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NEBRASKA
Good Life. Great Journey.
DEPARTMENT OF TRANSPORTATION

2024 Nebraska Asphalt Paving Workshop

Best Practices of Inspection and Construction for Asphalt Paving, Compaction, and Plant Operations

Learning Objectives

- Discuss where asphalt binder comes from and how is produced
- Explain different asphalt binder grading systems and the reasons for grading
- Recognize asphalt binder testing equipment and procedures

What is Asphalt (Bitumen, Asphalt Cement)?

"A dark brown to black cement-like residuum obtained from the distillation of suitable crude oils, naturally occurring sources, or combinations thereof."

ASTM D8

Asphalt binder is defined as an asphalt that may or may not contain an asphalt modifier.

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Natural (Native) Asphalts

- Asphalts occurring in nature
- La Brea Tar Pits
- Trinidad Lake Asphalt

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Refined Asphalts

Distilled from Petroleum

- Atmospheric
- Vacuum
- Steam

Can involve

- Air oxidation
- Solvent stripping
- Blending of residua of different stiffness characteristics

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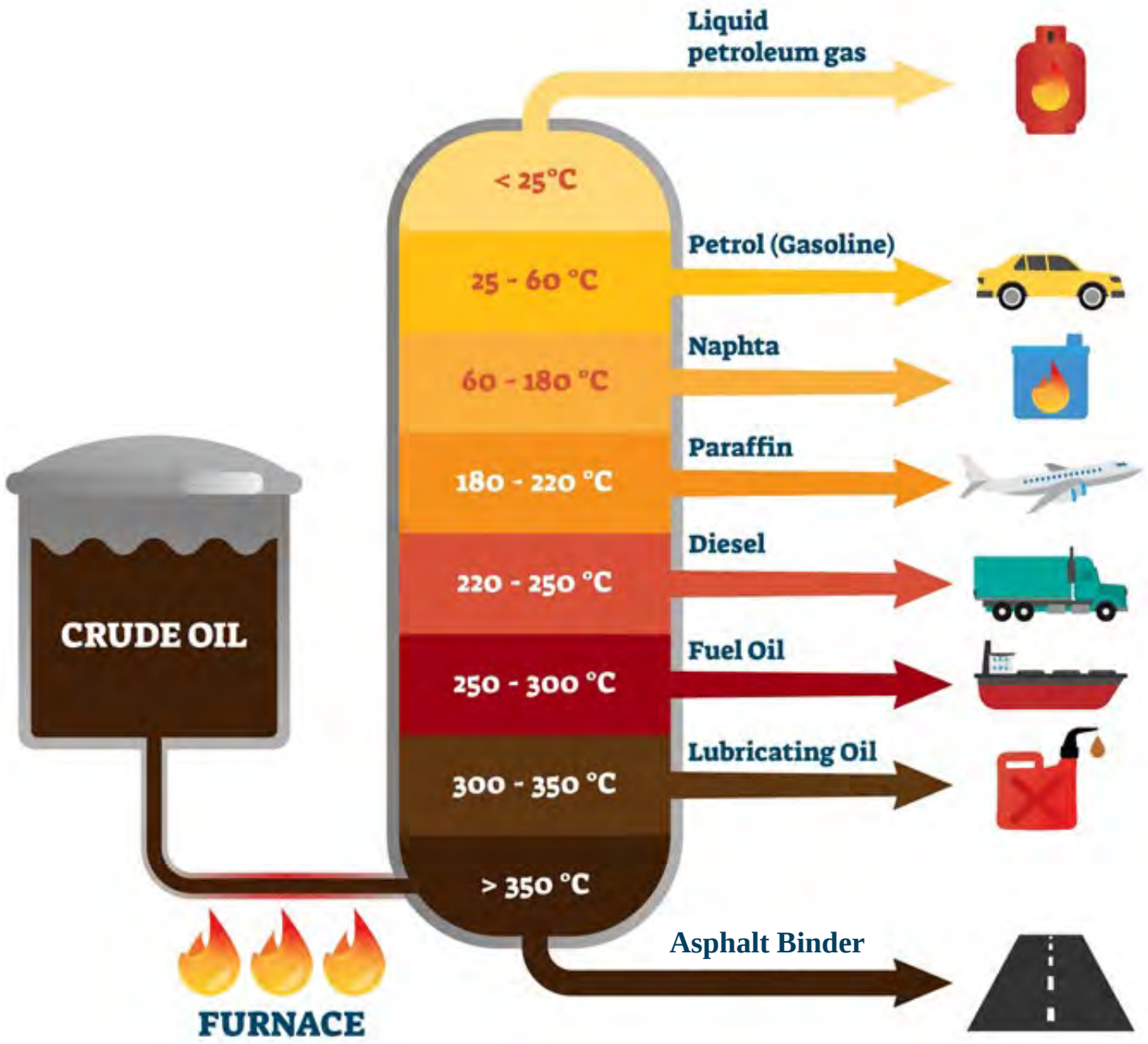
Crude Oil Distillation Process



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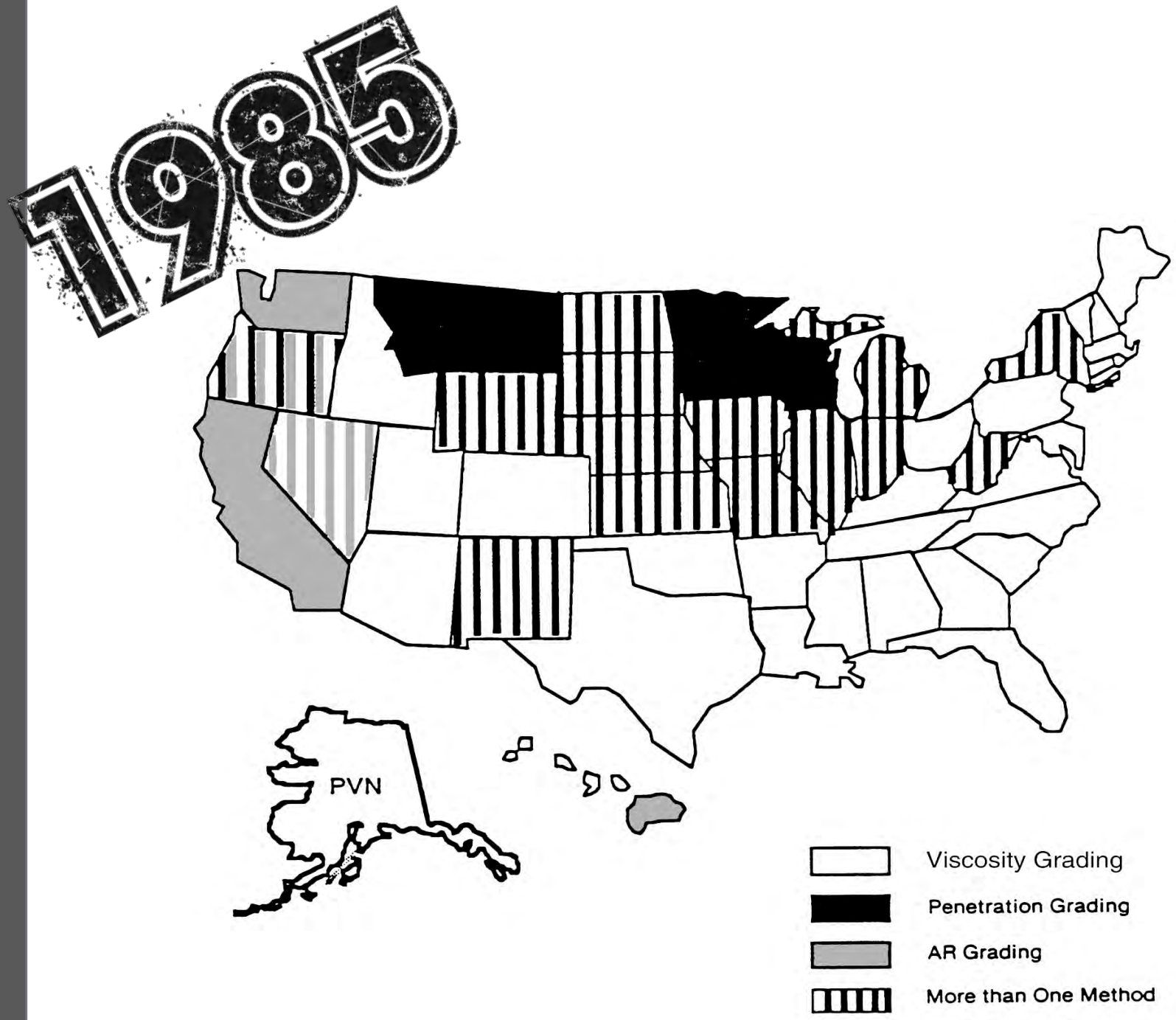
Why Grade Asphalt Binders?



Performance Graded Binder Specification

- AASHTO R29 – *Grading or Verifying the Performance Grade (PG) of an Asphalt Binder*
- AASHTO M320 (ASTM D6373) – *Performance-Graded Asphalt Binder*
- AASHTO M332 (ASTM D8239*) - - Performance Graded Asphalt Binder Using Multiple Stress Creep and Recovery (MSCR, J_{nr})*

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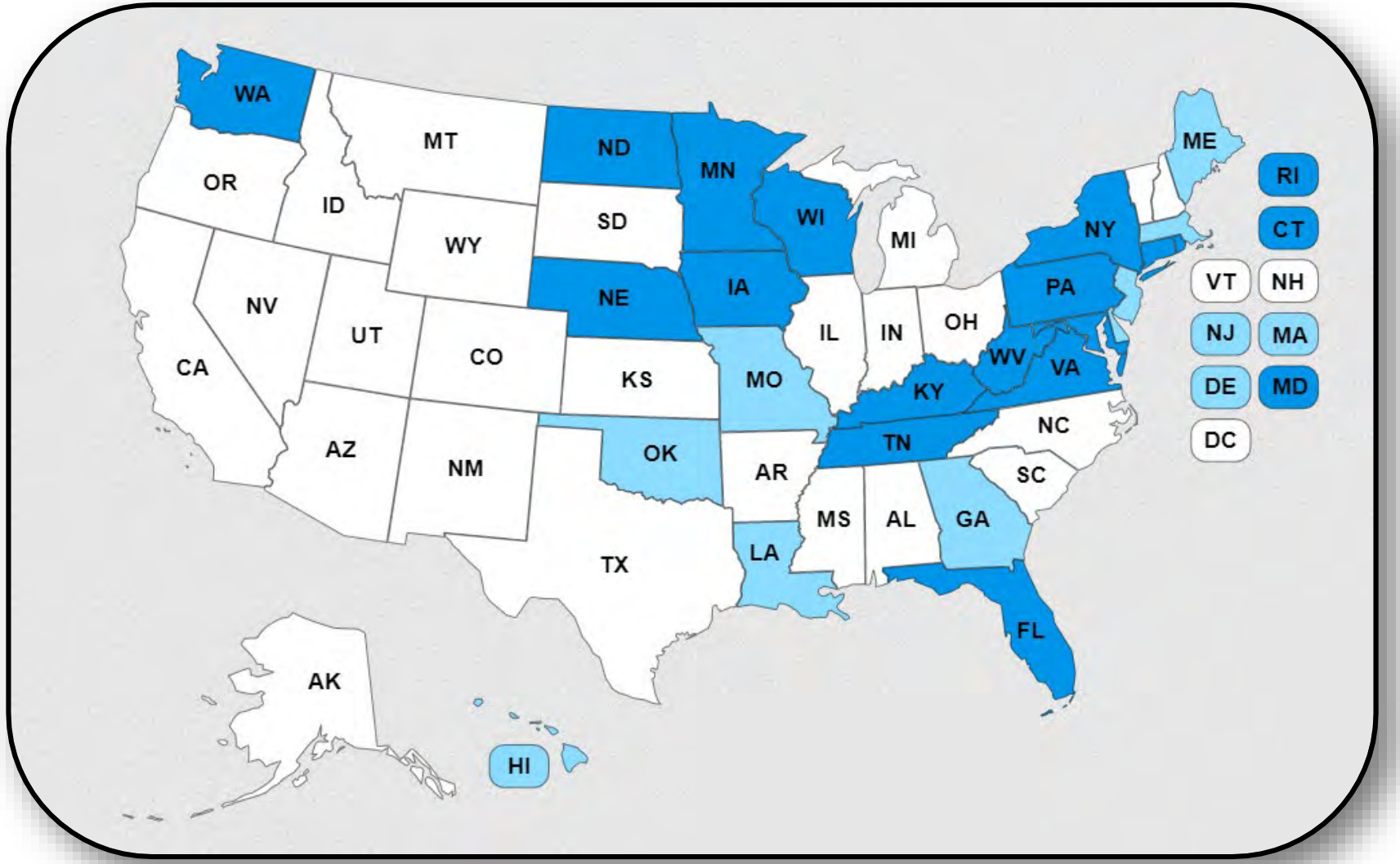
Current Trends



- M230 Specifications (PG)
- M320/M332 Specification (Mix)
- M332 Specification (MSCR)

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PG Binder Groundwork

WHEN	WHAT	HOW	WHERE
Construction			
Early (RTFO)			
Late (PAV)			

PG Specifications

- Based on Rheology
  - Study of flow and deformation
  - Describes the relationship between force, deformation, temperature, and time

- Asphalt binder is a linear, viscoelastic material
  - Temperature
  - Time of loading
  - Aging (properties change with time)

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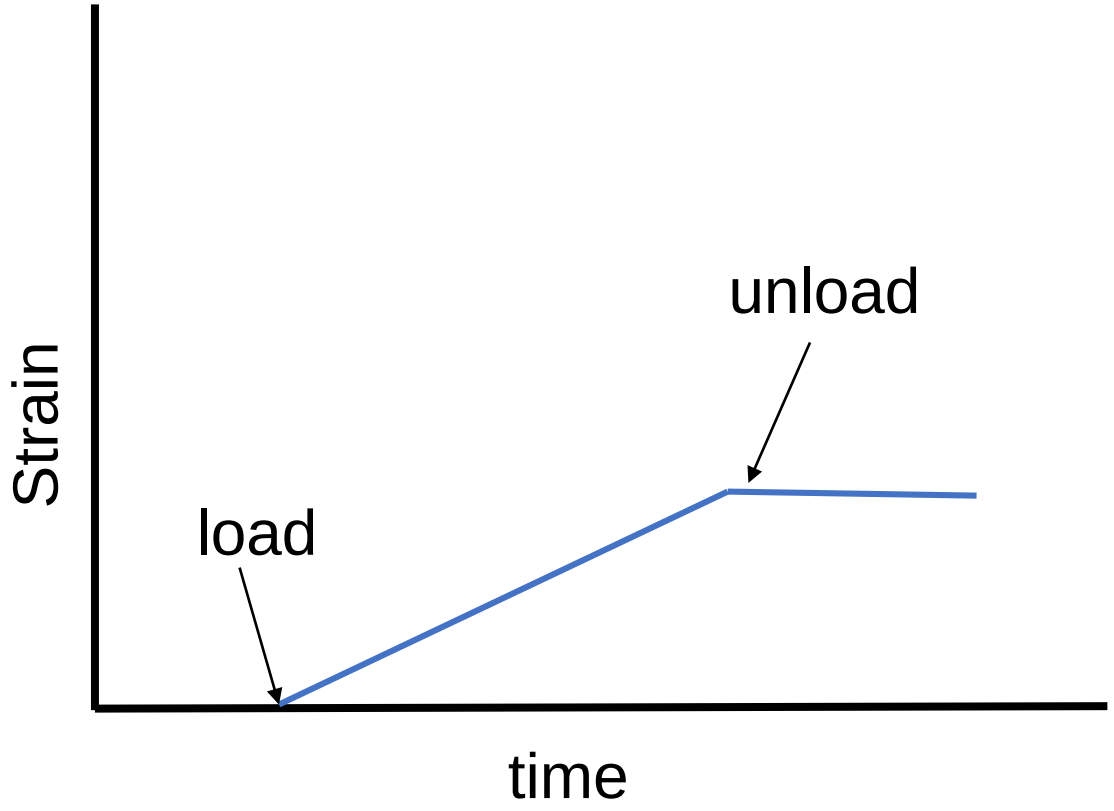
What happens when a load is applied?

- Viscous material:
  - Deformation starts immediately and continues until load is removed.
  - When load is removed, none of the deformation is recovered.



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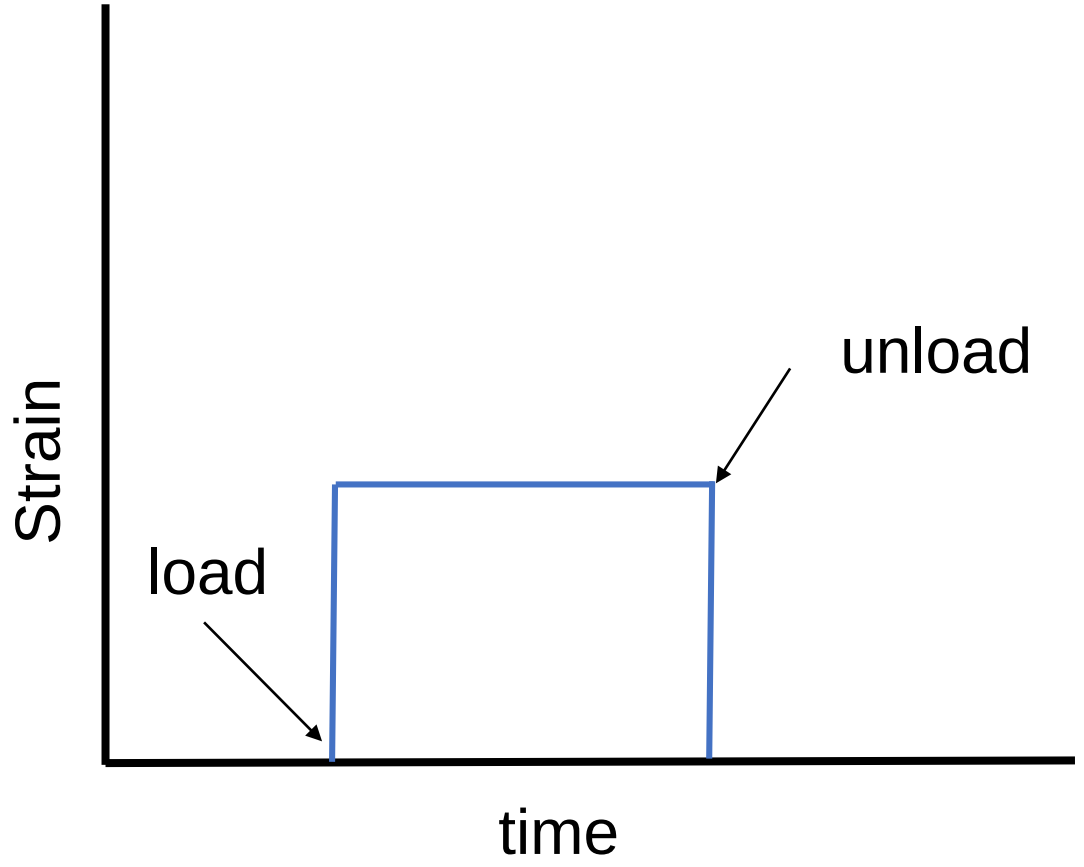
What happens when a load is applied?

- Elastic material:
  - Deformation occurs immediately and is recovered immediately when the load is removed.



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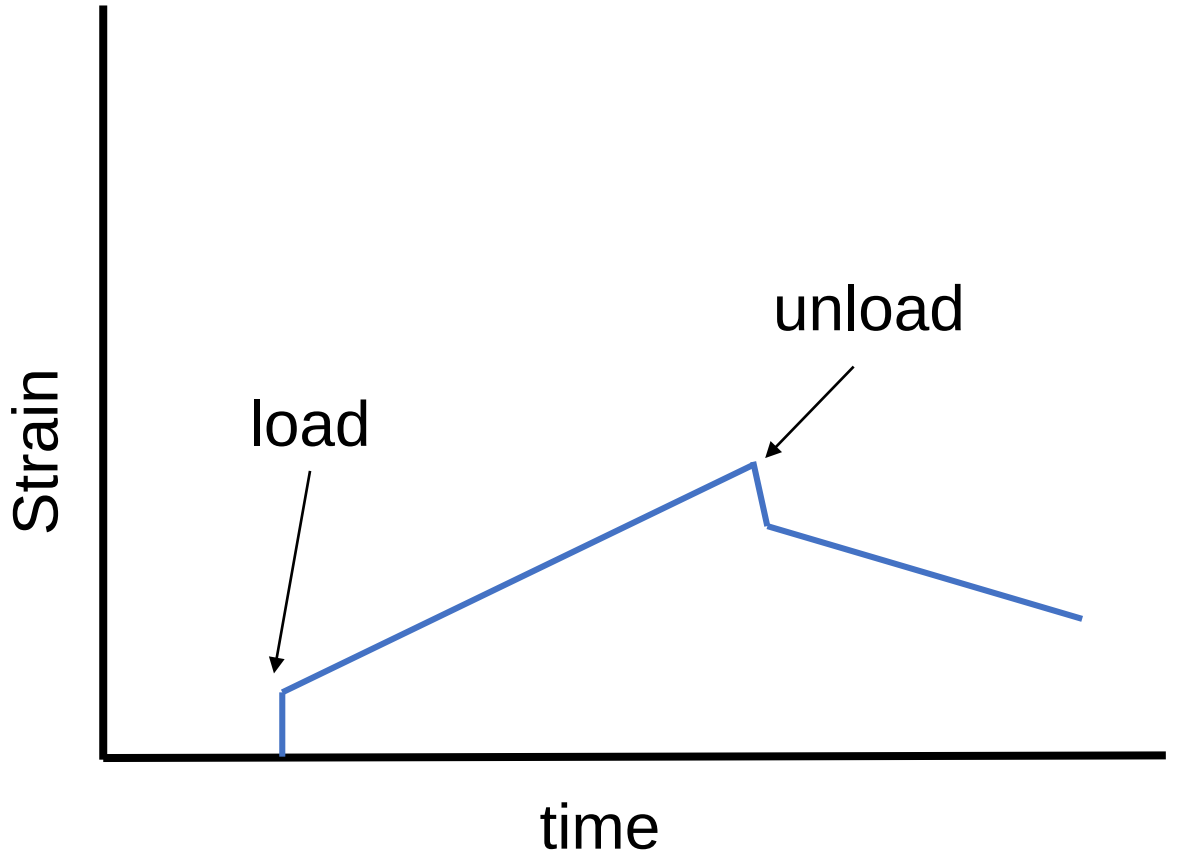
What happens when a load is applied?

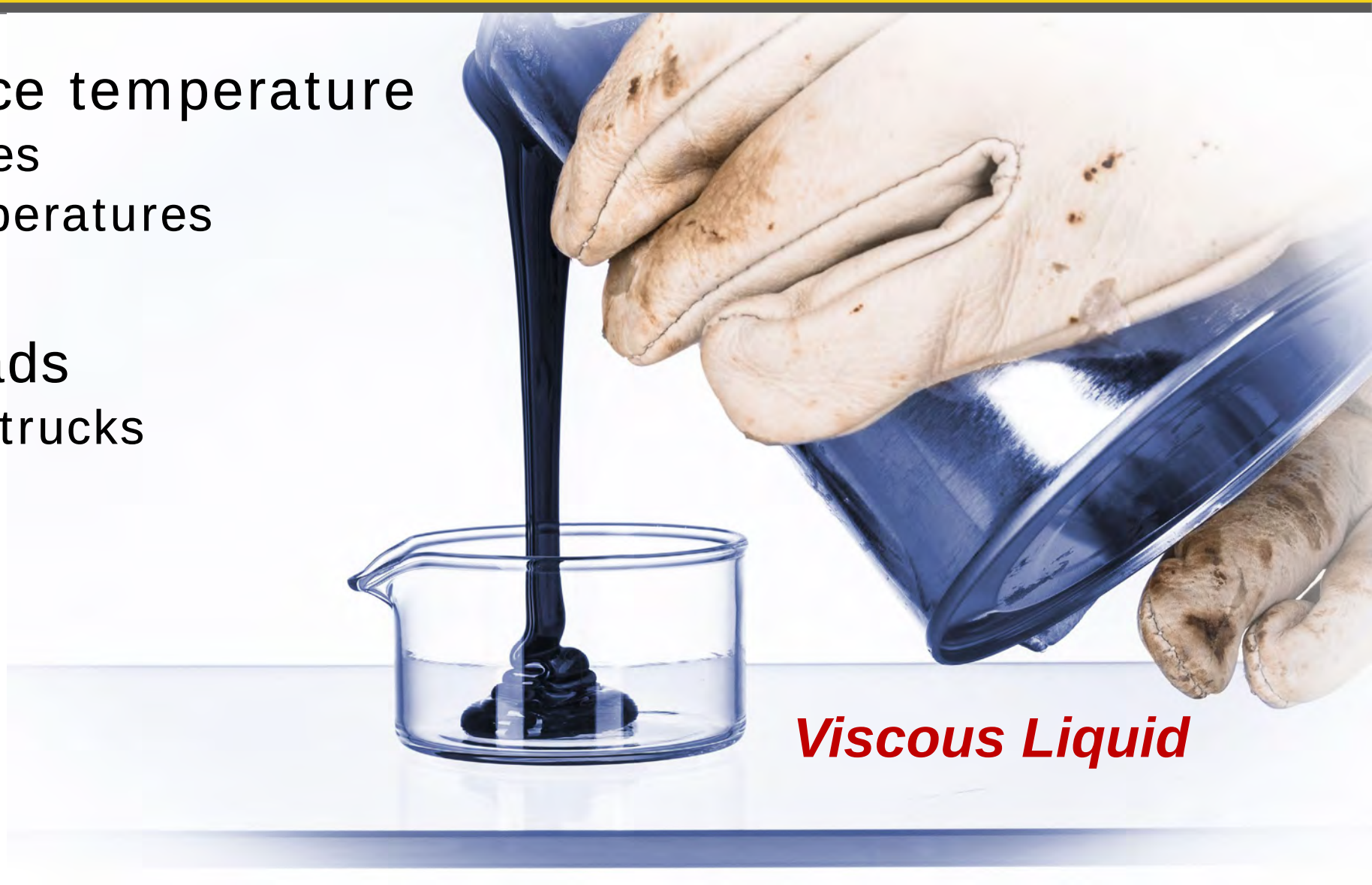
- Viscoelastic material:
  - Strain starts immediately and continues until load is removed. Partial recovery occurs.



Viscous Liquid

- High in-service temperature
  - Desert climates
  - Summer temperatures

- Sustained loads
  - Slow-moving trucks
  - Intersections



Pavement Behavior (Viscous Conditions)

- Permanent deformation (rutting)
- Mixture is plastic
- Depends on asphalt source, additives, and aggregate properties

Permanent Deformation

Elastic Solid

- Low temperature
  - Cold climates
  - Winter
- Rapid loads
  - Fast-moving trucks

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Pavement Behavior (Low Temperatures)

- Thermal cracks
  - Pavement contracts as temperature drops
  - Stresses build due to confinement
  - Occur when stress exceeds strength
- Depends on the source of asphalt and aggregate properties

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Thermal Cracking

Aging

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

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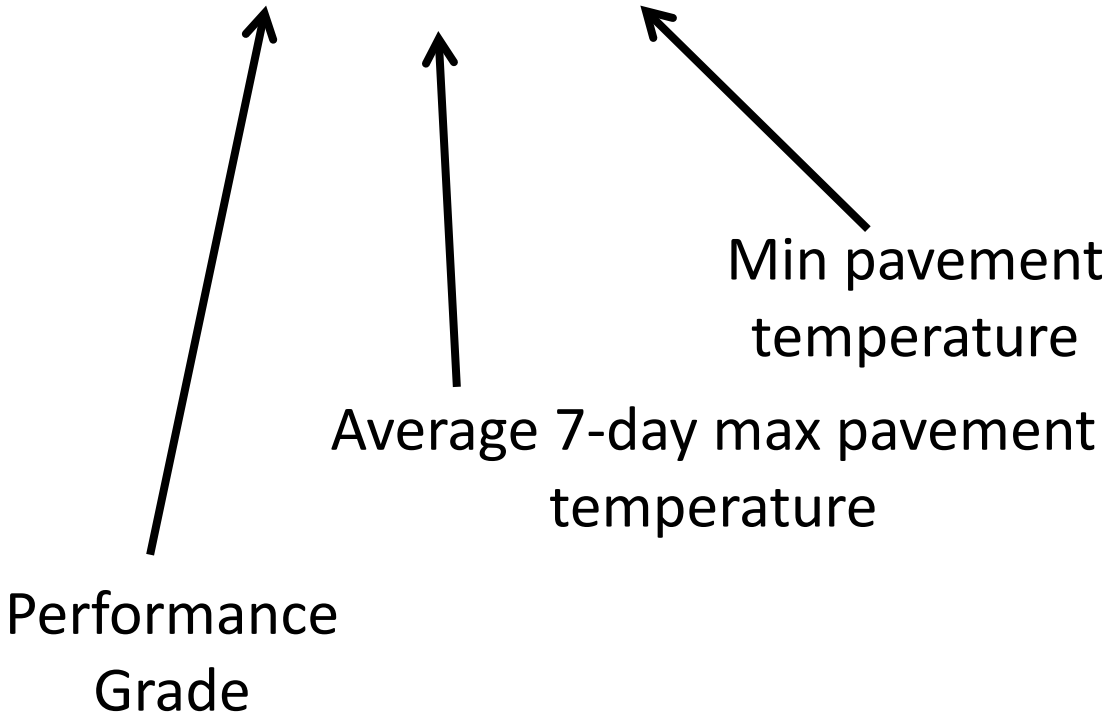
PG Asphalt Binder Specification

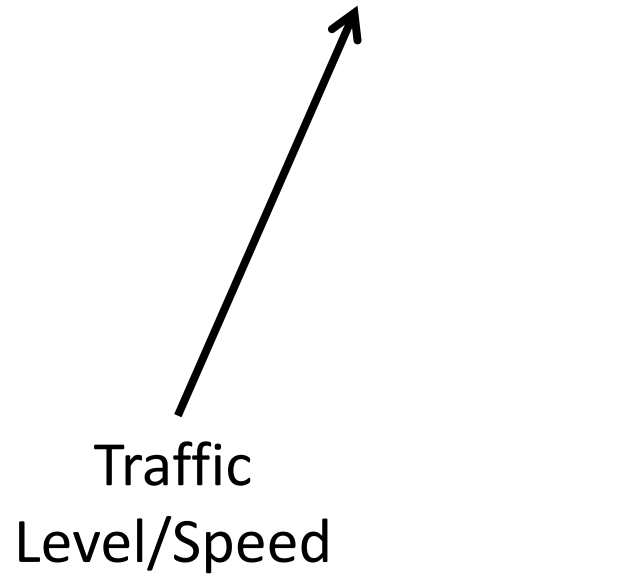
AASHTO M320

PG 64 - 22



AASHTO M332

PG 64H - 22



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Pavement Temperatures

- Calculated by LTPPBind software
- High temperature
  - 7-day maximum average
  - 20 mm below the surface of mixture

- Low temperature
  - 1-time minimum
  - At surface of mixture

Pave temp = *f* (air temp, depth, latitude)

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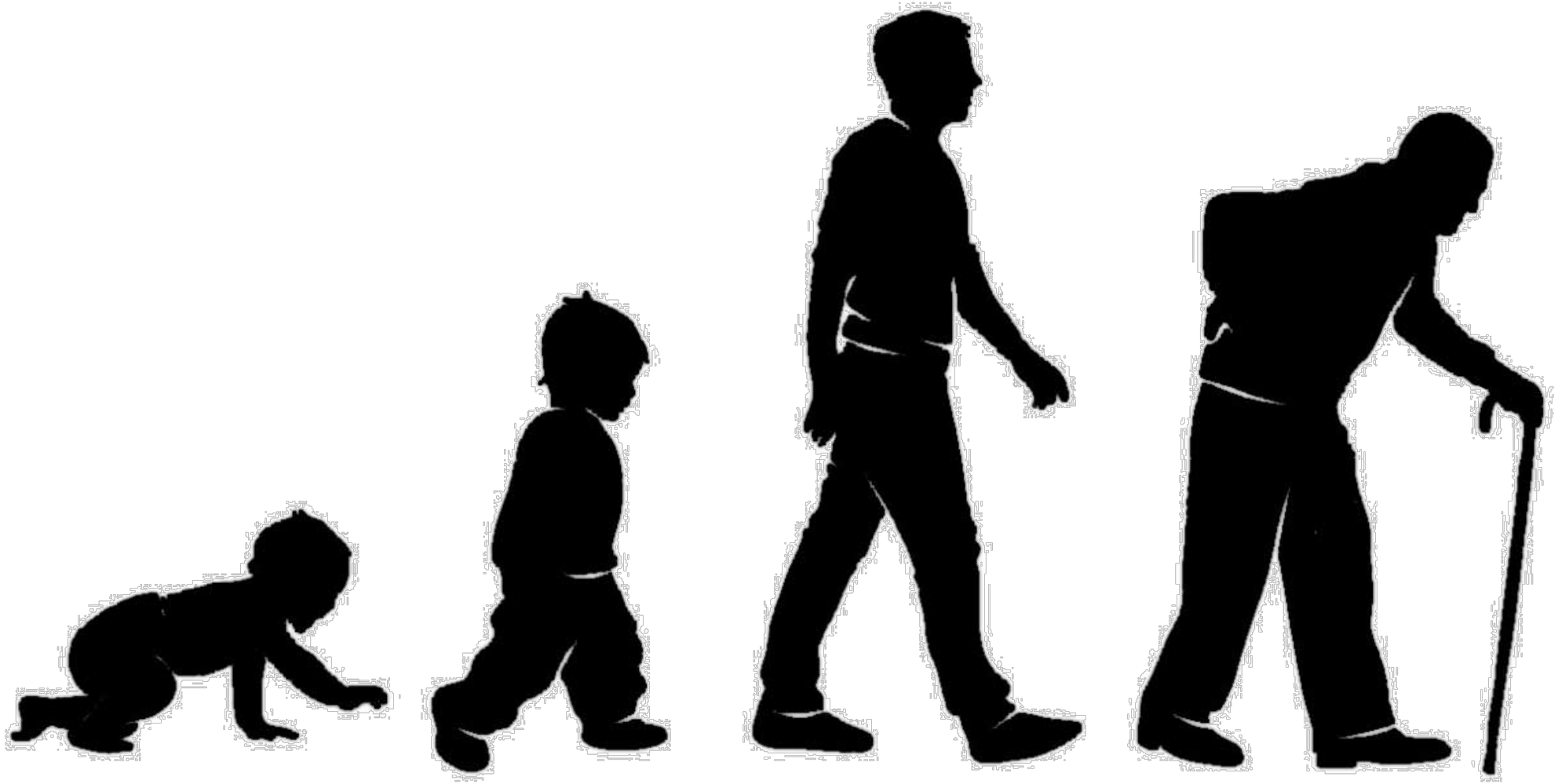
Aging Procedures



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Short Term Binder Aging

- Rolling Thin Film Oven - RTFO
  - Simulates aging from hot mixing and construction

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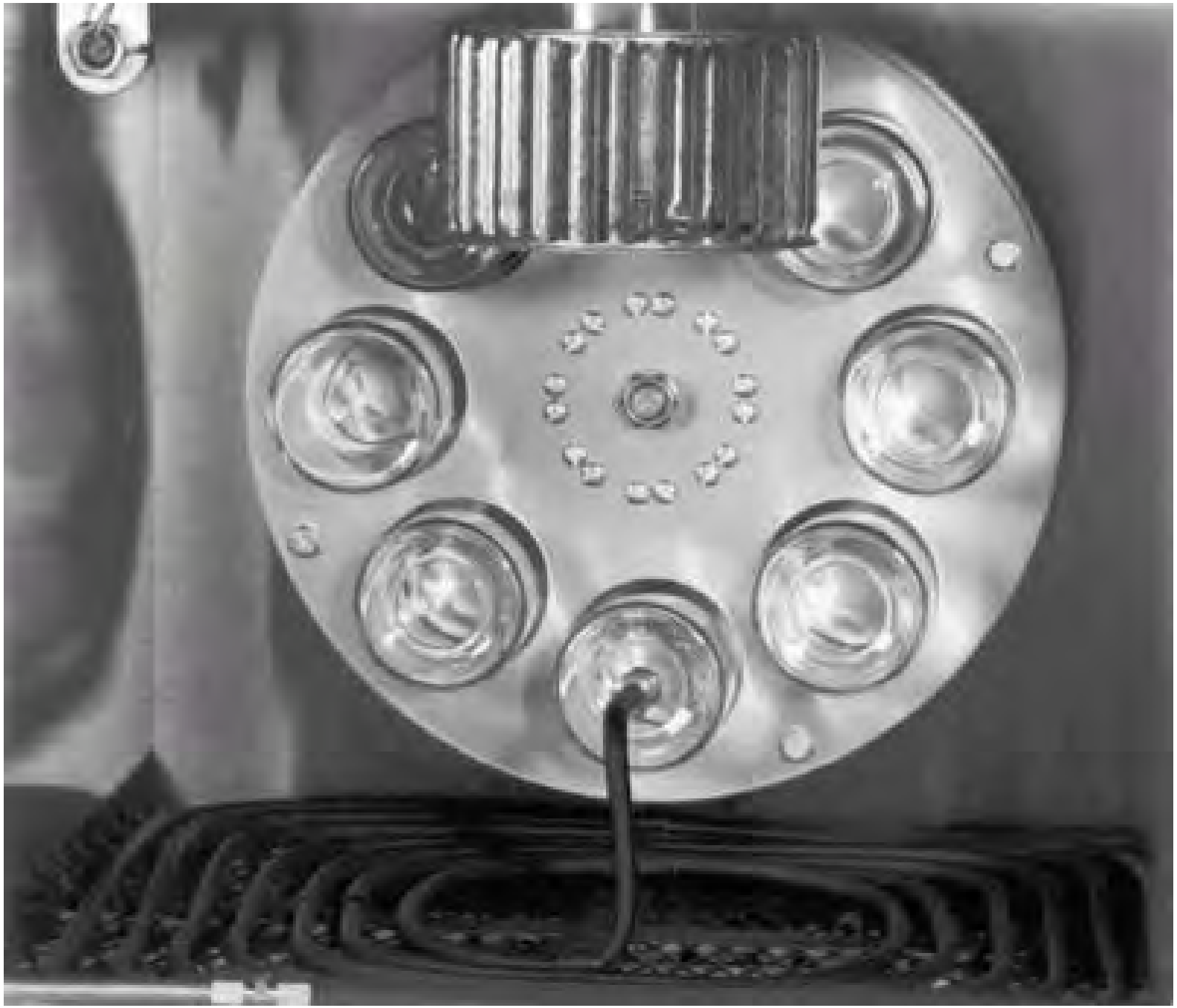
Inside of RTFO



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Bottles Before and After Testing

Pressure Aging Vessel (Long Term Aging)

- Simulates aging of an asphalt binder for 7 to 10 years
- 50-gram sample is aged for 20 hours
- No test result – AASHTO practice, not test method

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Pressure Aging Vessel

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Tests Used in PG Specifications

- Flash Point – safety
- Rotational Viscosity – pumpability / workability
- Dynamic Shear Rheometer – rutting and fatigue
  - Unaged
  - RTFO-aged
  - PAV-aged
- Bending Beam Rheometer – Low temperature cracking

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Rotational Viscometer

Is the asphalt binder able to be used at normal handling temperatures?
Output: viscosity @ 135°C

http://www.pavementinteractive.org/article/Rotational-Viscometer/

Dynamic Shear Rheometer

Does the asphalt binder have adequate rutting and fatigue cracking resistance?

Output:

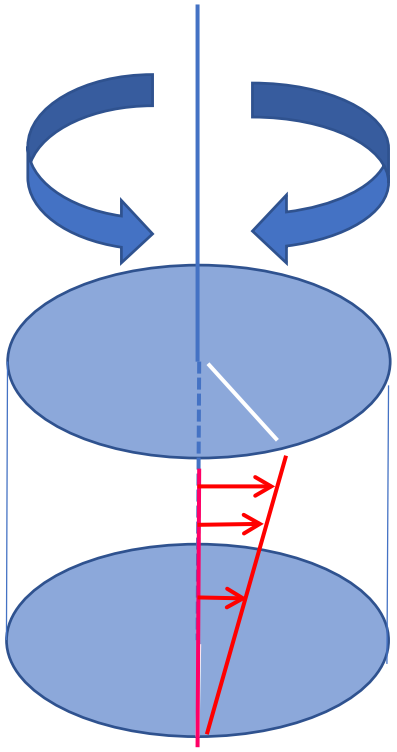
- Complex Shear Modulus (G*)
- Phase Angle (δ)

Or

- Non-recovered Creep Compliance (J_{nr})

Dynamic Shear Rheometer (DSR)

Parallel Plate



$$\tau_{max} = \frac{2T}{\pi R^3}$$

$$\gamma_{max} = \frac{\theta r}{h}$$

$$G^* = \frac{\tau_{max}}{\gamma_{max}}$$

Where:
T = Max applied torque,
R = Radius of sample, mm,
Θ = Deflection angle, radians,
h = Specimen thickness, mm

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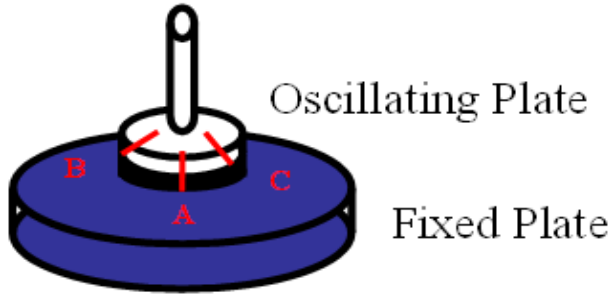
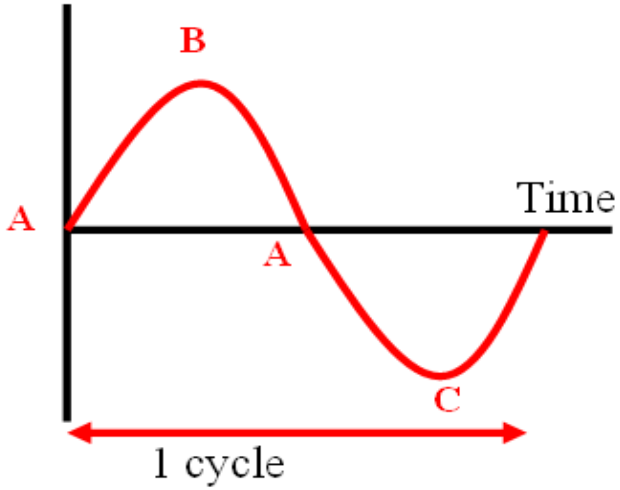
Dynamic Shear Rheometer (DSR)





Test operates at 10 rad/sec
or 1.59 Hz

360° = 2 π radians per circle
1 rad = 57.3°

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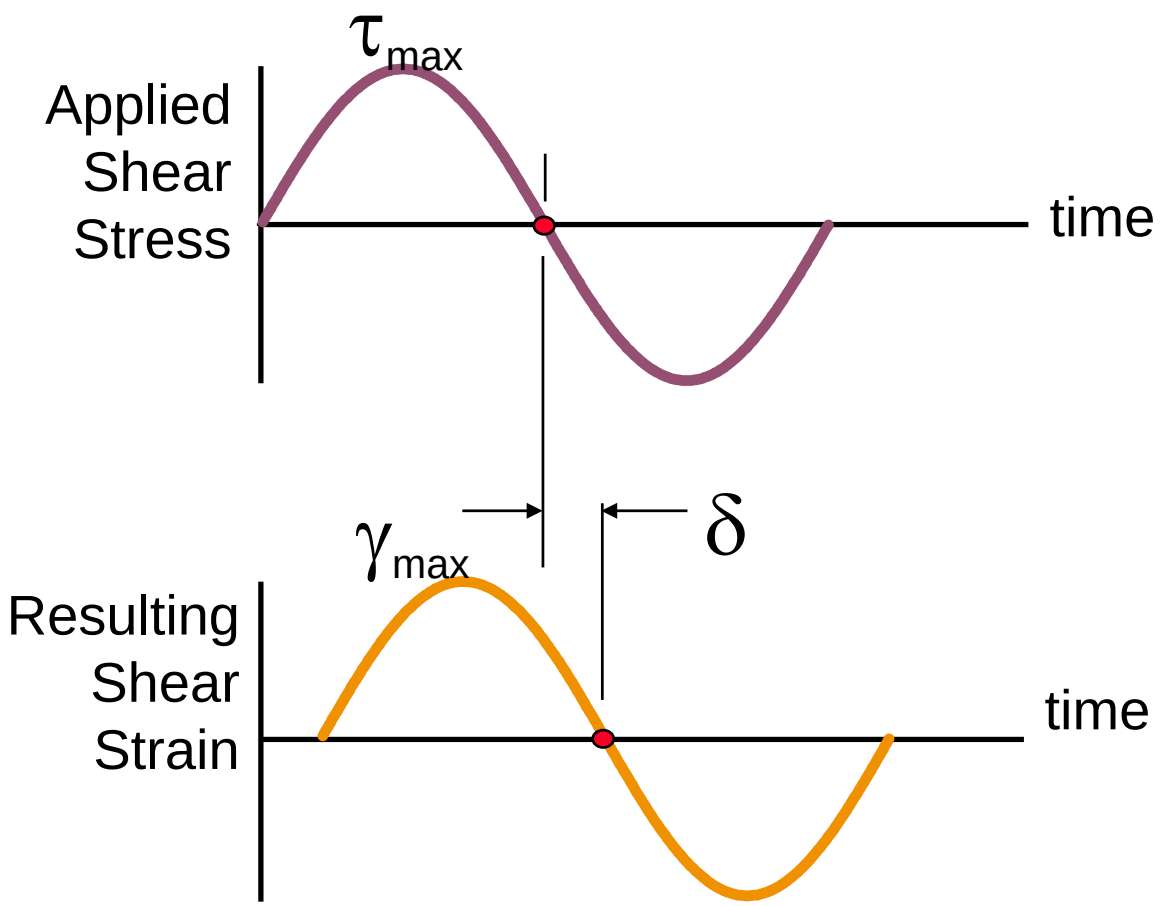
Viscoelastic: $0 < \delta > 90^{o}$



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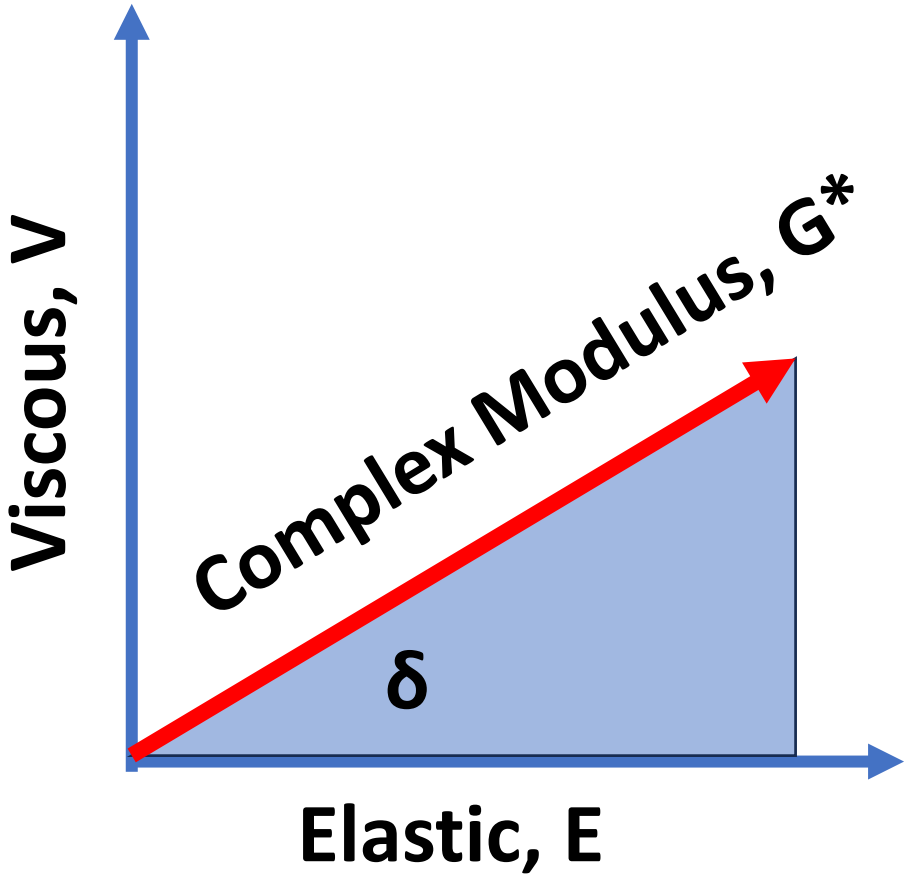
Rheological Diagram (SOH-CAH-TOA)



$\sin(\delta) = V / G^*$

HT, $G^* / \sin(\delta) \geq 2.2$ kPa

$(G^*)^2 / V$ = Empirical

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MSCR Test

- The MSCR test subjects the asphalt binder to cycles of loading and unloading (creep and recovery) at specified stress levels.

- It measures the ability of the binder to recover after being deformed, which is important for assessing its resistance to permanent deformation, or rutting.

J_{nr} (Non-recoverable Creep Compliance)

- J_{nr} is a parameter derived from the MSCR test. It quantifies the amount of **permanent deformation that remains** in the binder after the stress is removed.

- **A lower J_{nr} value indicates better resistance to rutting**,
  as it means the binder returns more to its original shape after the stress is removed.

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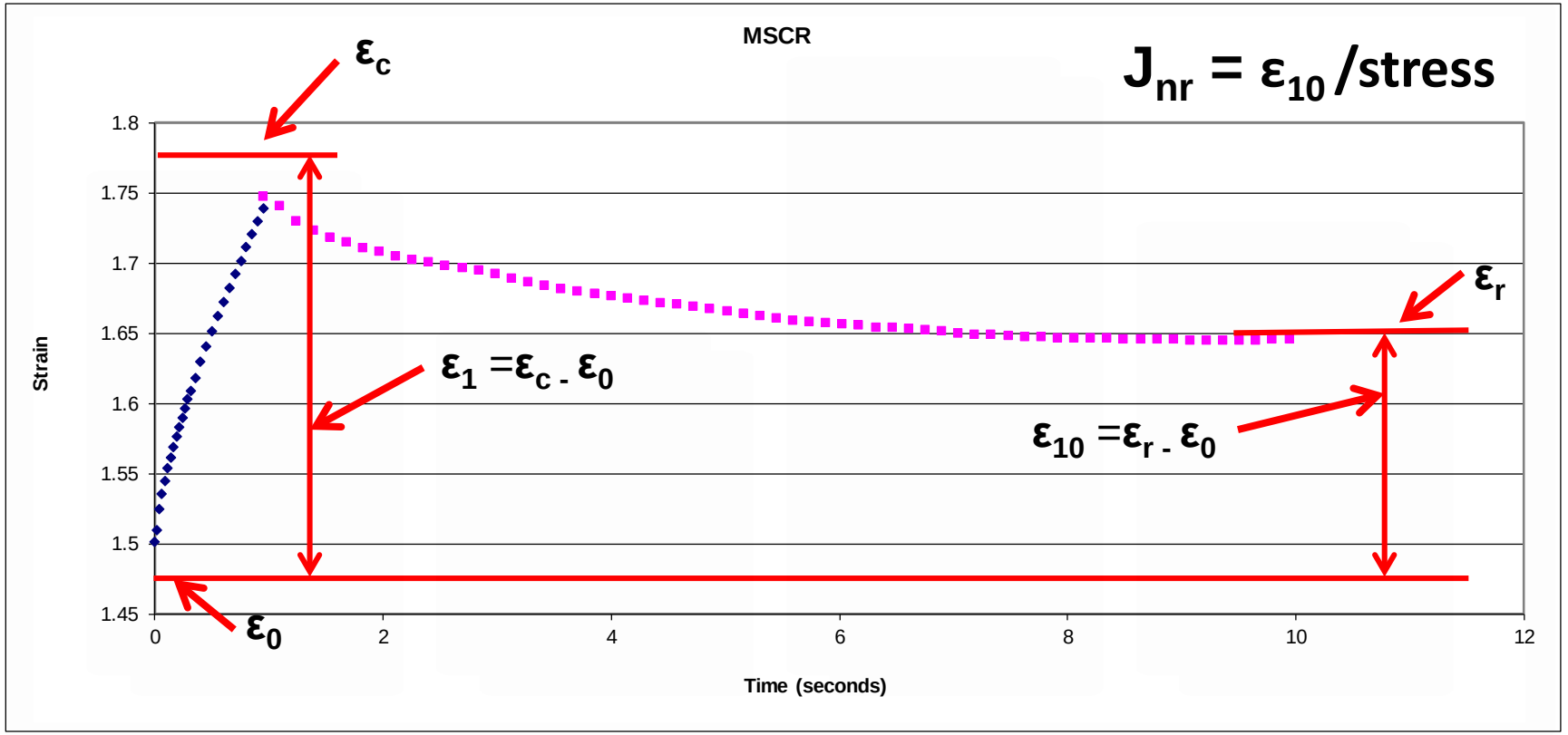
MSCR – 1 Cycle



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Examples of DSR Equipment

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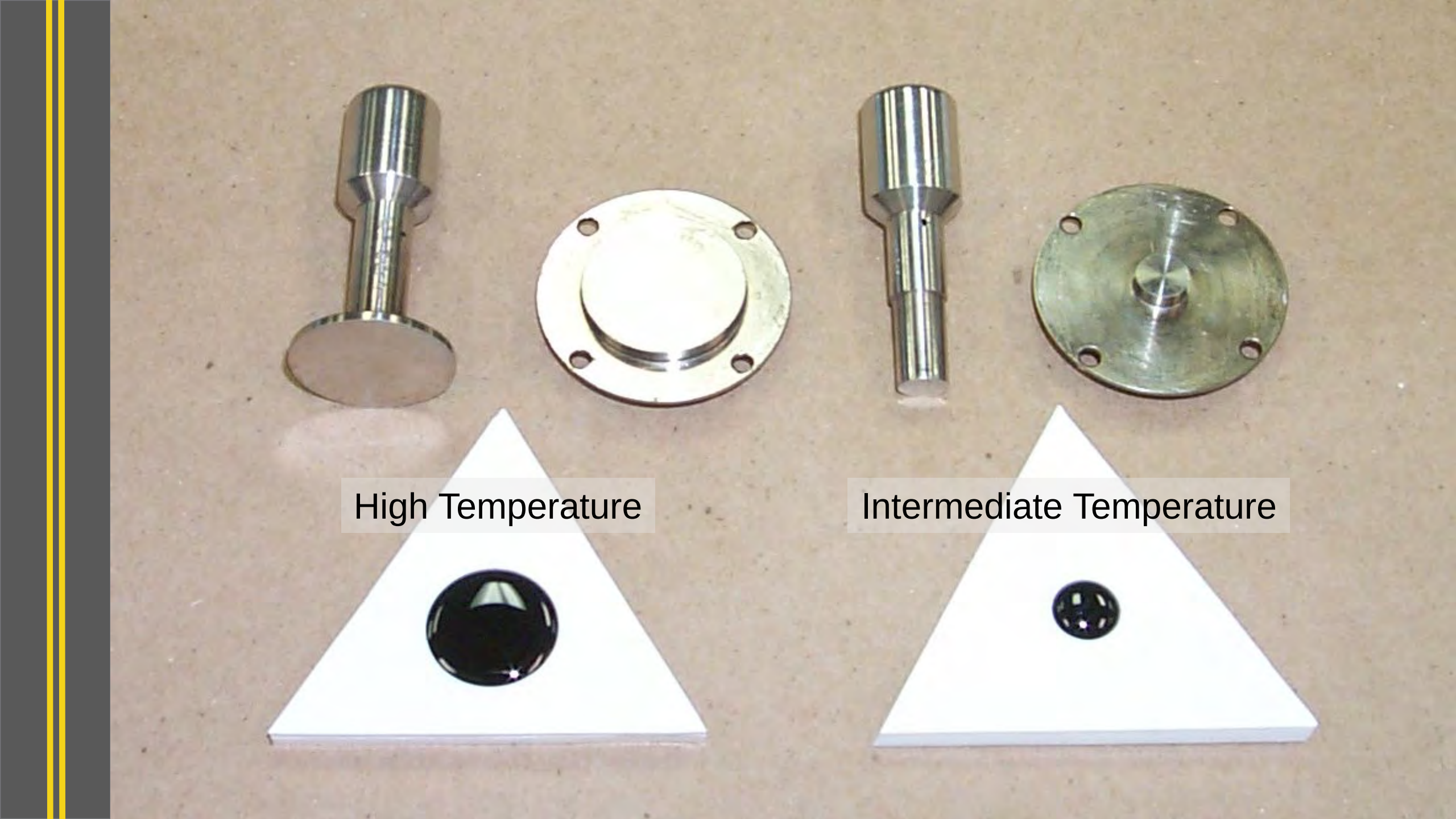
High Temperature
Intermediate Temperature

DSR at High Temperatures

Permanent Deformation or Rutting

- AASHTO M320
  - Complex Shear Modulus (G*) for stiffness
  - Phase Angle (δ) for elasticity

or

- AASHTO M332
  - Non-recovered Creep Compliance (J_{nr})

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Permanent Deformation

Question: How do we address rutting?

Answer: We want a stiff, elastic binder to contribute to mix rutting resistance

How: By increasing G* or decreasing δ (AASHTO M320) or by decreasing J_{nr} (AASHTO M332)

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Permanent Deformation

- Addressed by:
  - G*/sin(δ) on unaged binder > 1.00 kPa
  - G*/sin(δ) on RTFO aged binder > 2.20 kPa
  - J_{nr} traffic level limits

- Performance Grading criteria allows us to combine both parameters and optimize performance

Fatigue Cracking

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Fatigue Cracking

Question: How do we address fatigue?

Answer: We want a soft elastic binder (to sustain many loads without cracking)

How: By decreasing G* or decreasing δ

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Fatigue Cracking

- Addressed by:

  $G^* (\sin(\delta)) \leq 6{,}000\ kPa$

  $\delta \geq 42^\circ$ *if* $G^*(\sin(\delta))$ *is between* $5{,}000 - 6{,}000\ kPa$

A maximum on this parameter is set to ensure that the binder is soft enough to flex under traffic loads without cracking

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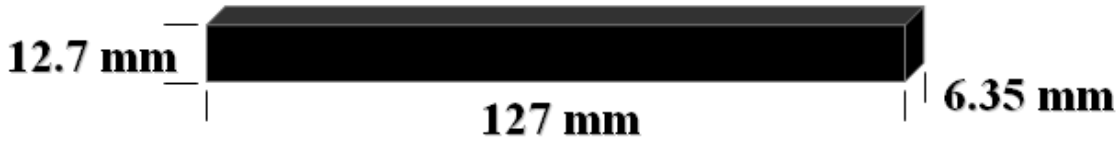
Bending Beam Rheometer

Does the asphalt binder have adequate resistance to thermal cracking?



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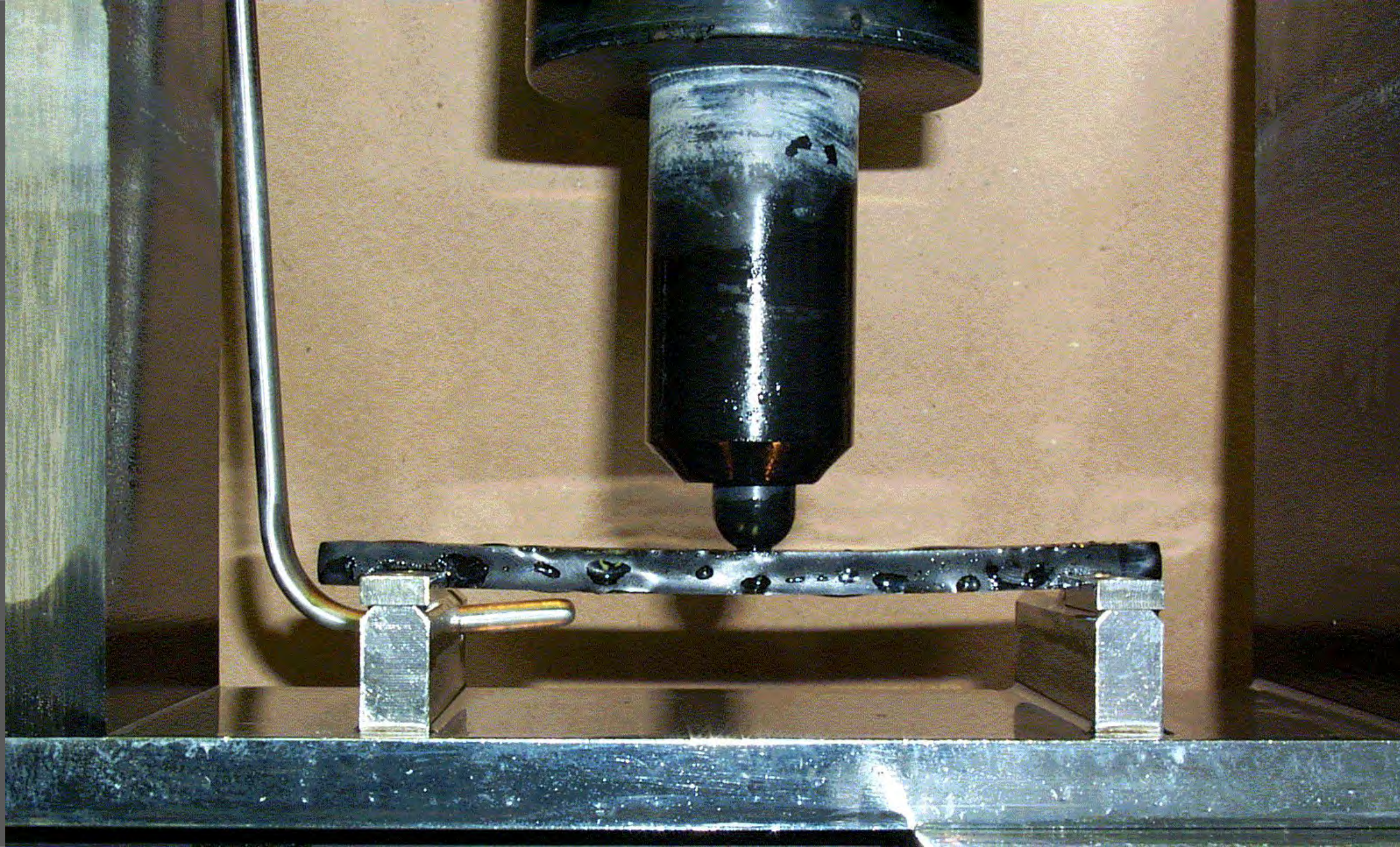
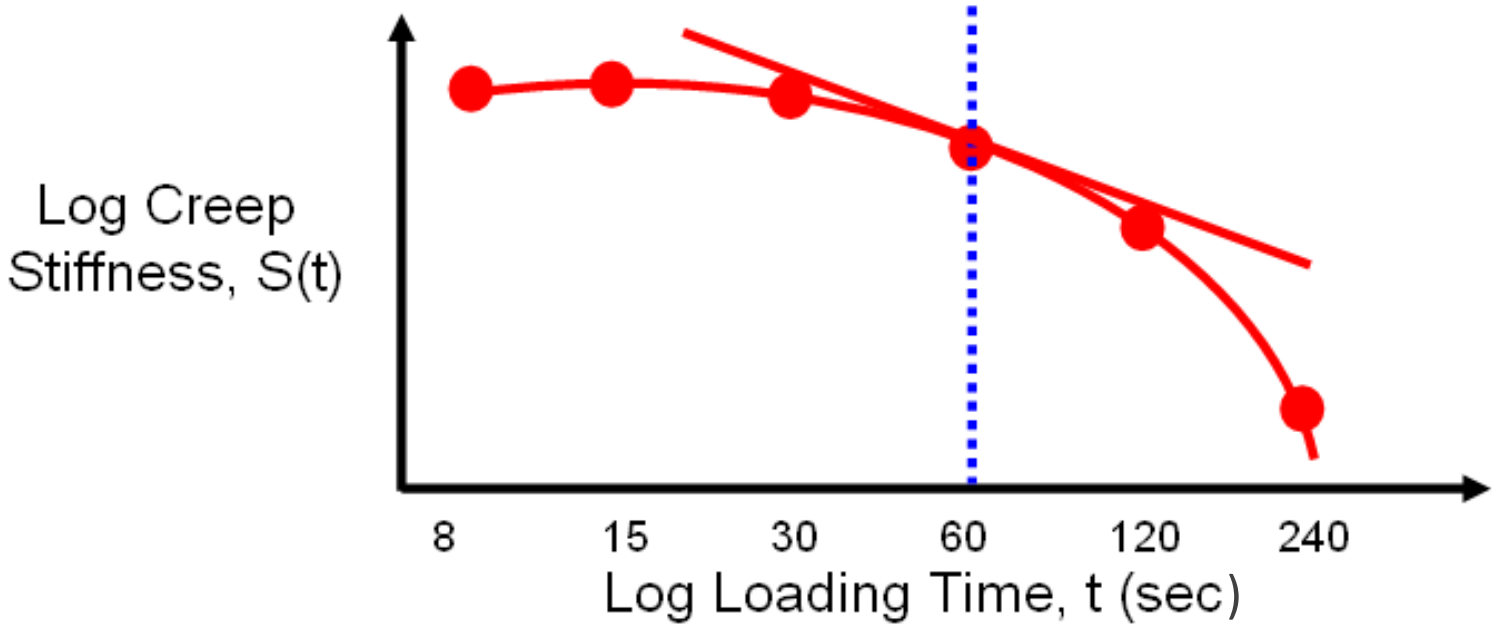


Bending Beam Rheometer

- Evaluates low temperature stiffness properties
  - Creep stiffness, S
  - Slope of response (m-value)



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Thermal Cracking

Question: How do we address thermal cracking?

Answer: Need asphalt binder that is not too stiff at cold temperatures and is able to relax thermal stresses.

How: By having a maximum stiffness and minimum m-value

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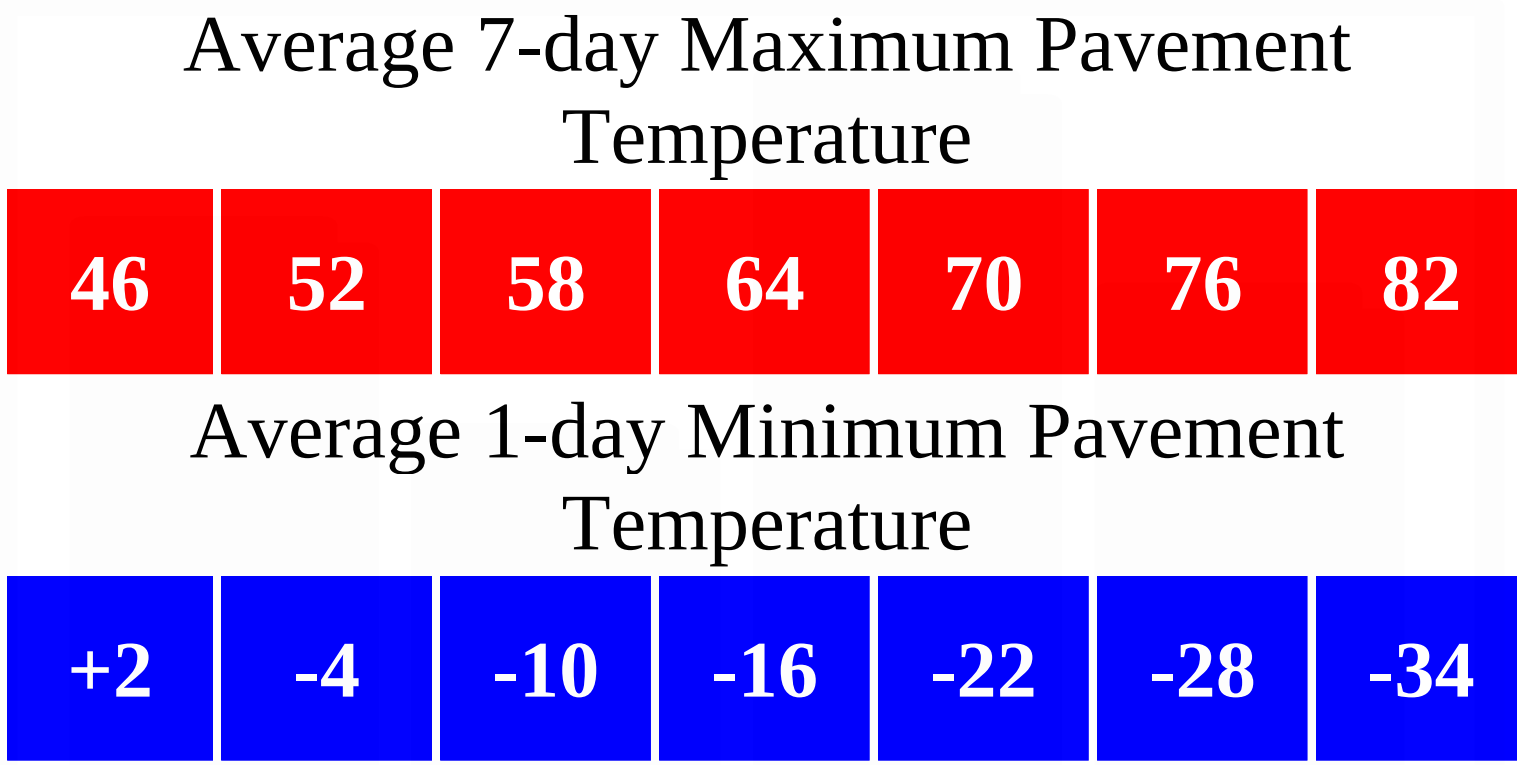
PG Grade Increments



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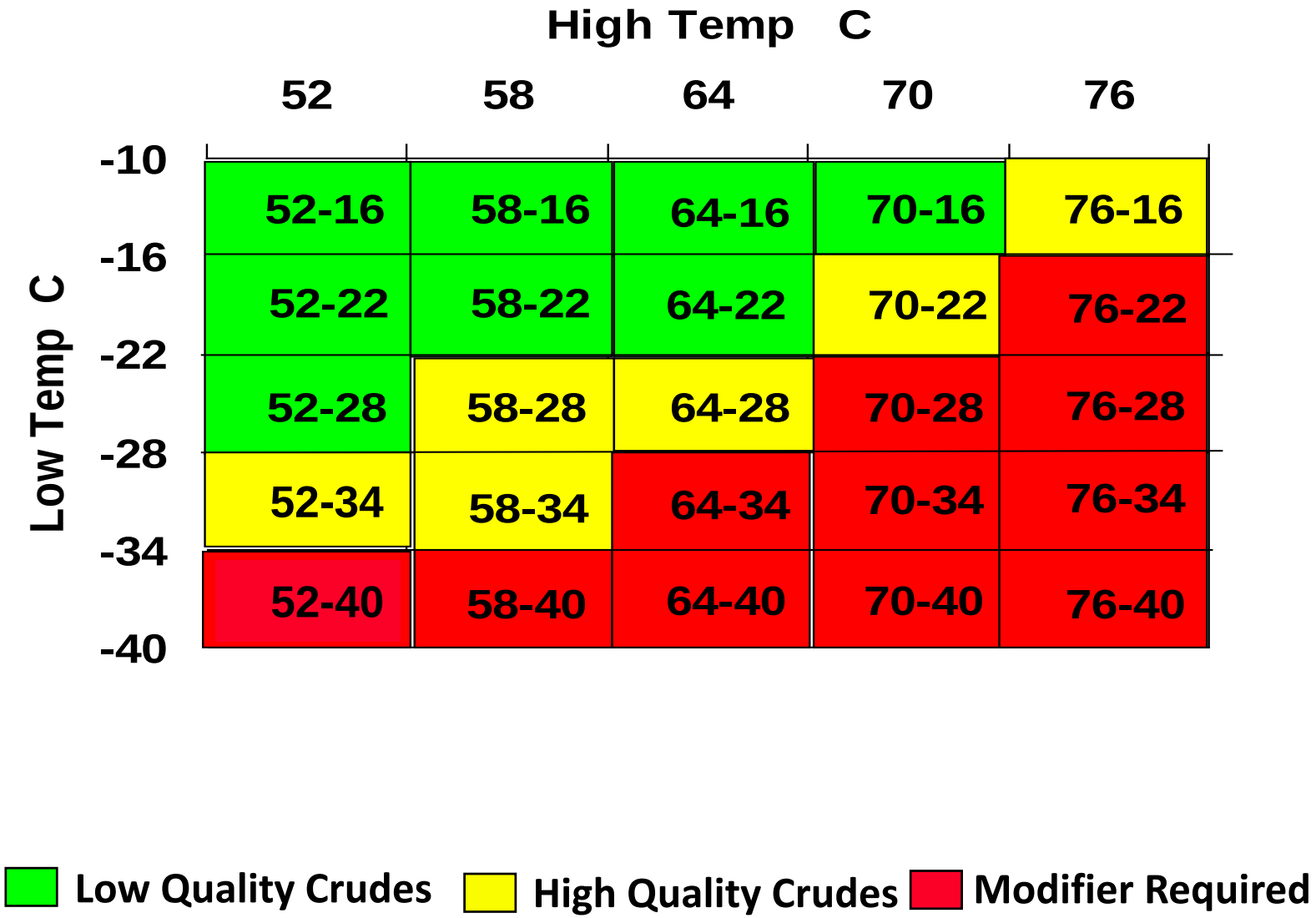
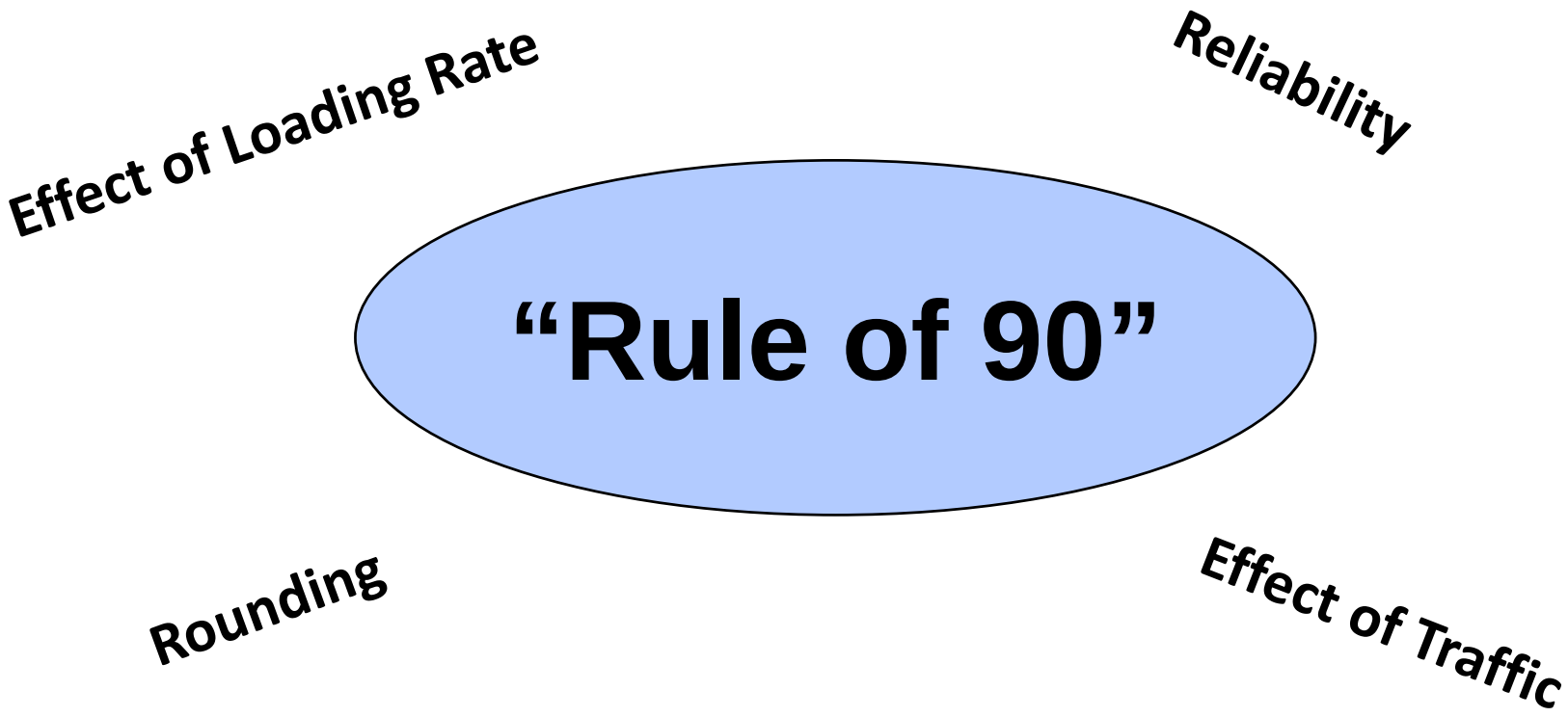
Prediction of PG Grades for Crude Blends



Is a PG a Modified Binder ?



Example: PG 64 - 34 has a temperature range of 64 to - 34 or 98 C. Therefore, this binder is probably modified !! *(Depends on Asphalt Source!)*

Traffic Levels in MSCR Grading

Designation	Traffic Loading, ESALs		Traffic Speed, kph (mph)
S – Standard	< 10 M	and	70 (44)
H – Heavy (ASTM, High)	10 – 30 M	and	20 to 70 (12 to 44)
V – Very Heavy	> 30 M	or	< 20 (12)
E – Extremely Heavy	> 30 M	and	< 20 (12)

SHVE: Smooth, Hearty, Versatile Elixir – Asphalt Binder's got the Groove!

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Criteria for J_{nr} by Traffic Levels at 3.2 kPa

Designation	Jnr at 3.2 kPa
S – Standard	≤ 4.5 kPa^{-1}
H – Heavy (ASTM, High)	≤ 2.0 kPa^{-1}
V – Very Heavy	≤ 1.0 kPa^{-1}
E – Extremely Heavy	≤ 0.5 kPa^{-1}

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Now What?

- Choose a PG binder grade for use on a project
  - Climate

- Climatic grade may be adjusted for
  - Traffic Speed
  - Traffic level

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How to Choose an Asphalt Binder Based on Climate

- Gather climate data from the database (LTPPBind)
- Convert air temperatures to pavement temperatures
- Use good judgement
  - Cost
  - Availability

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Effect of Traffic Speed on Binder Selection

- Dilemma
  - Specified DSR loading rate is 10 rad/sec
  - What about longer loading times?

- Use a binder with higher stiffness
  - Slow - - increase one high temp grade
  - Stationary - - increase two high temp grades
  - *No effect on low temp grade*

70 mph

ESAL = Equivalent Single Axle Loads

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Effect of Traffic Level

ESAL - Equivalent Single Axel Load 18,000 lbs

2.4 ESAL

12,000 lbs | 34,000 lbs | 34,000 lbs

0.49 ESAL

6,000 lbs | 15,000 lbs

0.0002 ESAL

2,000 lbs | 1,000 lbs

It takes 12,000 cars to provide the load of a single 18-wheel truck

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Effect of Traffic Level on Binder Selection

- 10 - 30 x 10^6 ESAL
  - Consider increasing - - one high temp grade
- 30 x 10^6 + ESAL
  - Recommend increasing - - one high temp grade

> **E**quivalent **S**ingle **A**xle **L**oads

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Effect of Traffic Speed on Binder Selection

- Example

  - for toll road PG 64-22
  - for toll booth PG 70-22
  - for weigh stations PG 76-22

or

70 mph → PG 64**S**-22

Slow → PG 64**H**-22

Stopping → PG 64**E**-22

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PG Binder System

WHEN	WHAT	HOW	WHERE
Construction	Safety Pump-ability Rutting	Flash Point Rotational Visc DSR – Jnr	230° min 3 Pa-s max T(high)
Early (RTFO)	Rutting	DSR	T(high)
Late (PAV)	Fatigue Low-Temp	DSR BBR	T(int) T(low)

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Learning Objectives Review

- How is asphalt made?
- Why do we need to grade asphalt binders?
- Name 3 test procedures used in the grading of asphalt binders
  - Rotational Viscometer
  - Rolling Thin Film Oven
  - Pressure Aging Vessel
  - Dynamic Shear Rheometer
  - Bending Beam Rheometer

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Questions –

Does it all make sense?

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Q. What is Water?

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Questions