paving Association (WAPA) worked with WisDOT to develop guidelines for selecting binder:

LOWER LAYERS:
58-28 S

OVERLAYS:
58-28 S, H, or V**

UPPER LAYERS:
Southern Asphalt Zone:
58-28 S, H, or V**

Northern Asphalt Zone:
58-34 S, H, or V**



Where might I see "H" designations?

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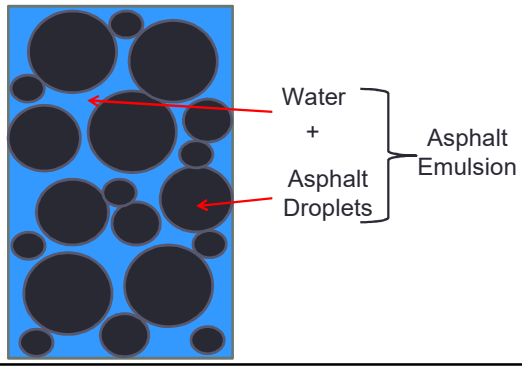
What are asphalt emulsions?

- Emulsion: insoluble dispersion of small droplets ['dispersed phase'] of one liquid in another liquid ['continuous phase'].
  - Common Examples: mayonnaise, cosmetic creams, some paints.

- In the most common case of asphalt emulsions:
  - Dispersed Phase: Asphalt (~55-70% B.W.)
  - Continuous Phase: 'Water' (~30-45% B.W.)
- Emulsions are *inherently* unstable…eventually the asphalt will separate from the water…



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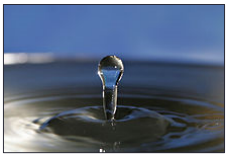
How are asphalt emulsions produced?

Liquid Asphalt

+

Polymer (sometimes)

+



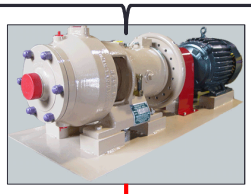
Water

+

Emulsifier

Fuel & other additives also common

'Soap Solution'



Colloid Mill

Provides mechanical energy to shear asphalt

Emulsion

A typical recipe may include:
32% Water
68% Asphalt
~2% polymer B.W. of asphalt
~0.5% emulsifier B.W. emulsion

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Life cycle of an asphalt emulsion…

1. Dispersion of asphalt droplets in a water + emulsifier medium. Emulsion is fluid and generally brown in color. Consistency: from watery to warm honey

2. Asphalt particles begin to flocculate and coalesce; water is removed from the system by evaporation, absorption, or by chemical reactions. Films turn **black** and are usually 'tacky'.

3. Asphalt particles coalesce completely and a uniform film is formed; water is almost completely removed from system. Films are **black** and may be tacky or semi-solid depending on application. **The resulting film is (nearly) the same as the asphalt that you started with to produce the emulsion.**

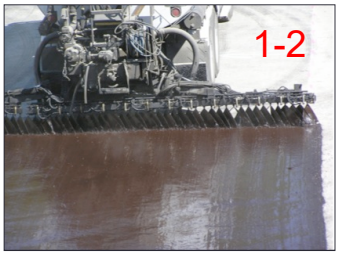

Image 2, 3: Pavement Interactive

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What are Asphalt Cutbacks

- Asphalt cement is solvent in petroleum fuel
  - Fuel is used to 'cut' the viscosity of the base asphalt
    - Still need to be heated, but less than pure asphalt
  - Provides more 'workability' at ambient temperature
  - Helps 'wet' dusty surfaces
- Fuel designed to "partially" evaporate over time, leaving behind base asphalt with a small amount of fuel.
- FYI: In Wisconsin, when the term "Hot Applied" is used in terms of Chip Sealing (Seal Coating), it is generally assumed to mean using an asphalt cutback.
  - MAC-5
  - MS-5

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Which asphalt material or treatment is "best" for my roads? (in no particular order)

1. Your experience
   - Not: "this is the way it has always been done"
   - But: "we've had good <u>success</u> with <u>this material</u> and <u>this aggregate source/design</u> in the past" then ask WHY?
2. Your specification & Climate (requirements)
   - Time to open? High traffic? Special demands?
3. Your contractor
   - Many specialize in certain types of application
   - …But don't be afraid to ask

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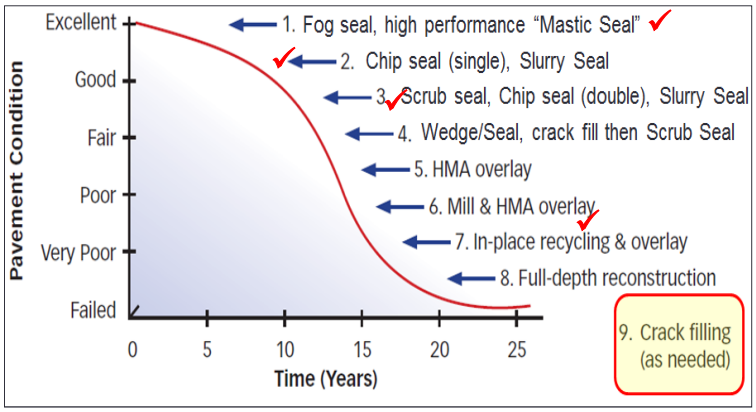
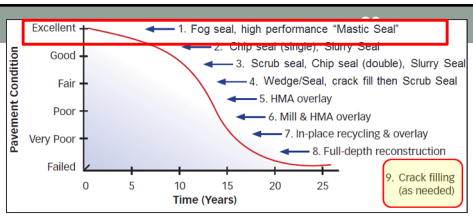
A few common treatments and examples over the lifespan of a new road…



"Mastic" Seals



- Problem: Oxidation and H20 intrusion starts from Day-1
- One Solution: High performance pavement sealers have entered the marketplace that produce a lasting, black surface and eliminate chips
  - These materials are tailored to the climate and type of project (road, parking lot, or rec. trail)

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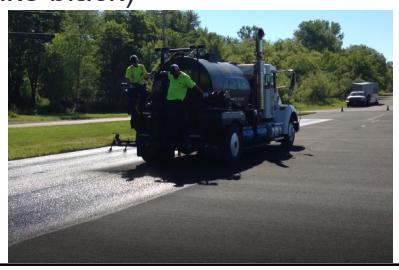
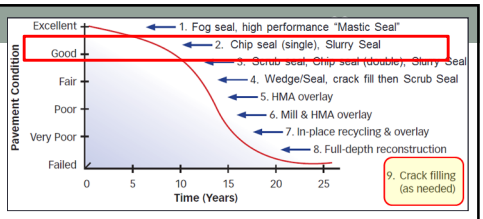
Mastic Seals

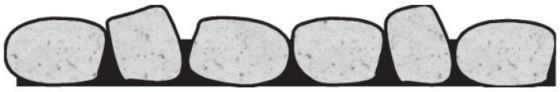
- These are central-plant produced and applied by a certified applicator.
- Process is quick and comparable to chip sealing in terms of service life
- Many municipalities don't like the mess of chip sealing (dust, loose chips, etc.) but understand the benefit of preservation (residents also like black)



"Chip Seals" (A.K.A. Seal Coat)



- Objective: A single-layer thickness of aggregate bound to existing roadway surface with asphalt binder:



- Contractor must select:
  - Appropriate Aggregate
  - Appropriate asphalt binder
  - Rates at which to lay each ingredient.

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Designing a chip seal

- What to look for: Functional distress only
  - thermal cracking, surface raveling, MINOR fatigue
- Engineers have control over 3 major aspects of the construction process:
  - Selection of aggregate
  - Selection of application rates
  - Selection of the emulsion
- We do not have control over one very important factor
  - WEATHER
    - We want warm, dry, low humidity
    - High humidity – longer cure times
    - Rain – dilutes and washes away emulsion
    - However – favorable weather will not make up for poor construction practice!

All of these factors must be considered for a successful project…

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What am I looking for?

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Common Asphalt Emulsions for Chip Seals in Wisconsin:

CRS – 2(P, L)

- Requires "clean" aggregate
  - Less than ~1% Dust
- Chemical break
  - Usually slightly to sig. faster cure than anionic

HFRS – 2(P, L)

- Can handle higher dust content
- Slower set and cure
- May remain 'softer' for longer periods

In both types polymer/latex will aid in chip retention and speed up set/time to open in areas:

- High/Heavy Traffic
- Heavy turning areas
- High reliability design areas

So, which emulsion is right for my town/county?

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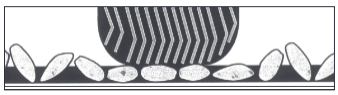
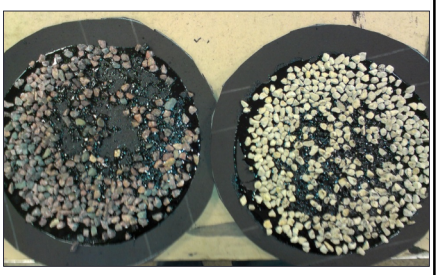
Aggregate considerations

- Gradation
  - Near single sized is best → Majority of aggregate is retained on one or two sieves
  - Low (< ~1%) dust content for cationic
- Size
  - Not really a limiting factor, since we can design application rates to account for size
- Shape
  - Cubical, fractured is best
  - Flat, Flaky will flatten → bleeding
  - Pea Stone will role over → tracking
- Abrasion Resistance
  - High resistance is best – friction surface
- COST
  - What's available in your region?
  - What are the project restraints?





Wrong choice of aggregate

A better choice

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Let's Look at a few examples from around the State:

- *Traditionally*: Most Wisconsin County 'chips' will be 100% passing the 3/8" sieve, and be primarily contained on the ¼" and No. 4 sieves (called an FA-2.5 in some areas)
- *More recently*: Trend toward moving smaller, e.g., 100% passing the ¼" sieve and up to 60% or so passing the No. 4 (called FA-2)
- BOTH will produce excellent results, IF size/shape/gradation is accounted for…
  - DO NOT assume that using the same methods will produce the same result if aggregates change.
- In both cases:
  - Look for "most" aggregate to be retained on 1-2 successive sieves.
  - Look for less than 1% dust for cationic, and less than ~2.5% for HF.
  - Look for highly fractured stone (avoid using 'Pea Stone'…it's cheap for a reason)
  - Look for cubical stone, not potato chips.

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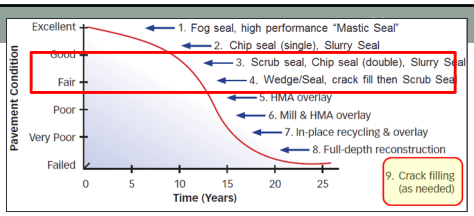
Signs something isn't right:

Normal wear and tear is expected,
- Excessive chip loss
- Bleeding/Flushing
- Running off

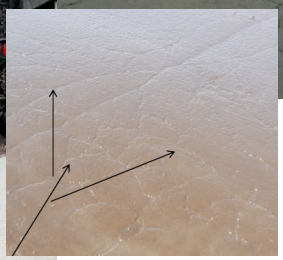
are not…

Things to pay attention to:
- Pavement temperature
- Precip. Forecast
- Shade
- Time to open

"Scrub Seals"

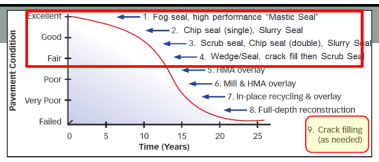


- Specialized process AND emulsion designed to address slightly more advanced crack patterns and aging.



Images: Asphalt Materials Inc.

Fog seals

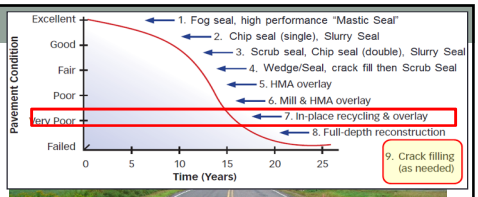


- Light coating of asphalt emulsion
  - Over existing surface – can 'rejuvenate', add residue
  - Over chip seal to aid in chip retention
- Traditionally, CRS-2(P) dilute or CSS-1H dilute have been used:
  - Application Rate Fog Seal: ~ 0.1 gal/sy (diluted) → 0.05 gal/sy (undiluted)
- "Newer" quick-fogs are entering the market

Skipping Ahead: Reclamation (FDR)

Good candidates….

- Extensive *structural* distress; could be accompanied by *functional* distress
  - Adequate base stability – soft spots need to be corrected
  - Subgrade quality
  - Sufficient base depth
  - Patching: OK, but adds variability in materials



Partial depth patching

Bottom-up fatigue cracking of thin AC layers (alligator cracking)

Wheel edge longitudinal fatigue cracking

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What are some advantages?

- Maintenance: side slope (mowing operations)
- Safety – edge effects: "growing the road"
- The complete existing cross-section does not need to be reclaimed if already overbuilt:
  - Mill 2-3 inches, save RAP
  - FDR on remaining layer
  - Overlay with mix incorporating RAP from millings
- Do we need a *structural* overlay in all instances?
  - Experience is no:

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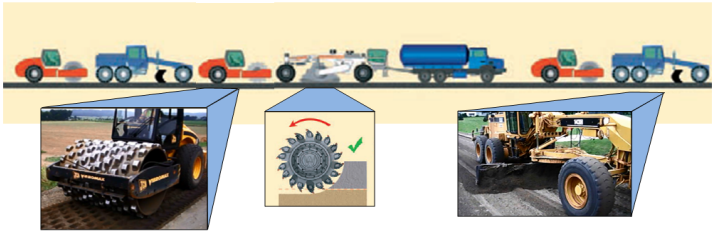
Field order of operations

- Material pre-pulverized to specified depth
  - Material is compacted using padfoot rollers until feet walk out
  - Moisture content monitored
  - Graded to rough shape
- Stabilization train injects material to predetermined depth < initial pulverization depth
  - Compacted using padfoot rollers
  - Graded to shape and drum rollers to finish



Graphic adapted from Wirtgen Cold Recycling Technology, 2012

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A quick primer on mix designs

- Great Resource: http://www.wispave.org/wp-content/uploads/dlm_uploads/d-Breakout-Volumentrics-Eggen-OMNNI.pdf
- Beginning with 2017 season, WisDOT has overhauled their asphalt mix design process:
  - "E" mixtures are reclassified:

Current "E" Mixes	ESAL Level (20 years)	New Classification	ESAL Level (in millions)
E-0.3	< 300,000	LT	Light Traffic < 2 M
E-1*	300,000 to < 1,000,000		
E-3	1,000,000 to < 3,000,000	MT	Medium Traffic 2 M – 8 M
E-10*	3,000,000 to < 10,000,000		
E-30	10,000,000 to < 30,000,000	HT	Heavy Traffic > 8 M
E-30X*	≥ 30,000,000		

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Mix Designs, Cont'd

- WisDOT has also recently adopted efforts to INCREASE the amount of virgin AC that is going into new mixtures:

460.2.1 General

Revise 460.2.1 to regress air voids from 4.0% design to 3.0% target. This change was implemented in ASP 6 effective with the December 2016 letting.

(1) Furnish a homogeneous mixture of coarse aggregate, fine aggregate, mineral filler if required, SMA stabilizer if required, recycled material if used, warm mix asphalt additive or process if used, and asphaltic material. Design mixtures conforming to table 460-1 and table 460-2 to 4.0% air voids to establish the aggregate structure.

(2) Determine the target JMF asphalt binder content for production from the mix design data corresponding to 3.0% air voids (97% Gmm) target at the design the number of gyrations (Ndes). Add liquid asphalt to achieve the required air voids at Ndes.

(3) For SMA, determine the target JMF asphalt binder content for production from the mix design data corresponding to 4.0% air voids (96% Gmm) target at Ndes.

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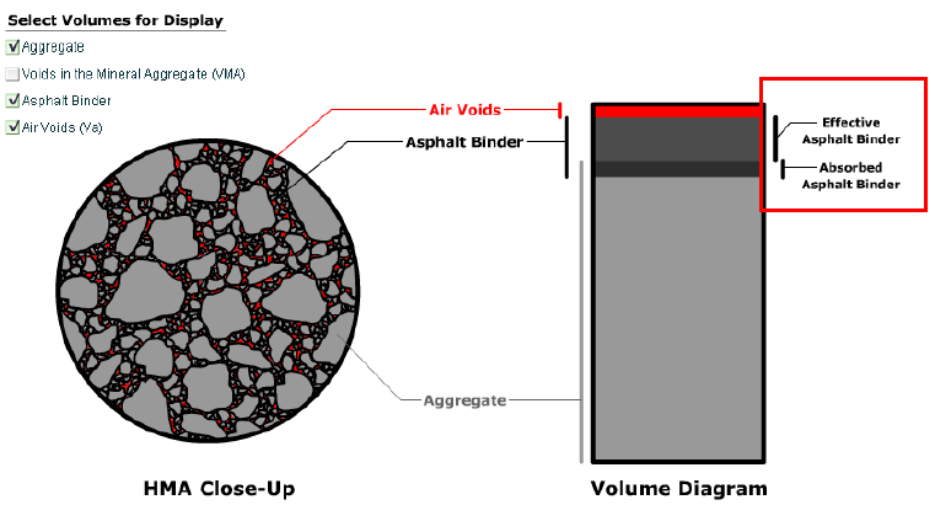

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Great, so which design do I use?

- LT, MT, or HT?
  - Choose **based on your design ESALS**
  - Extreme circumstances? Farm implements, slow traffic, etc.
    - May consider moving to MT
- Nominal Max Size (NMAS): 3 (19 mm / ¾”), 4 (12.5 mm / ½”), or 5 (9.5mm / 3/8”)
  - The smaller you go, the ‘tighter’ the surface, and the more AC you get, but also costs you more.
  - The smaller you go, the thinner the lift thickness you can compact efficiently (wedging):
    - For fine graded mixtures: **3 X NMAS < Lift Thickness < 6 X NMAS**
    - For example, for a ½” mix, the lift should be between 1.5” – 3”
- RAP/RAS – NOT a bad thing, but need to be accounted for.

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Wrap up:

- Every roadway network **and** each individual roadway is different: there is no one size fits all
  - Set up a database with real numbers and look at different options
  - There’s a saying about doing the same thing over and over and expecting different results…
- New processes (and old processes) are becoming more available.
- Ask questions.

Thank You

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