National Concrete Consortium

September 18, 2012
Seattle, Washington

Guidance for Characterization of Existing Asphalt Pavement Prior to Concrete Overlays

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Decision Matrix for Bonded Concrete Overlays (Draft)

	Level of Distress [1]		
Type of Distress in HMA	Low	Moderate	High
Rutting	OK < 0.25 Inches[2]	OK from 0.25 to 0.5 inches[2]	Possible > 0.5 inches[2]
Fatigue Cracking	OK	OK	Possible
Longitudinal Cracking	OK	OK	OK
Transverse Cracking	OK	OK	OK
Potholes	OK	OK	Possible
Shoving	OK	OK	Possible
Bleeding	OK	OK	OK
Raveling	OK	OK	OK
Stripping in Lower Layers	OK	Possible	Depends

1. As defined from the Long-Term Pavement Performance (LTPP) program's Distress Identification Manual
2. CDOT's criteria

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Distress Type	Highway Classification	Distress Level		
		Adequate	Marginal	Inadequate
Fatigue cracking (% of wheel path area)	Interstate/Freeway	<5	5 to 20	>20
	Primary	<10	10 to 45	>45
	Secondary	<10	10 to 45	>45
Longitudinal cracking in wheel path (ft/mi)	Interstate/Freeway	<265 (50.2 m/km)	265 to 1060 (50.2 to 200.8 m/km)	>1060 (200.8 m/km)
	Primary	<530 (100.4 m/km)	530 to 2650 (100.4 to 501.9 m/km)	>2650 (501.9 m/km)
	Secondary	<530 (100.4 m/km)	530 to 2650 (100.4 to 501.9 m/km)	>2650 (501.9 m/km)
Composite pavement reflection cracking crack width (in.)	Interstate/Freeway	<0.50 (12.7 mm)	0.25 to 0.50 (6.4 to 12.7 mm)	>0.50 (12.7 mm)
	Primary	<0.50 (12.7 mm)	0.50 to 0.75 (12.7 to 19.1 mm)	>0.75 (19.1 mm)
	Secondary	<0.50 (12.7 mm)	0.50 to 0.75 (12.7 to 19.1 mm)	>0.75 (19.1 mm)
Transverse crack spacing (ft)	Interstate/Freeway	>200 (61.0 m)	100 to 200 (30.5 to 61.0 m)	<100 (30.5 m)
	Primary	>120 (36.6 m)	60 to 120 (18.3 to 36.6 m)	<60 (18.3 m)
	Secondary	>120 (36.6 m)	60 to 120 (18.3 to 36.6 m)	<60 (18.3 m)
Mean depth of rutting in both wheel paths (in.)	Interstate/Freeway	<0.25 (6.4 mm)	0.25 to 0.40 (6.4 to 10.2 mm)	>0.40 (10.2 mm)
	Primary	<0.35 (8.9 mm)	0.35 to 0.60 (8.9 to 15.2 mm)	>0.60 (15.2 mm)
	Secondary	<0.40 (10.2 mm)	0.40 to 0.80 (10.2 to 20.3 mm)	>0.80 (20.3 mm)
Shoving (% of wheel path area)	Interstate/Freeway	None	1 to 10	>10
	Primary	<10	10 to 20	>20
	Secondary	<20	20 to 45	>45
Applicability of Bonded Concrete Overlays				
Applicability of Unbonded Concrete Overlays				

Asphalt Pavement Evaluation Before Placing Concrete Overlay


Photo courtesy of Anita Kan

1. Pavement History
2. Asphalt Distresses
3. Physical Properties of the Asphalt Pavement (thickness inputs)
4. Final Revaluation Report

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What are We Putting Overlays On?

- Age of Different Asphalt Layers
- Estimate Remaining Life (before and after)
- Performance History
- Performance Grades of Lifts (records)
- Pavement Management Records
- Type and Amount of Traffic Now and in the Future
- Elevations and Grade Restrictions

PG Asphalt Binder Spec

- Grading System Based on Climate (Temperatures in °C)

PG 58-34

Performance Grade

Average 7-day max pavement design temp

Min pavement design temp

Rule 90- Some states use binder modifiers such as polymers

High Temperature Pavement Concerns

- Rutting Concerns (mix+asphalt binder)
  - PG 70 – 28 stiffest (98% reliability)
  - PG 64 – 28
  - PG 58 – 28
- Permanent Deformation
  - Need a binder stiff enough to resist:
    - Rutting
      - High ESAL's
      - Slow moving traffic, creep speed
    - Shoving -- stopping movements at intersections

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Cold Temperature Pavement Concerns

- Thermal Concerns (binder properties)
  - PG 58 – 40 softest
  - PG 58 – 34
  - PG 58 – 28
- Thermal Cracking
  - Asphalt cannot relieve stress as fast as pavement contracts -- results in transverse cracks
  - Need a binder soft enough to resist:
    - Shrinkage cracks

Typical Pavement Management Data

- Highway or Street Section Data
- Distress count and Distress length
- Measurement of Roughness
- Measurement of Rutting
- Individual Distresses that were found (alligator cracking, transverse cracking, longitudinal cracking, etc.) and severity level

Understanding Asphalt Pavement

Elements in Design and Construction which can lead to Asphalt Distress

- Binder content
- Air Voids
- Aggregate

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Voids in Asphalt Mixes

- 6% in place voids in asphalt mixes is normal
- In-place voids should be between 3± to 8±%
- significant rutting can occur once voids are below 3%. Once rutting began, the integrity of the mix can be lost and the voids increase.
- Study of segregated mixes, showed that the asphalt mixes have low permeability as long as voids ≤ 8 %
- High initial voids may result in increased oxidation causing more cracking and raveling if not subject to significant traffic to provide further compaction

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Segregation

Segregation are construction related HMA pavement problems (binder, aggregate, air voids) that can lead to low asphalt content, low density, high air voids, rutting and fatigue failure

Mix design.

The key mix design parameters in segregation susceptibility are gradation and asphalt content (AASHTO, 1997). Specifically, open-graded mixes and low asphalt binder content mixes are particularly prone to segregation.

Aggregate Segregation:

In balance of coarse or fine aggregate

Coarse Aggregate Is considered the most prevalent and damaging type of segregation.

- Mishandling Stockpile
- Asphalt truck loading and unloading
- Asphalt paver- hopper operation, auger speed, and disruptions in paver movement.

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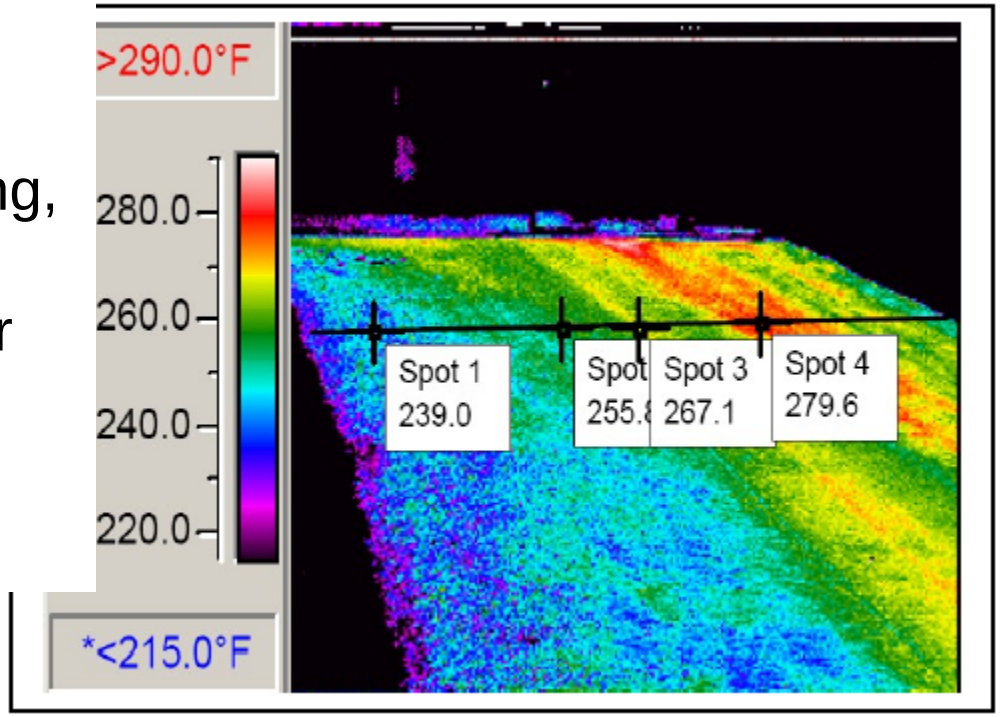
Temperature Differentials (segregation)

Large mat temperature differences resulting from placement of a significantly cooler portion of HMA mass into the mat. Cooler areas can results in inadequate compaction due to increased HMA viscosity – commonly taken as 175°F).

Results in isolated spots of decreased strength, reduced fatigue life, accelerated aging/decreased durability, rutting, raveling, and moisture damage. Temperature differentials greater than about 25°F can potentially cause compaction problems (Willoughby et al. 2001).



Characteristics Checks of Asphalt Pavement before Placing Concrete Overlay


Photo courtesy of Anita Kan

Asphalt Distresses

- Visual Examination
- Distress Identification / Causes
- Core and analysis
- Testing

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Asphalt Cracking

Summary of Possible Causes:

- Poorly constructed paving lane joint
- Shrinkage from hardening of asphalt and/or daily temperature cycling
- The first stage of fatigue cracking
- Concrete cracks reflecting through asphalt overlay

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Working Cracks

From Horizontal Movement of Pavement

- Decrease support in underlining subbase or subgrade
- Shrinkage of underlining subgrade due to dry or cold weather

Thermal Cracking

- Common form of deterioration on pavements in cold climates.
- Shrinkage of the asphalt due to low temperatures combined with asphalt binder hardening are main causes.
  - Asphalt binder in pavement is contracting more than the mix aggregates particles when temperature drops.
  - Causes the asphalt film to get thinner around aggregates..

Medium Severity

High Severity

Top Down Cracking

Traditionally, pavement cracking is thought to initiate at the bottom of the HMA layer where the tensile bending stresses are the greatest (a bottom-up crack).

Second mode of crack: Top down cracking

- A low stiffness upper layer caused by high surface temperatures.
- High surface horizontal tensile stresses due to truck tires (wide-based tires and high inflation pressures are cited as causing the highest tensile stresses).
- Age hardening of the asphalt binder resulting in high thermal stresses in the HMA (most likely a cause of the observed transverse cracks).

Alligator Cracking

A series of interconnected cracks caused by fatigue failure of HMA surface under repeated traffic loading.

Summary of Possible Causes:

- Excessive Loading
- Weak or thin surface, base or subbase
- Poor drainage
- Dried out asphalt binder from oxidation

Low to Medium Severity

High Severity

Raveling

- Wearing away of pavement surface caused by dislodging of aggregate particles.
- Can be hardening of the asphalt binder, poor quality mix or poor compaction.
- Progressive disintegration from raveling occurs from surface downward as a result of dislodgement of aggregate particles.

Low to Medium Severity

High Severity

Raveling

Summary of Possible Causes: Loss of bond between aggregate particles and the asphalt binder as a result of:

- Dust coating on aggregate particles forces asphalt binder to bond with dust rather than aggregate
- Aggregate Segregation: Fine particles missing from aggregate matrix, asphalt binder only able to bind remaining coarse particles at their relatively few contact points.
- Inadequate compaction during construction: High density required to develop sufficient cohesion within HMA.
- Mechanical dislodging by certain types of traffic (studded tires, snowplow blades or tracked vehicles).

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Stripping

The loss of bond between aggregates and asphalt binder that typically begins at the bottom of the HMA layer and results in loss of structural support

Summary of Possible Causes:

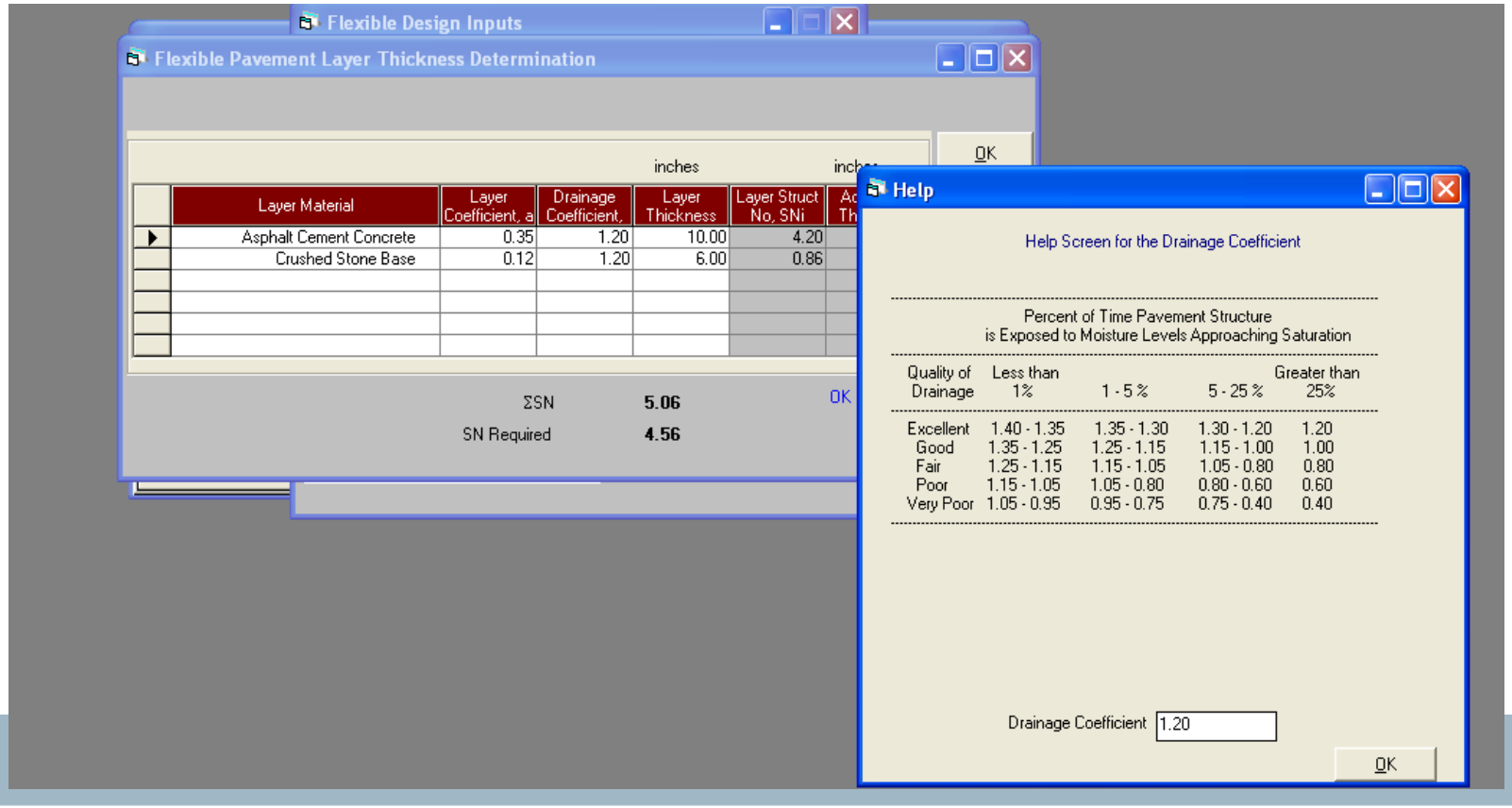
- Water in the HMA causing asphalt binder stripping along the aggregate face
- Bottom-up stripping is difficult to recognize because it manifests itself on the pavement surface as other forms of distress including rutting, shoving/corrugations, raveling, or cracking.
- Asphalt overlays over existing open-graded surface course can result in stripping.

Asphalt Stripping Leading to Fatigue Failure

Bottom Half Completely Stripped

Stripping- Drainage Coefficient

- The presence of moisture in an asphalt pavement is a concern for stripping when there are frequent heavy loads applied..
- Sum programs for thickness design use a drainage Coefficient (Cd) . This impacts the structural number (SN) of a flexible pavement based on the conditions surrounding the pavement. A high coefficient means better the drainage and thus a higher structural value is given to the asphalt layer.
- The screen shot below shows the drainage coefficient factor in the WINPAS program.



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Rutting

There are two different types of road ruts, which Colorado refers to as “Plastic flow” and “Wear”.

- Plastic flow ruts are formed by heavy trucks during the warm summer months,
- Wear ruts are usually formed by tire studs or snow chains actually grind away the road surface

Plastic Flow Rut

Studded Tire Ruts

Rutting

- Improper mix design or manufacture (e.g., excessively high asphalt content, excessive mineral filler, insufficient amount of angular aggregate particles)
- Insufficient compaction of HMA layers during construction. If it is not compacted enough initially, HMA pavement may continue to densify under traffic loads.
- Wheel line stripping of asphalt.

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Laboratory Wheel Tracking Devices

- Laboratory wheel-tracking devices can be used to make rutting, fatigue, moisture susceptibility and stripping predictions.
- Different types of wheel-tracking devices;
  - Asphalt Pavement Analyzer (APA)
  - Hamburg Wheel Tracking Device

Asphalt Pavement Analyzer (APA)

Comparison of a rut-resistant HMA (left) and a rut-susceptible HMA (right) after 8,000 load cycles in the APA

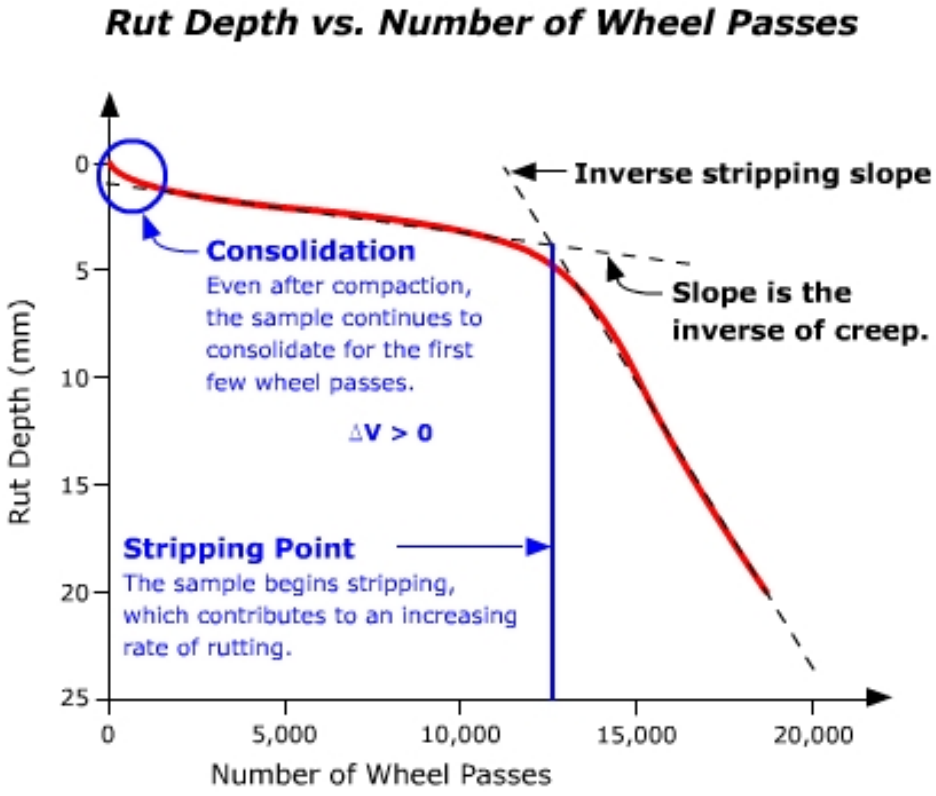
Hamburg Wheel Tracking Device

- **Post-compaction consolidation.** The rut depth at 1,000 load cycles is assumed due to continued consolidation.
- **Creep slope**. The inverse of the rutting slope after post-compaction consolidation but before the stripping inflection point.
  - Creep slope is used to evaluate rutting potential instead of rut depth
  - Because the number of load cycles at which moisture damage begins to affect rut depth varies between HMA mixtures and cannot be conclusively determined from the plot.

Hamburg Wheel Tracking Device (HWTD) from (Stuart and Youtcheff, 2001)

Hamburg Wheel Tracking Device

- **Stripping inflection point.**
  - The point at which the creep slope and stripping slope intercept.
  - Used to evaluate moisture damage potential.
  - If the stripping inflection point occurs at a low number of load cycles (e.g., less than 10,000), the HMA mixture may be susceptible to moisture damage.
- **Stripping slope.**
  - A measure of the accumulation of moisture damage.



Moisture Induced Stress Tester (The M.i.S.T. ™)- (Stripping)

- The M.i.S.T. is designed to simulate the stripping mechanisms that occur in HMA pavement layers.
- The M.i.S.T. consists of a pressurized chamber that pushes and pulls water through a compacted asphalt sample, simulating the action of an automobile tire on the road.
- The tests can be performed at different pressures and temperatures to replicate different traffic and environmental conditions.

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Shoving & Slippage

A form of plastic movement typified by ripples (corrugation) or an abrupt wave (shoving) across pavement surface. Distortion is perpendicular to traffic direction.

Summary of Possible Causes:

- Braking or accelerating vehicles, and usually associated with vertical displacement particularly in track lanes.
- An unstable (i.e., low stiffness) asphalt layer caused by mix contamination, poor mix design, or lack of aeration of liquid emulsion.

Low to Medium Severity

High Severity

Depressions

Summary of Possible Causes:

Frost heave or subgrade settlement resulting from inadequate compaction and /or poor drainage of the subgrade.

Asphalt Lifts and Condition

Bond Shear Tests

'igure 1: Carleton In-Situ Shear Strength Test (CISSST)

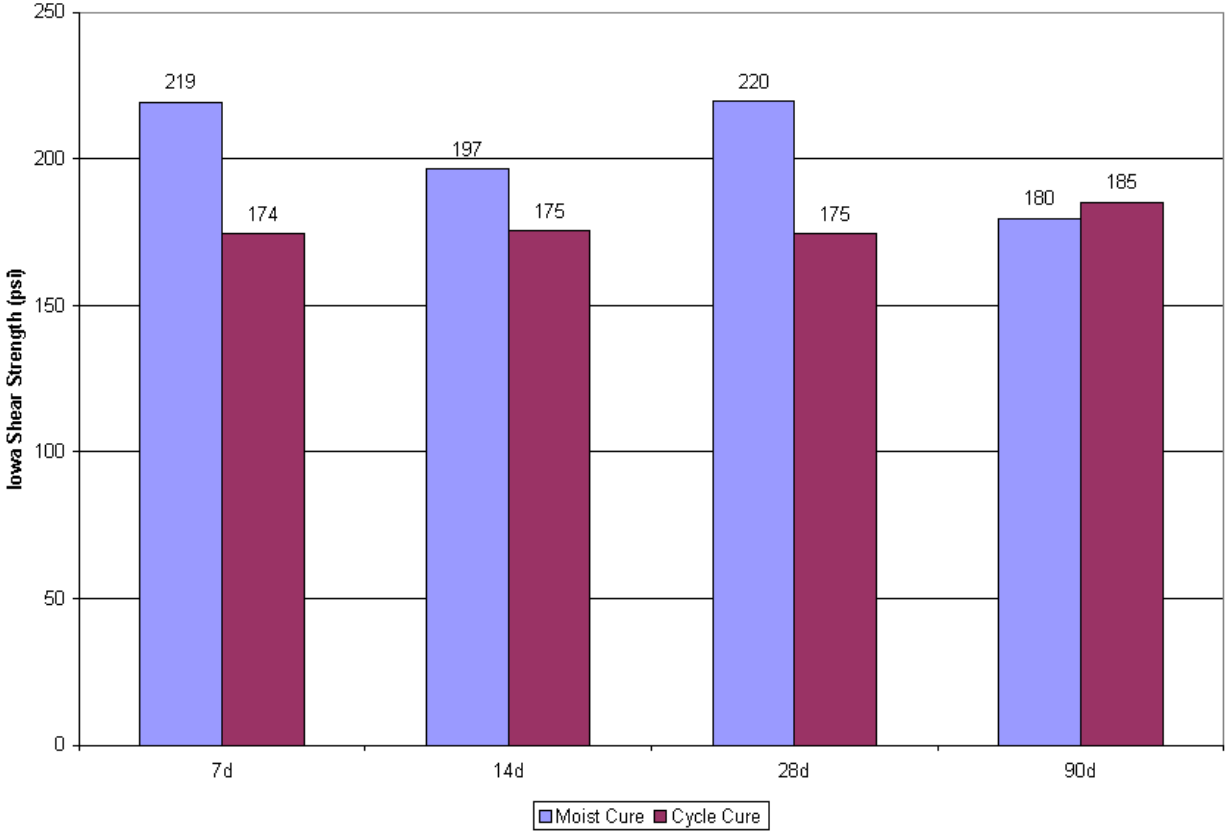
Carleton Shear test is a modified torsion test

The Superpave Shear Tester (SST) is a closed-loop feedback, hydraulic system that can apply axial loads, shear loads, and confinement pressures to asphalt concrete specimens at controlled temperatures

The dynamic shear rheometer (DSR) is used to characterize the viscous and elastic behavior of asphalt binders at medium to high temperatures.

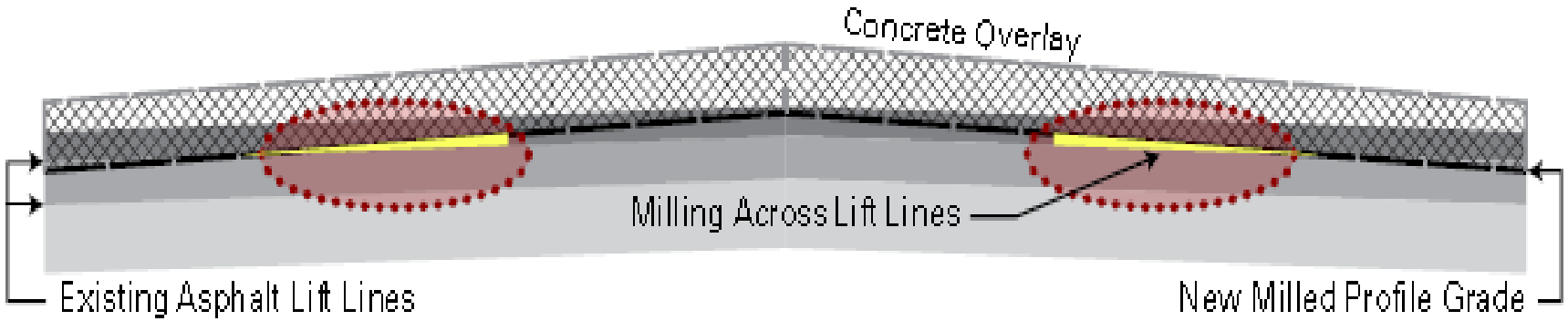
Iowa Shear Tests

Iowa Shear Test



2008 Purdue Study- Evaluation of Performance and design (Bonded Concrete Overlays over Asphalt)

Crossing Lift Lines



- Know Lift Lines (thru coring)
- Avoid profile milling that crosses lift lines
- Attempt not to mill within one inch form the lift line

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Mill Surfaced Resulting In Thin Asphalt Lift Issues

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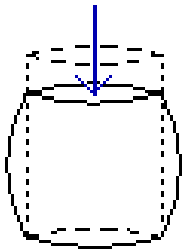
Asphalt Stiffness

- An important value needed in concrete overlay thickness
  - Modules of Elasticity of asphalt
  - Temperature of asphalt

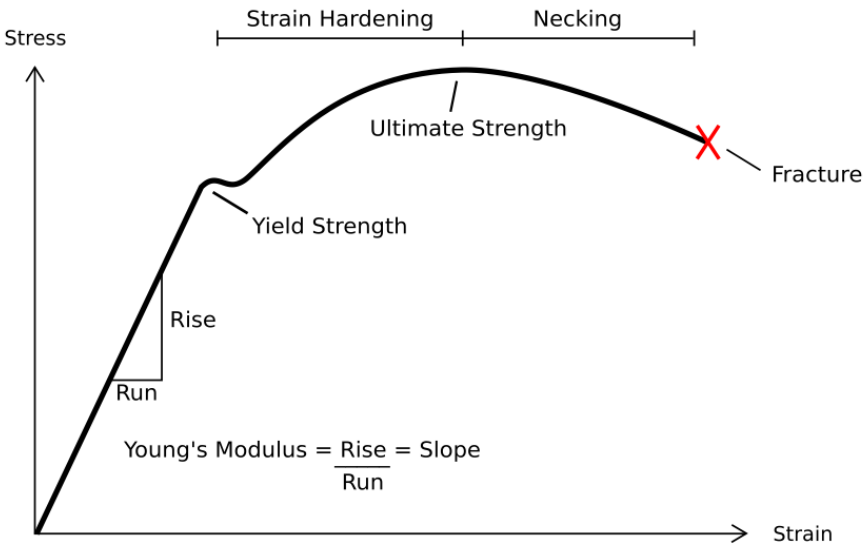
Elastic (Young's) Modulus

- **Modulus of Elasticity**, is the mathematical description of an object or substance's tendency to be deformed elastically (i.e., non-permanently) when a force is applied to it. The elastic modulus of an object is defined as the slope of its stress–strain curve in the elastic deformation region: As such, a stiffer material will have a higher elastic modulus.

$$\lambda \stackrel{\text{def}}{=} \frac{\text{stress}}{\text{strain}}$$



Compressive stress results in deformation which shortens the object but also expands it outward.



Typical stress vs. strain diagram with the various stages of deformation

Estimates for Dynamic Modulus of Elasticity of Asphalt (E)

1. General values – rough estimates based on previous projects.
2. From Estimate - AASHTO Ware Pavement Design (MEDDG) - Using Matt Witczak equations
3. From Falling Weight Deflectometer (FWD) using Back-Calculation methods.

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Rough Estimate
Elastic Modules of HMA Layer

Condition	E_{AC} (psi)	Comment
Poor	100,000	Severely fatigue crack
Moderate	350,000	Some level of distress
Good	600,000	Surface distress but can be milled

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Establish E_{HMA} effective

1. Estimate E_{HMA} of new mix
   - Mixture design established based on geographical location & LTPP Bind (software)
   - E_{HMA} established using mixture design

2. Adjust E_{HMA} of new mix
   - Aging of binder
   - Fatigue caused by traffic prior to overlay

HMA condition	Fatigue cracking (%)	Damage factor	E_{HMA} reduction (%)
Adequate	0 – 5%	0.4	10
Marginal	5 – 15%	0.6	20

3. E_{HMA} effective is established to account for hourly changes in HMA temperature once overlaid based on equivalent damage

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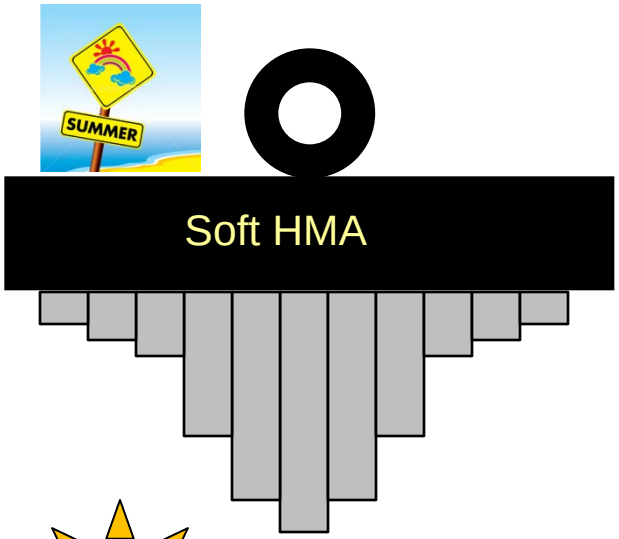
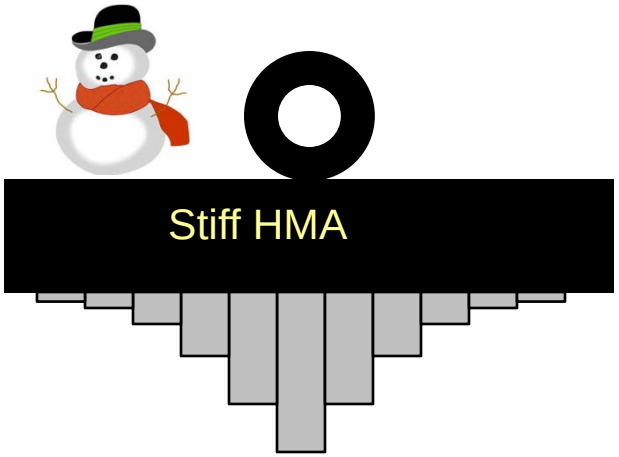
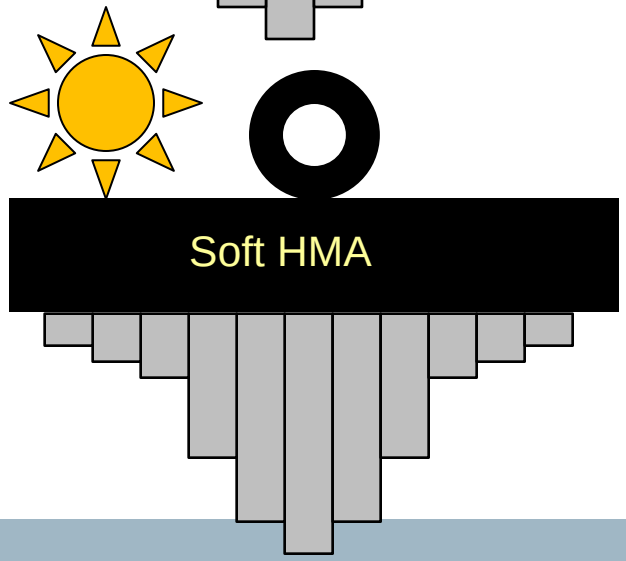
Temperature Dependence of E_{HMA}

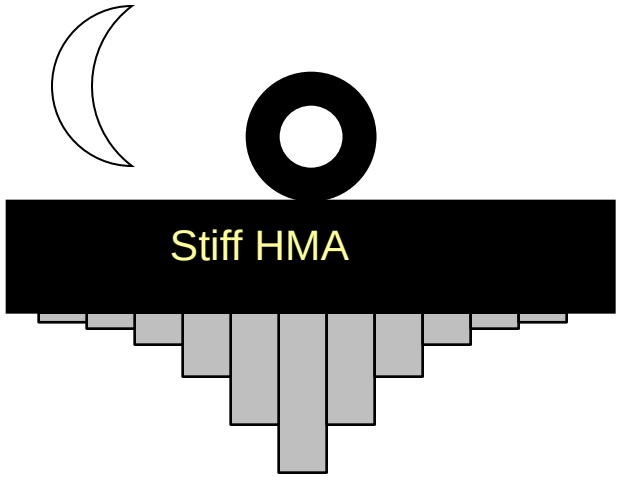
Seasonal variation





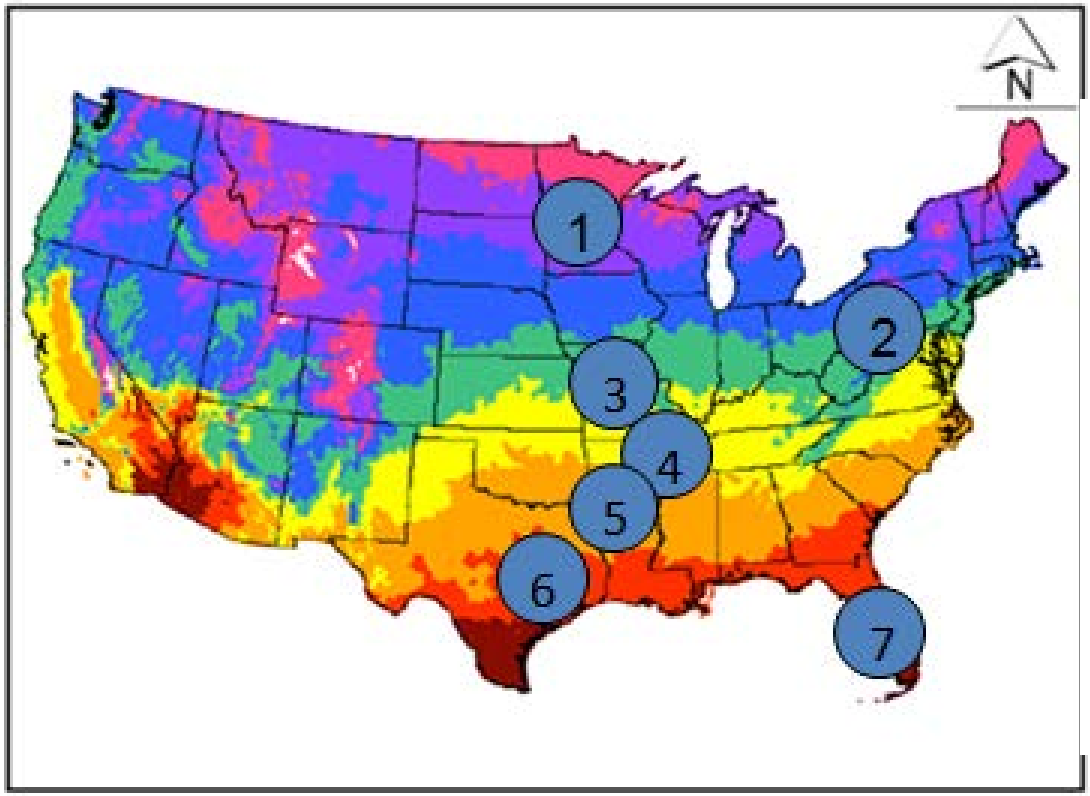
Daily variation





Seven Zones Based on AMDAT

AMDAT = Annual mean daily average temp.



Region ID	Color code	AMDAT (°F)
1		32.0-45.0
2		45.1-50.0
3		50.1-55.0
4		55.1-60.0
5		60.1-65.0
6		65.1-70.0
7		>70.0

(http://cdo.ncdc.noaa.gov/climaps/temp0313.pdf, accessed on January, 2010).

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Asphalt Modulus of Elasticity Laboratory Measurement

Confined Dynamic Modulus Test

Falling Weight Deflectometer

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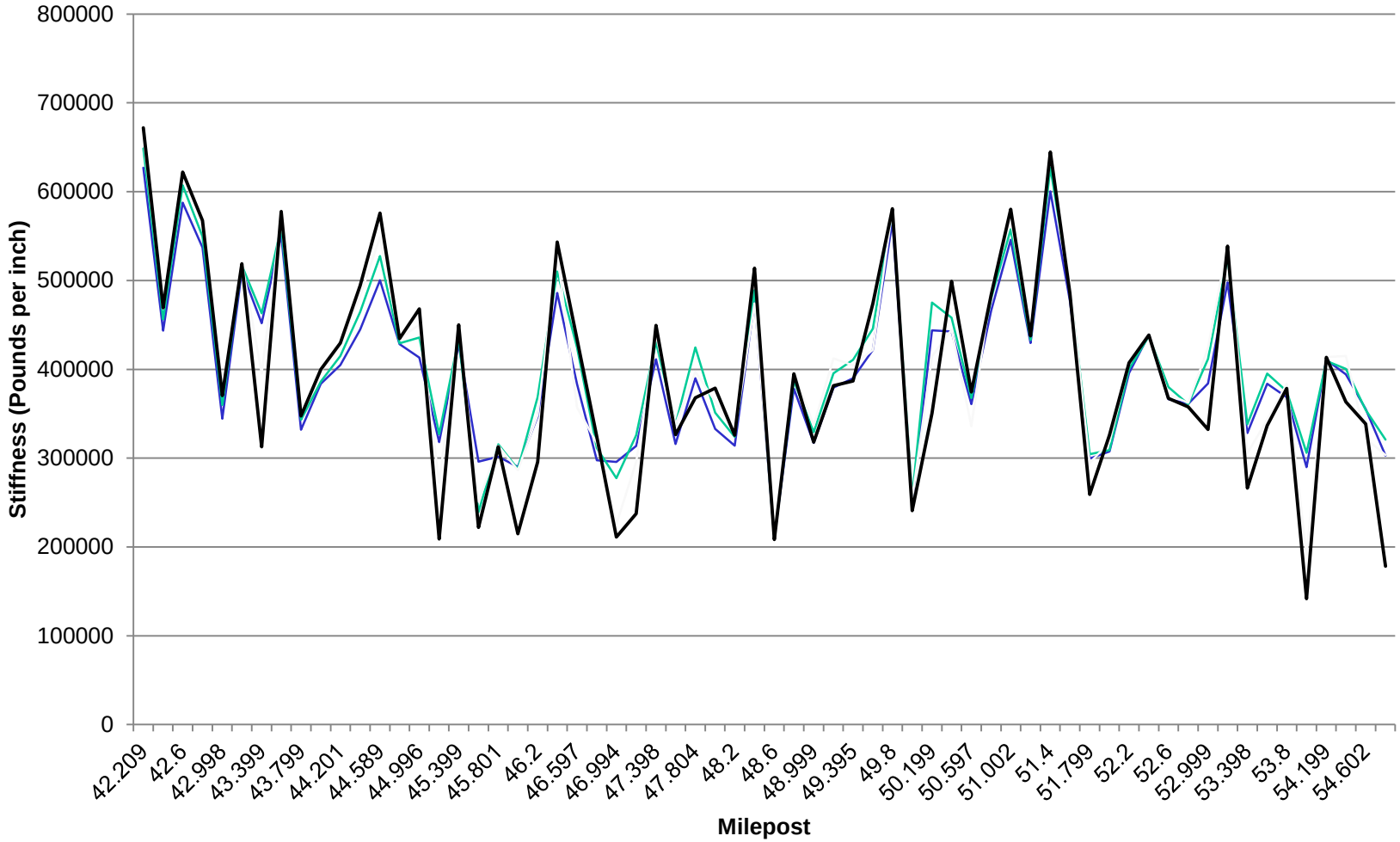
Colorado SH 149

Soil A 2-4 to A 2-7



Reliability 80 % with Dynamic Modulus of Elasticity mean 294,308. psi

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Determination of Modulus of Subgrade Reaction (K value)

1. From Estimate - Numerous Estimates available
   - For soil based on type and thickness
   - For granular material based on gradation and thickness
   - From CBR (Dynamic Cone Penetrometer)
   - For asphalt (for unbonded overlays as composite with other base materials). Mostly from software programs such as ACPA's subgrade K-value calculator
2. From Falling Weight Deflectometer (FWD) using Back-calculation methods.
   - Some programs require dynamic K value

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Modulus of Subgrade (K)

Bonded Overlay

- The modulus of subgrade reaction, k, incorporates any type of material below the HMA pavement and is considered a composite value (subgrade/subbase).
- The k value has been found to have negligible effects (from 50 pci to 200 pci; default input value 100 pci) on UTW design.

Unbonded Overlay

- Modulus of subgrade reaction. K incorporates the HMA pavement, subbase, subgrade and is composite value.

Lessons Learned

Minimize the temperature differential between the existing pavement surface and the concrete overlay during placement and curing. This is especially critical during cool-weather-paving

- The day/night temperature differential will cause movement in the existing pavement; it will expand during the day and contract at night.
- To prevent cracking in the overlay, the overlay must reach saw strength before the underlying pavement's nighttime contraction.
- Specifying a minimum overlay mix temperature of 65°F has proven to be helpful in mitigating this set-time issue.
- The concrete can set from the bottom up, delaying the sawing window. Temporarily covering the overlay with plastic after paving helps the concrete to set

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Questions?

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THANK YOU!

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