Performance Graded (PG) Asphalts

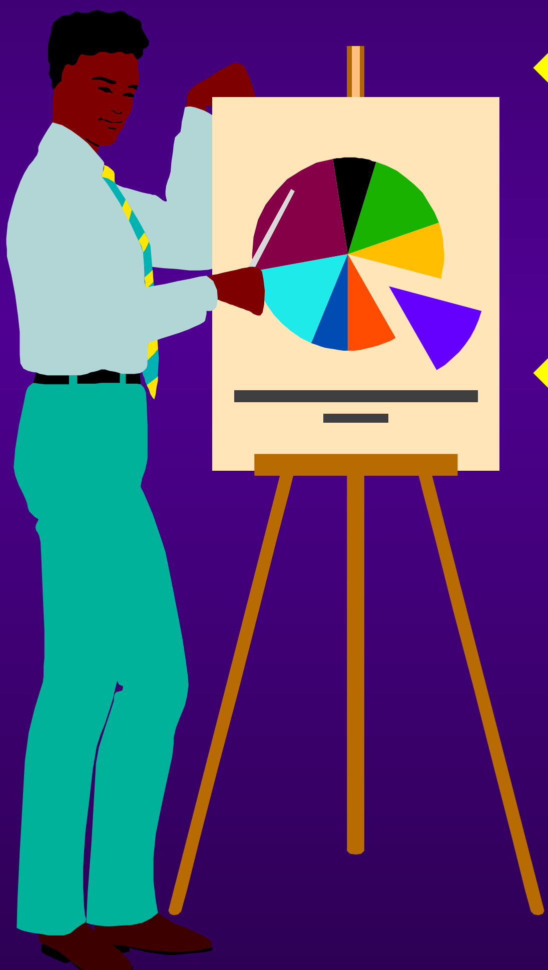
CITGO Asphalt

A Driving Force In Asphalt

SUPERPAVE Update for NJDOT/NEAUPG Mechanistic Pavement Design Seminar

Princeton, NJ - Feb. 25, 2003

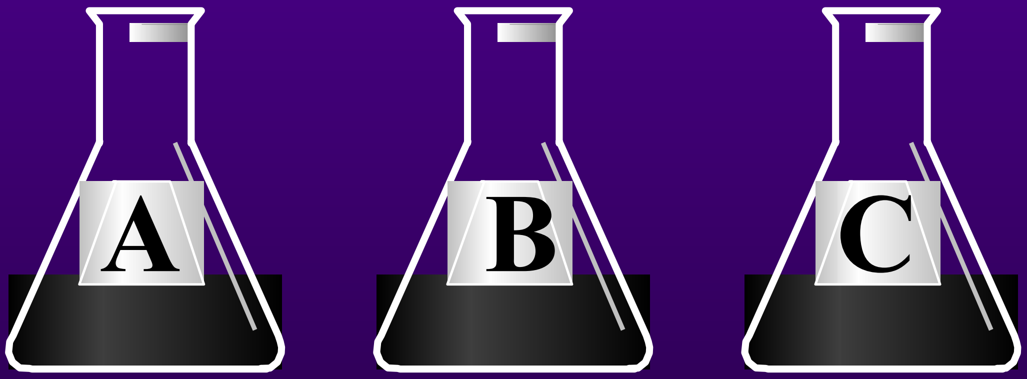
What is SUPERPAVE?



- New Asphalt Binder specification
- New Mix Design procedure using a new laboratory compaction device

We Have Three Asphalt Binders

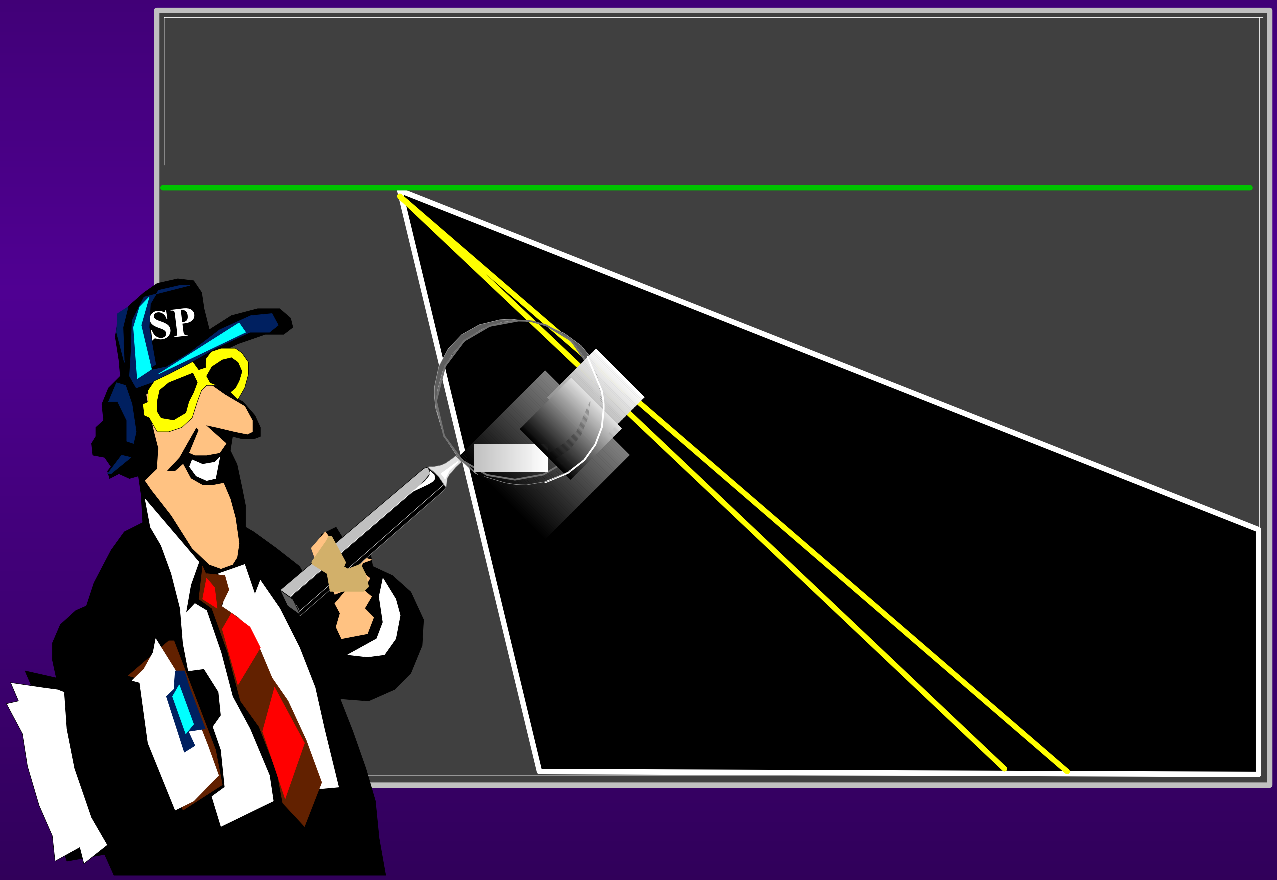
- **Q.** How do we determine which asphalt binder is best for our project?
- **A.** The asphalt binder that gives the best performance



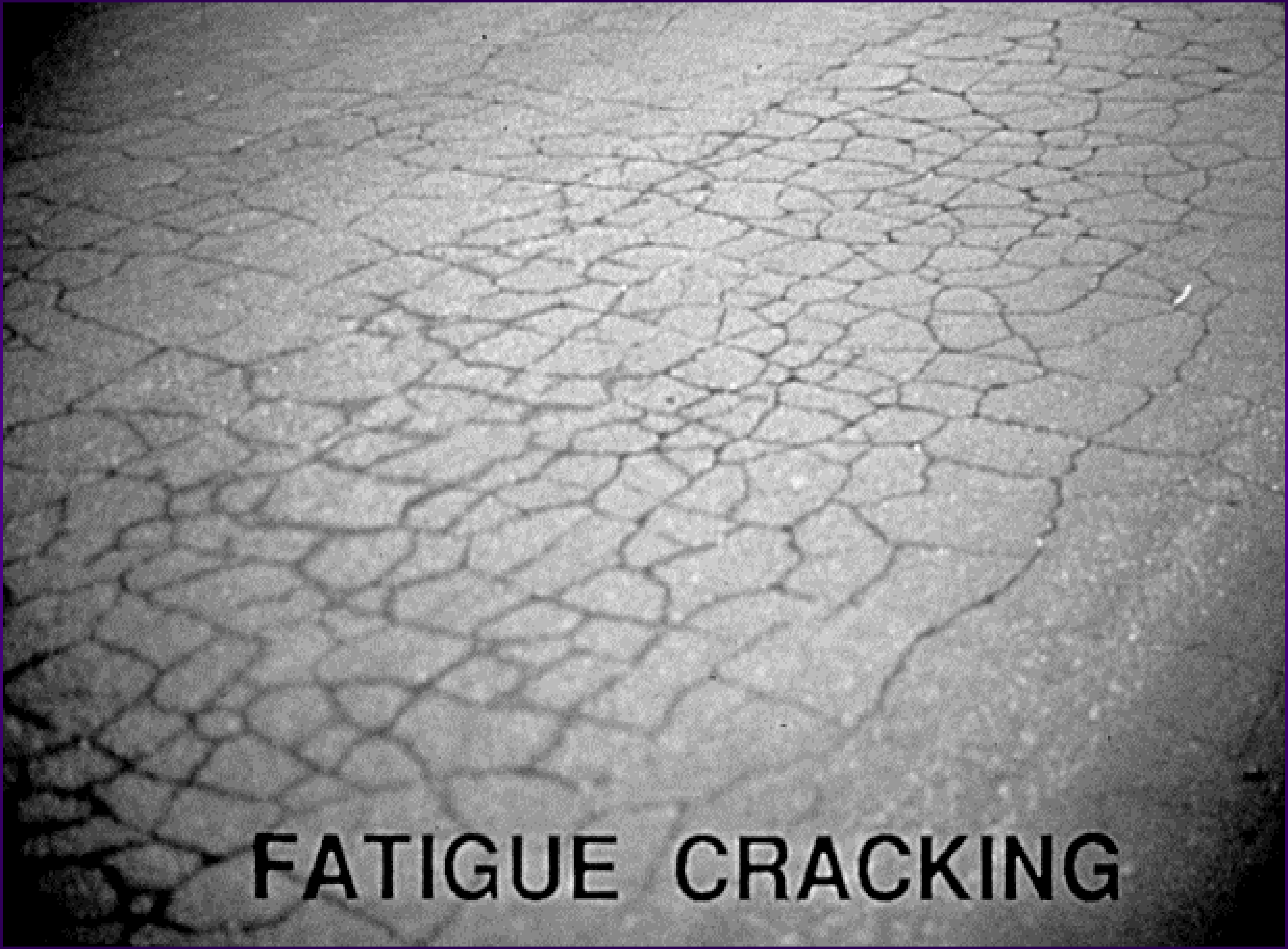
Performance ?

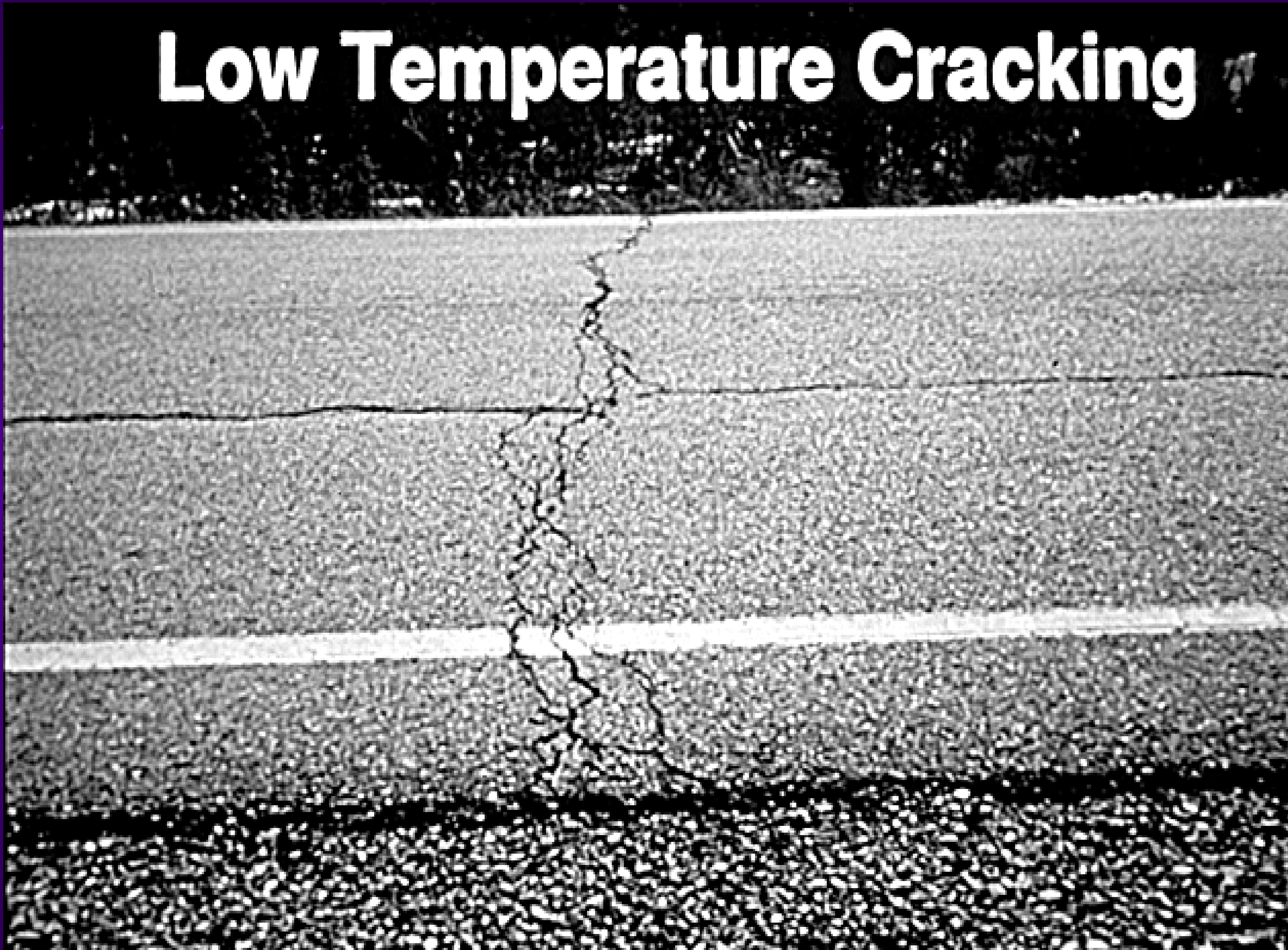
- Q. What areas of poor performance do we want to avoid ?
- Or, in other words, how do our <u>asphalt pavements fail</u> ?

How do asphalt pavements fail ?

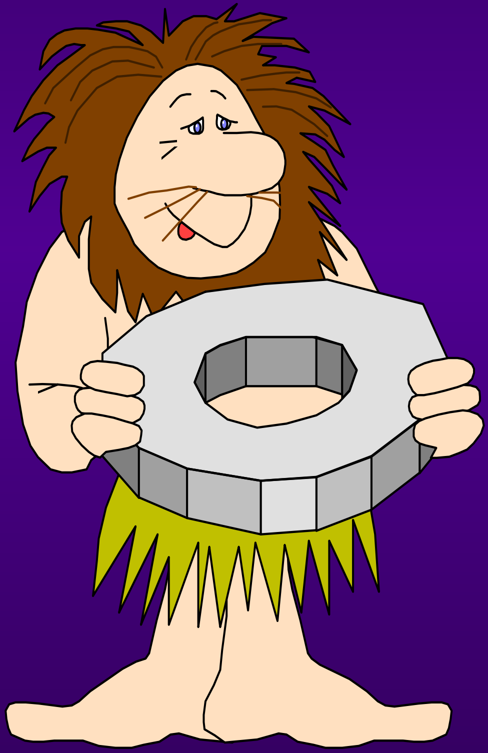



Rutting


FATIGUE CRACKING

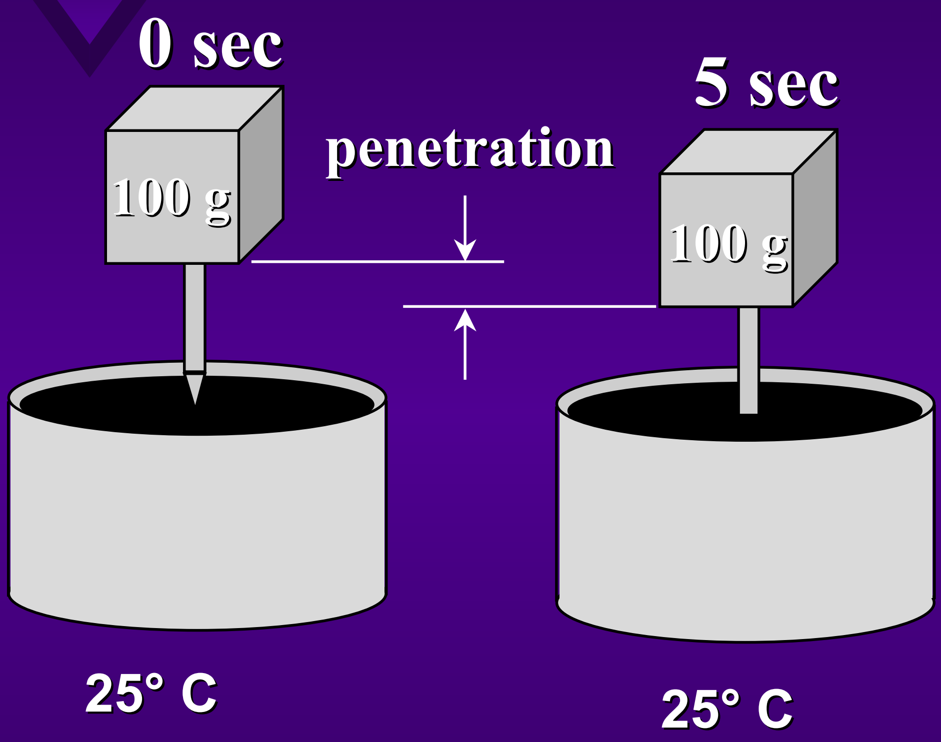

Low Temperature Cracking

How Did We Measure Asphalt Properties Before the PG Grading System?

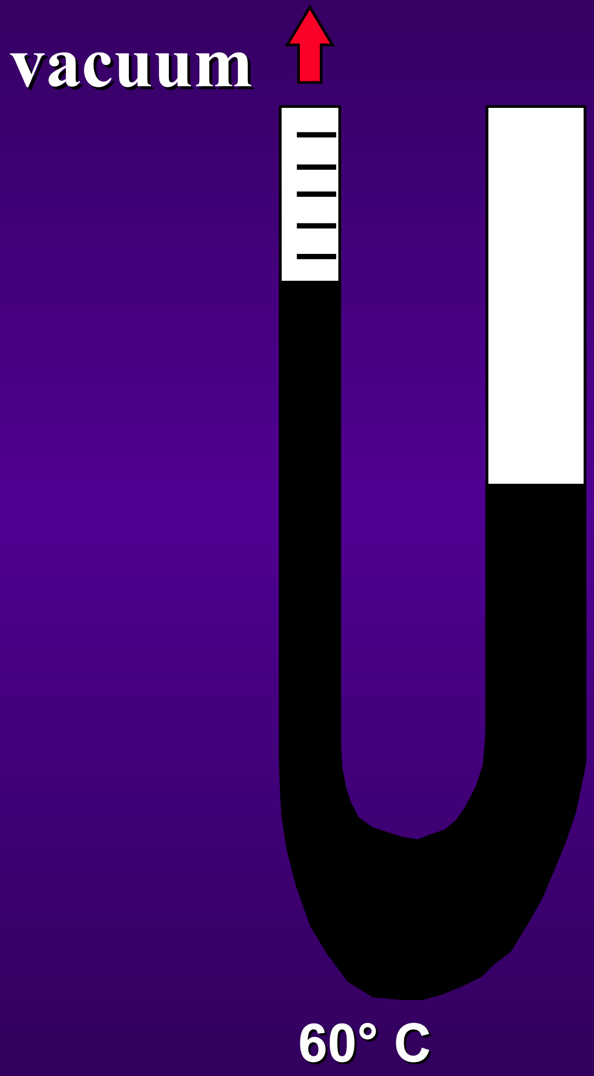


- Penetration Grading
- Viscosity Grading

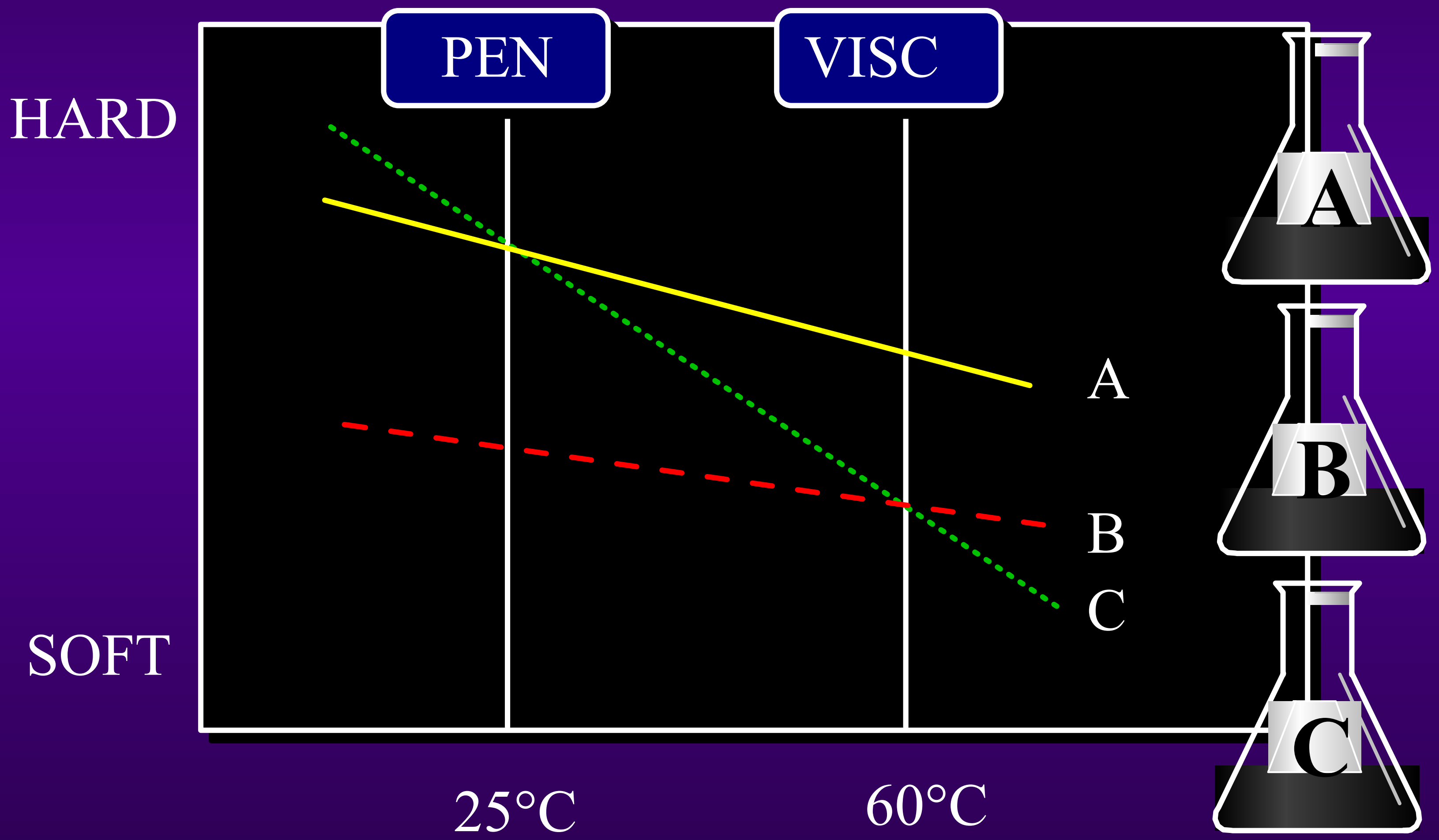
Penetration



Viscosity

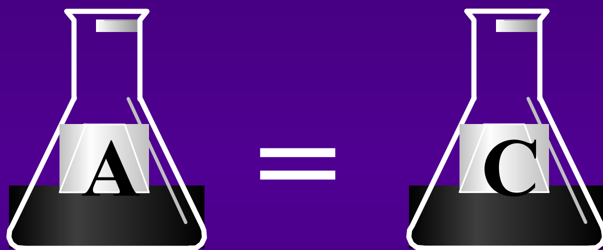


Problem with one temperature grading

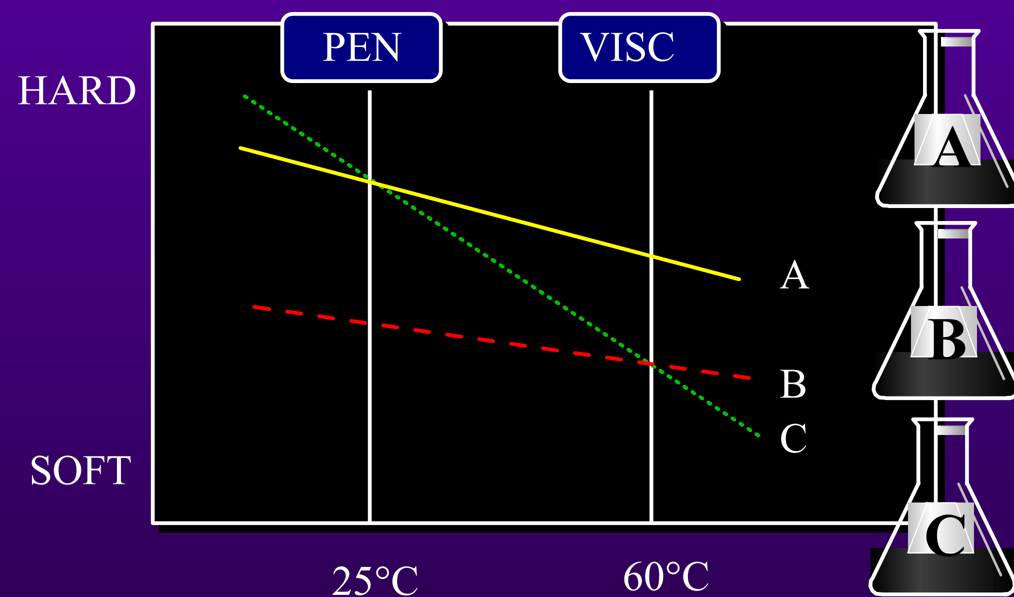


Problem with one temperature grading

- According to the Penetration system:



- According to the the Viscosity System:



Need to Correct this Problem

- Develop Preformance Related tests and specification
- Asphalt is a visco-elastic material
- Protocols need to be Temperature based

Temperatures

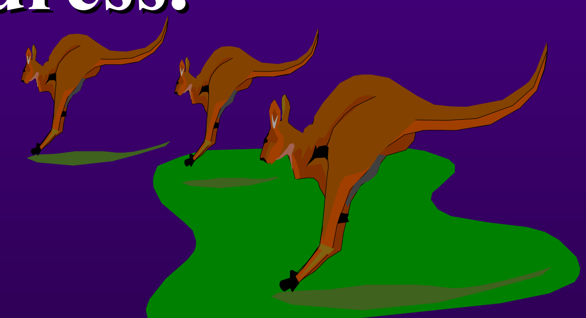
- **1. Rutting occurs at high pavement temperatures, $T_{(high)}$**

- **2. Fatigue Cracking occurs at intermediate pavement temperatures, $T_{(inter)}$, and**

- **3. Low Temperature Cracking occurs at low pavement temperatures, $T_{(low)}$.**

Aging

- Asphalt binders undergo aging through the loss of volatiles *(a.k.a. loss of light ends)* and oxidation.
- From the standpoint of determining an asphalt binder's performance there are three key ages we need to address.

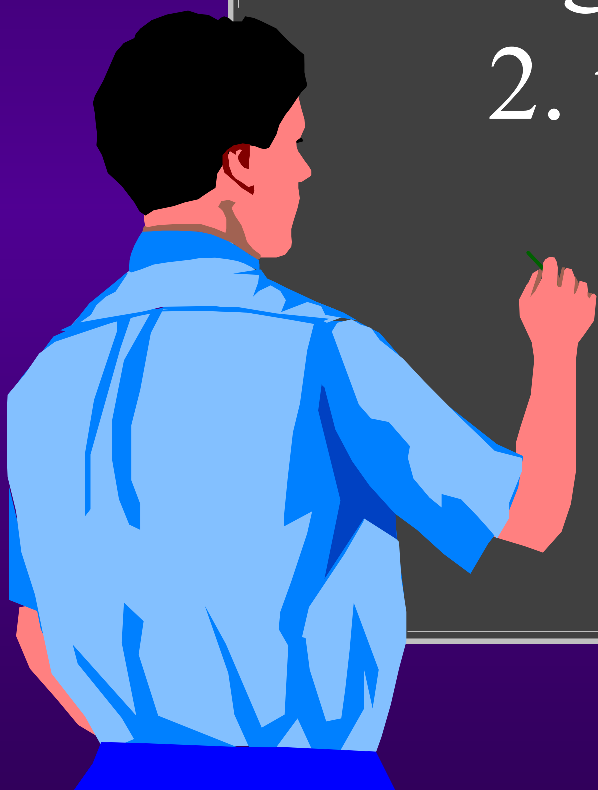


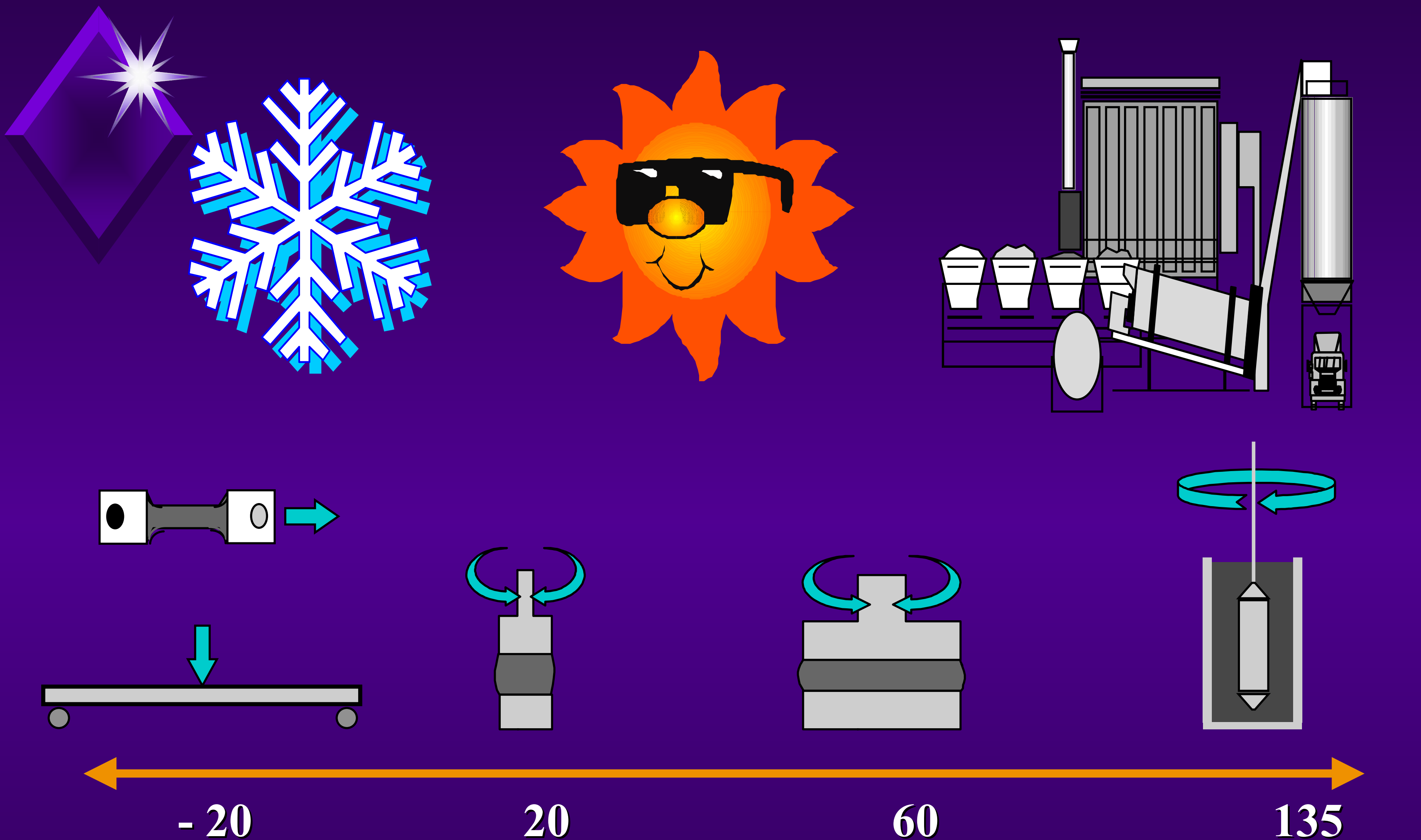
Key Aging

- New material - no aging
- During construction
  - Aging in the plant
  - Aging during placement
- Late in the pavement's life
  - 7 - 10 years of service

Asphalt binder's response to loading is a function of. . .

1. age
2. temperature





Pavement Temperature, C

Weather Database Performance Grade Increments

Average 7-day Maximum Pavement Temperature						
46	**52**	**58**	**64**	**70**	**76**	**82**
Average 1-day Minimum Pavement Temperature						
-10	**-16**	**-22**	**-28**	**-34**	**-40**	**-46**

Superpave Asphalt Binder Specification

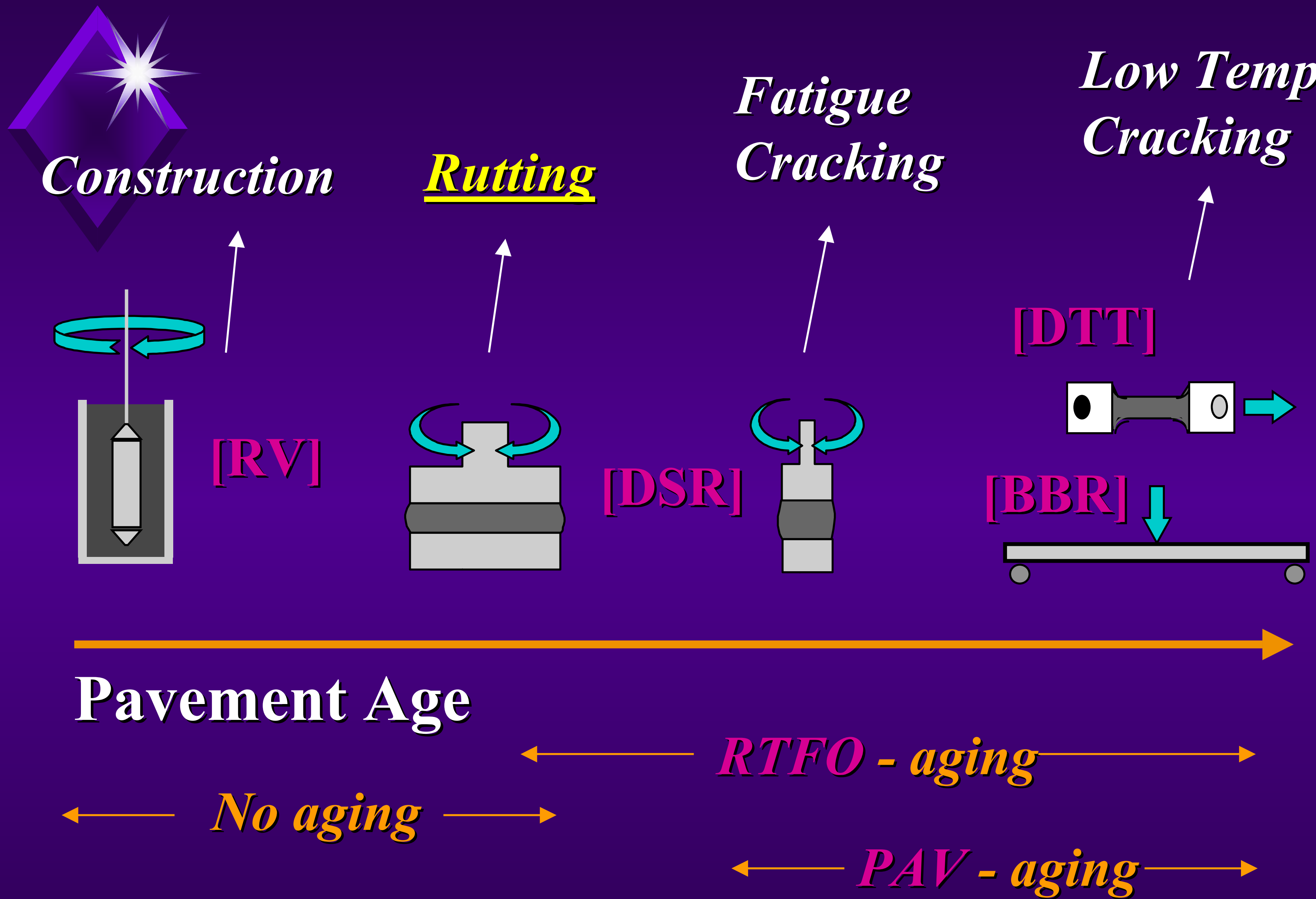
- **Grading System Based on Climate**

PG 64-22

Performance Grade

Average 7-day max pavement design temp

Min pavement design temp

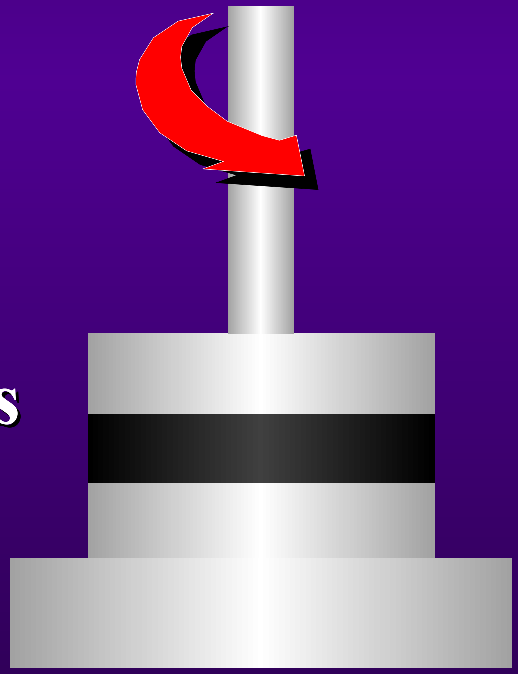


Construction
Rutting
Fatigue Cracking
Low Temp Cracking
[RV]
[DSR]
[DTT]
[BBR]
Pavement Age
RTFO - aging
No aging
PAV - aging

Dynamic Shear Rheometer, DSR

- Apply a oscillating shear stress
- Measure strain

- A materials modulus is
  - Modulus = Stress / Strain
  - A measure of material stiffness



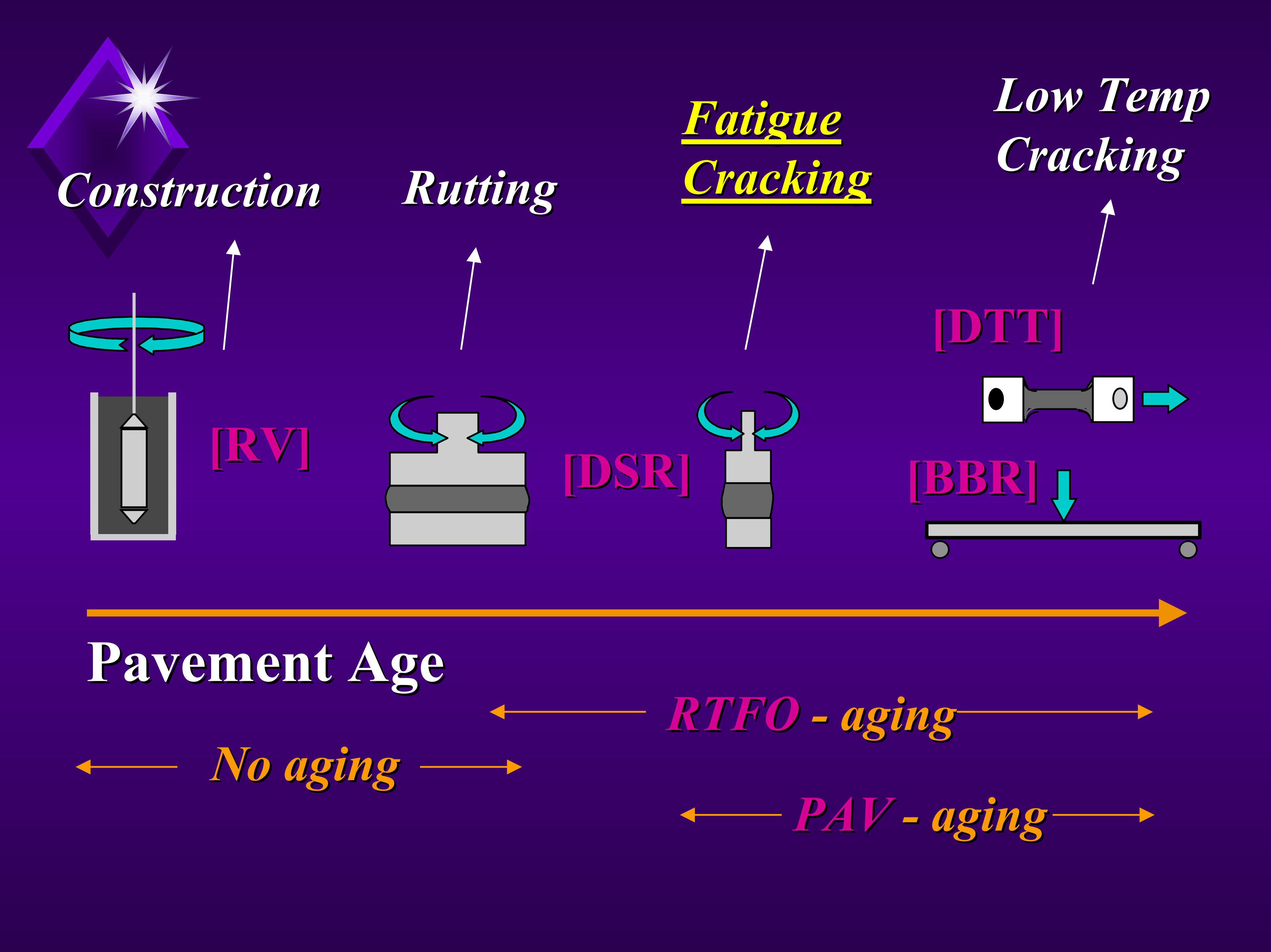
DSR provides G^* and δ

- G^*, Complex Shear Modulus
- δ , Phase Angle

- G^* / sin δ
  - Correlates to rutting resistance.
- G^* sin δ
  - Correlates to fatigue resistance.

Rutting Specification - Minimum Stiffness @ $T_{(high)}$

- G^* / sin δ > 1.00 kPa on unaged binder
- G^* / sin δ > 2.20 kPa on RTFO aged binder



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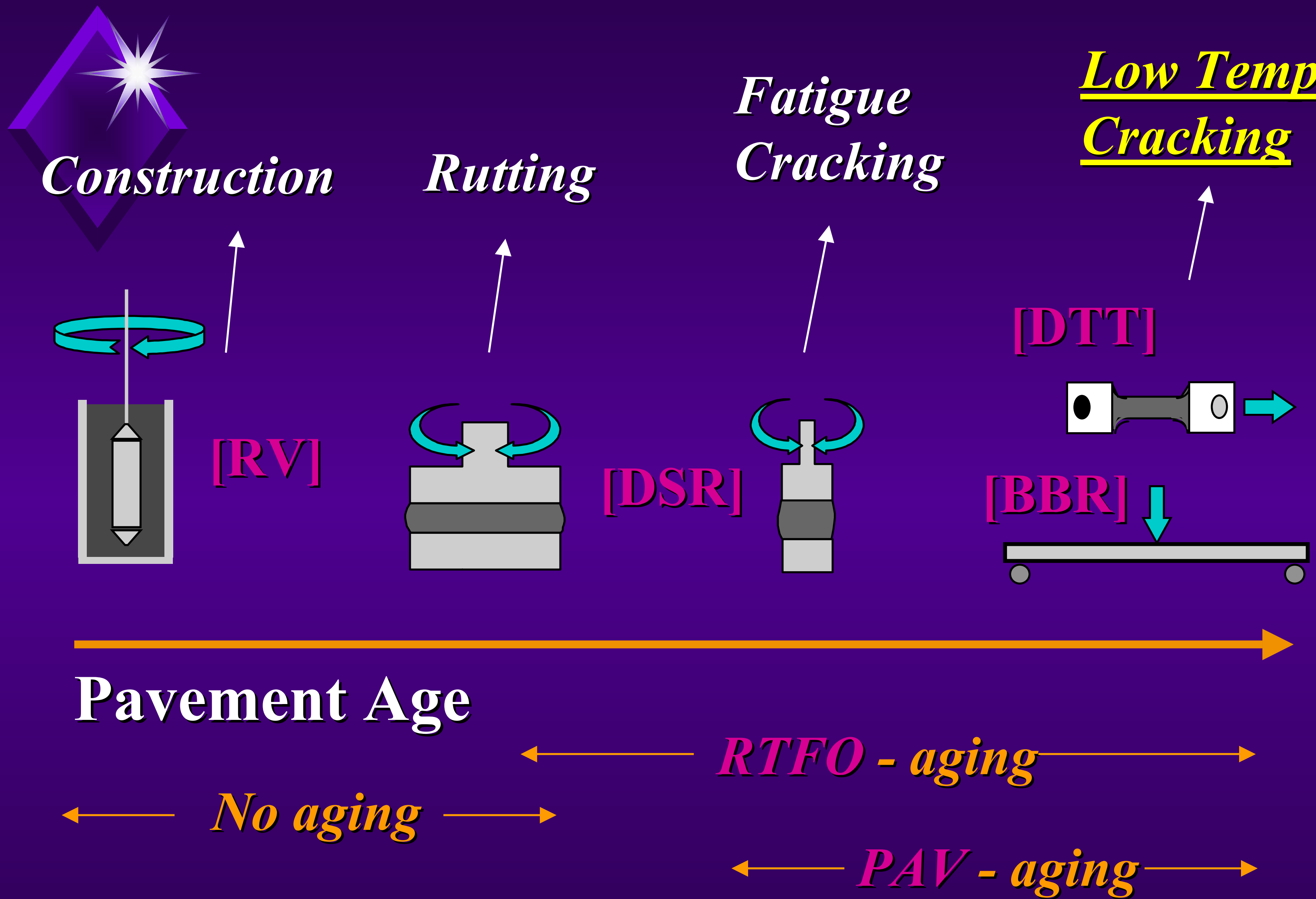
Fatigue Cracking Specification - Maximum Stiffness @ $T_{(inter)}$

- $G^* \sin \delta < 5000$ kPa on PAV aged binder



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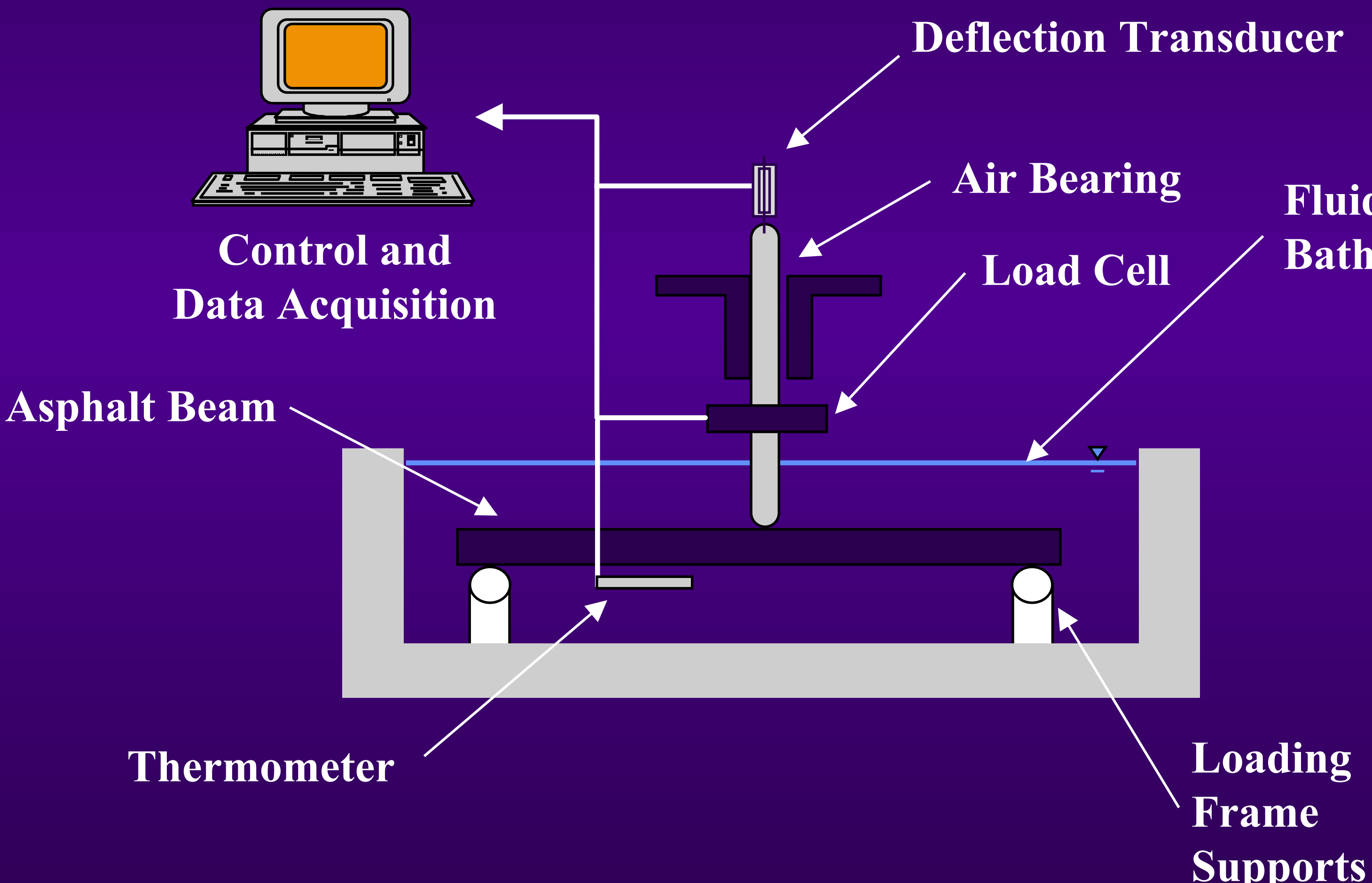
Superpave Binder Specification

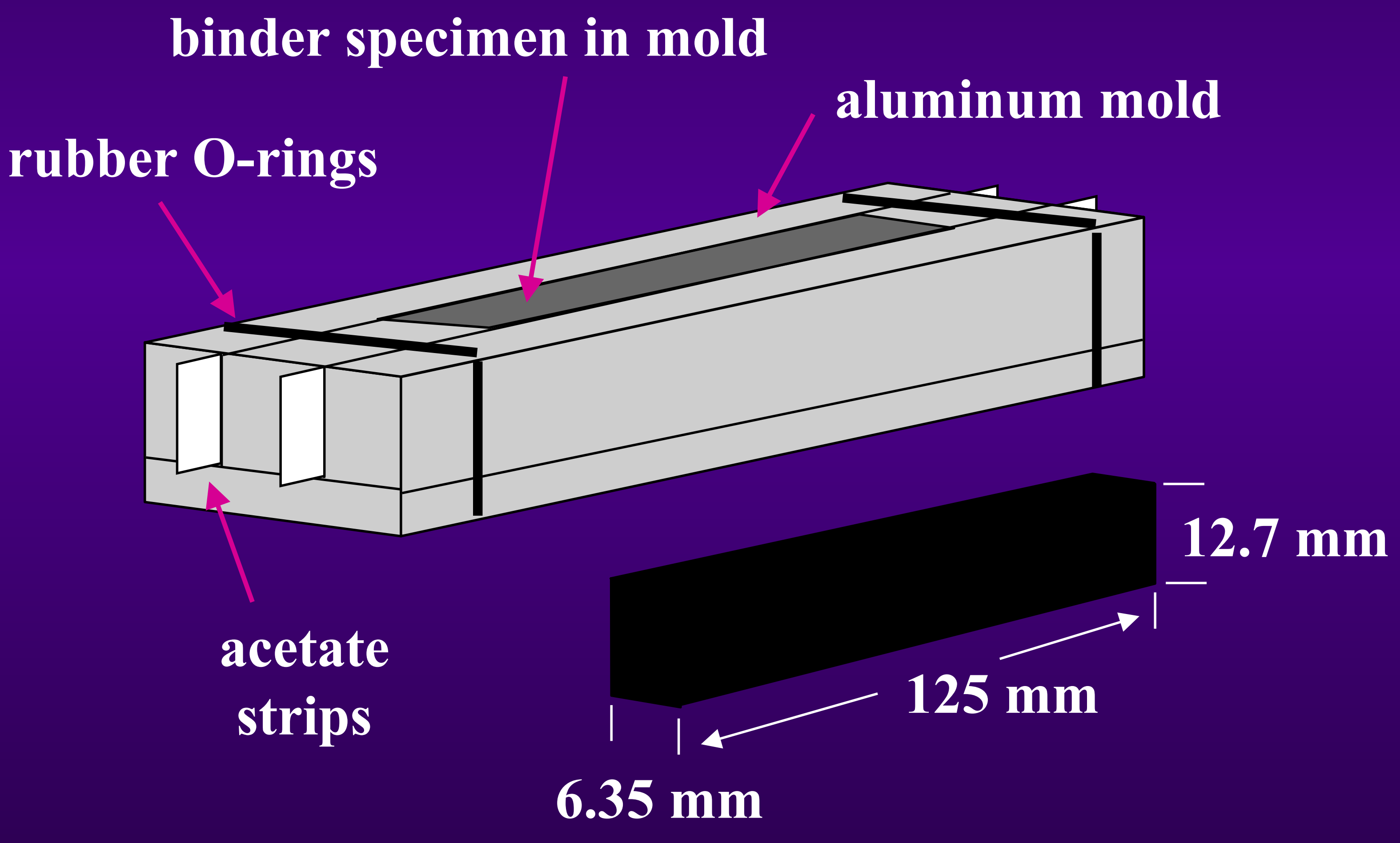
Low Temperature Characterization

- **The Bending Beam Rheometer (BBR) determines the Creep Stiffness (S) of an asphalt binder at low temperatures.**
- **If a binder is too stiff at service temperatures, you can expect low temperature cracking.**

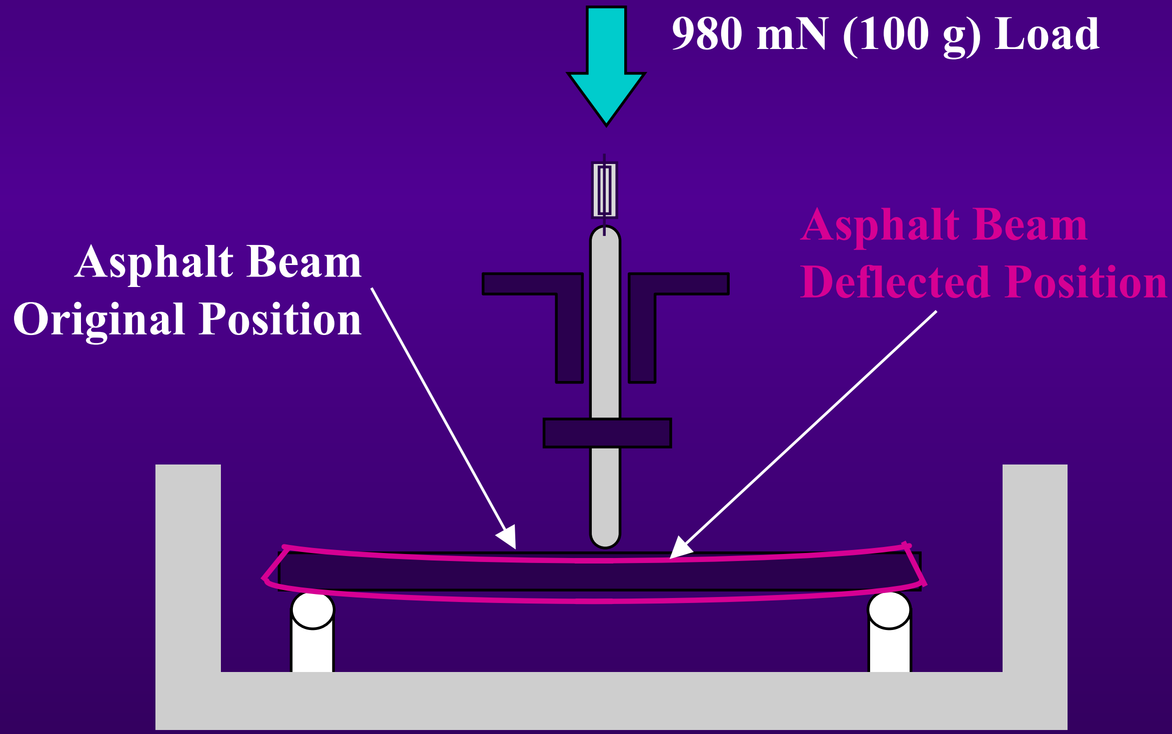
Bending Beam Rheometer, BBR



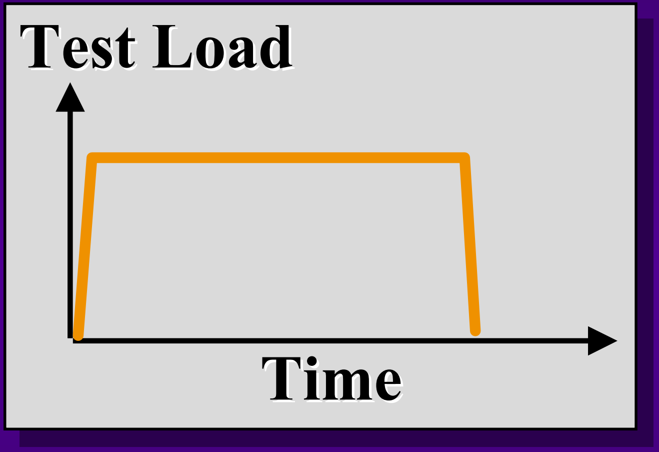
Bending Beam Rheometer, BBR

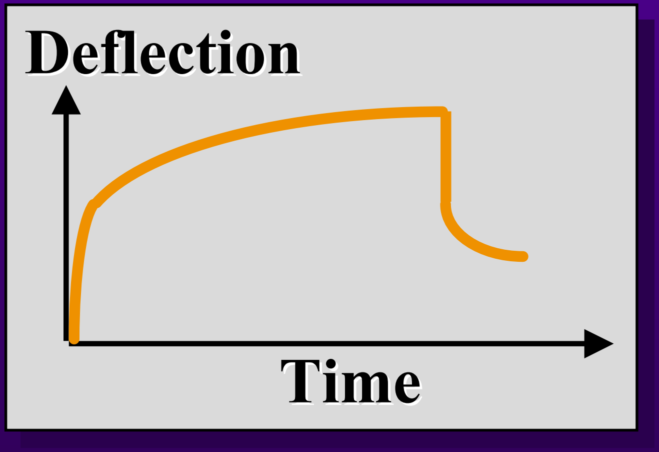


Bending Beam Rheometer, BBR

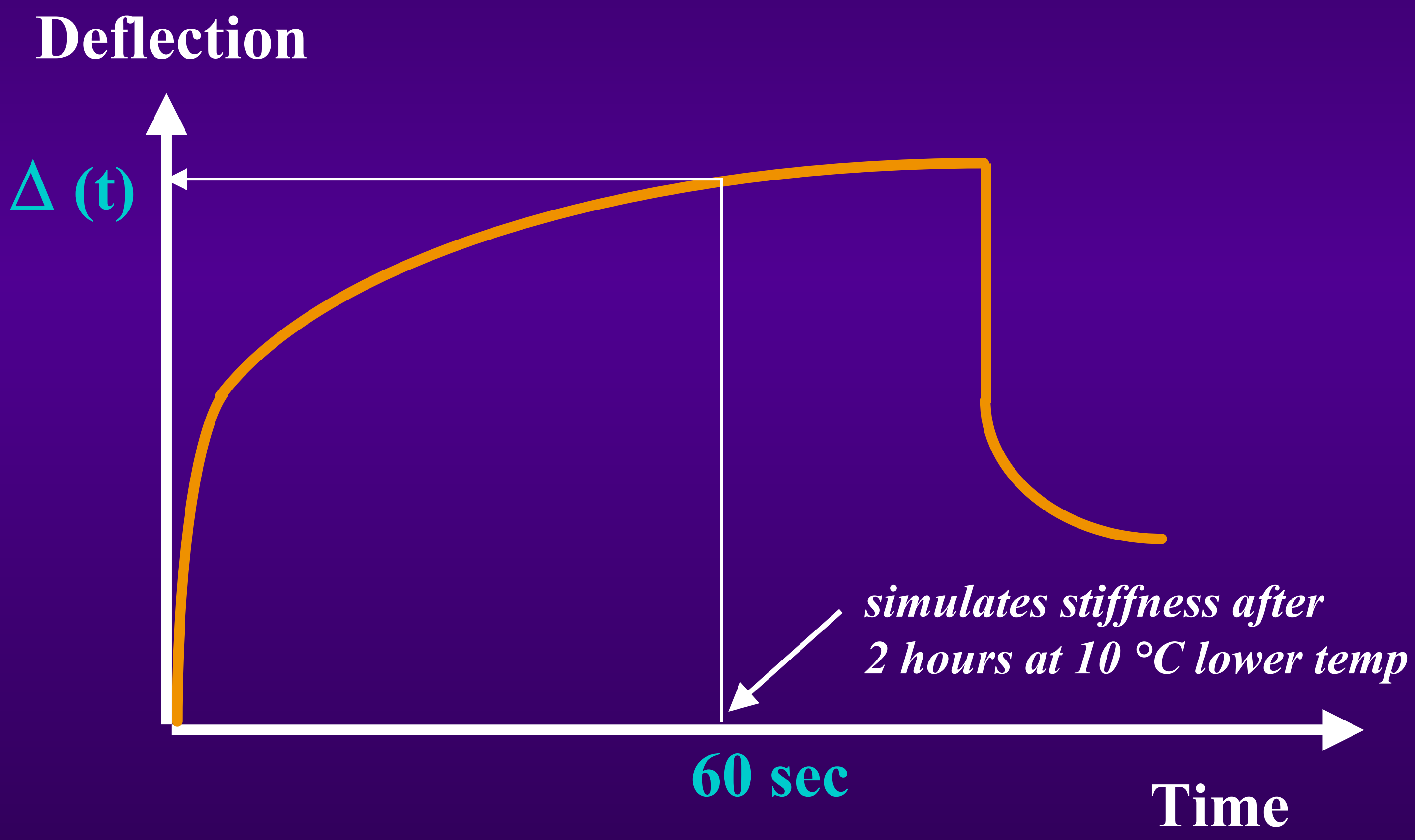


***B**ending **B**eam **R**heometer, BBR*

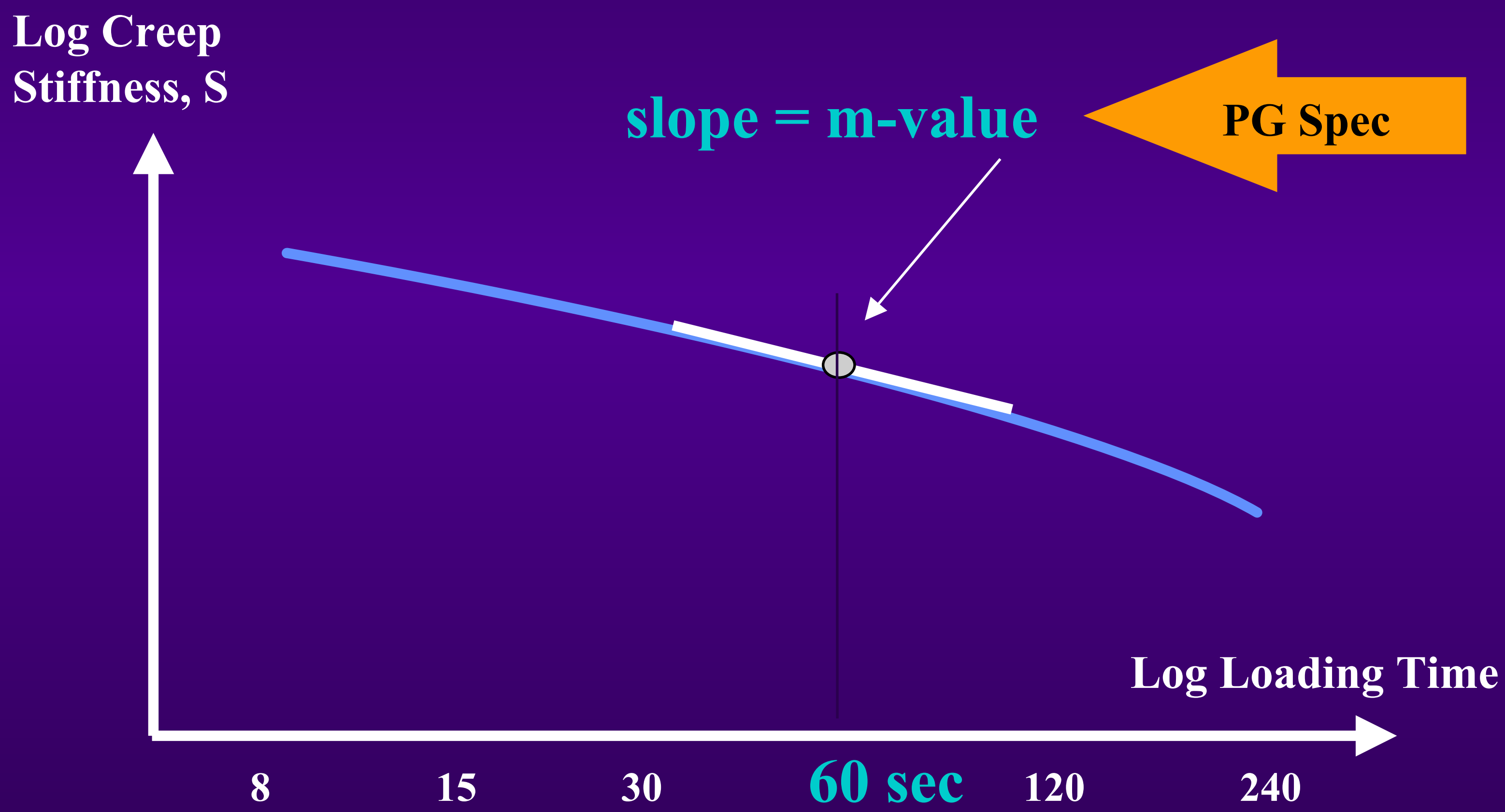




Bending Beam Rheometer, BBR



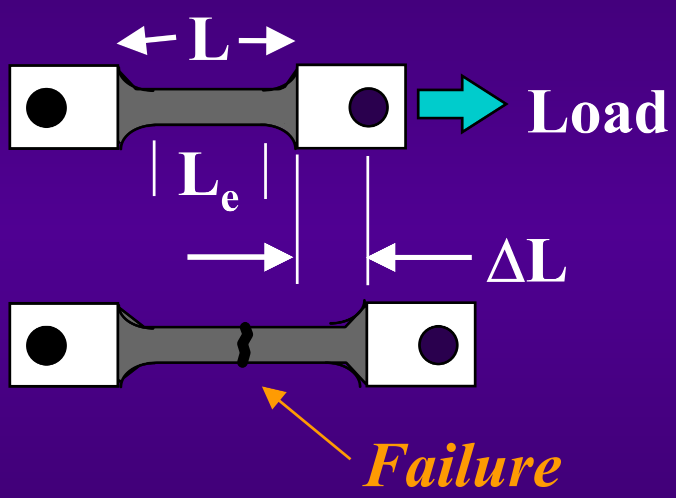
BBR Data - Relaxation



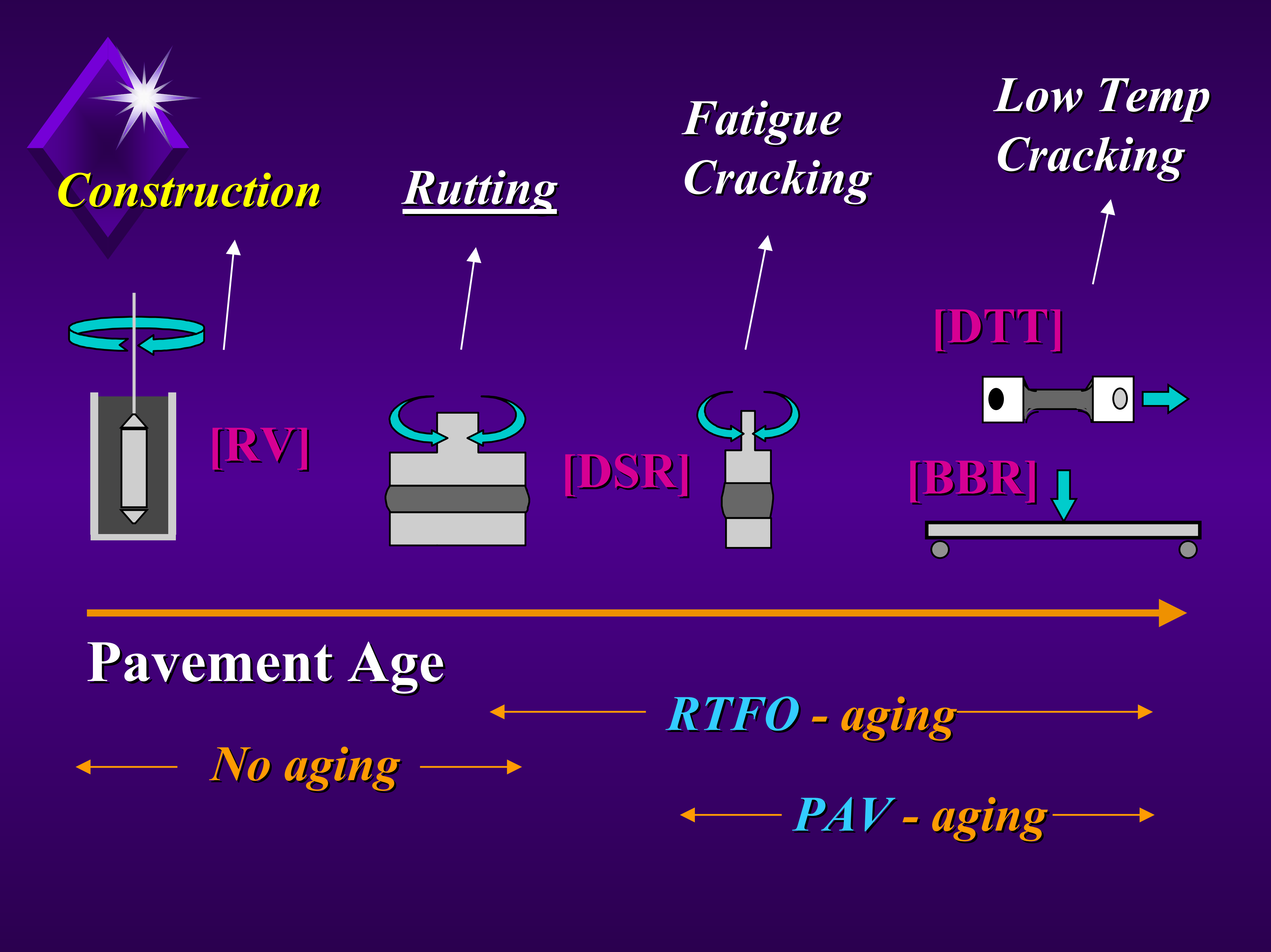
Low Temperature Cracking Specification

- Maximum Creep Stiffness Value (S)
  - S < 300 MPa
- Minimum m-value
  - m > 0.300

Direct Tension Test, DTT



$$\text{failure strain } (\varepsilon_f) = \frac{\text{change in length } (\Delta L)}{\text{effective gauge length } (L_e)}$$



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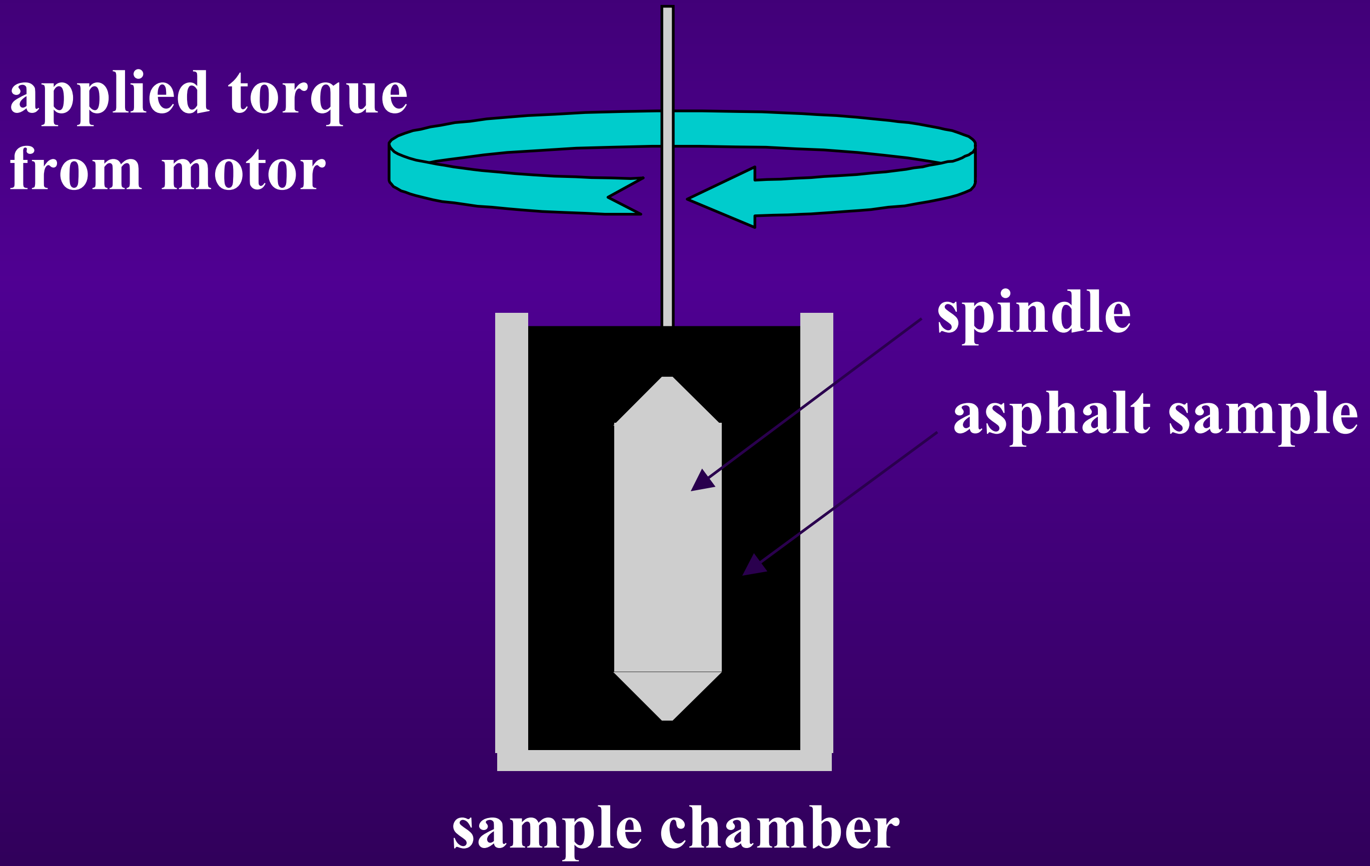
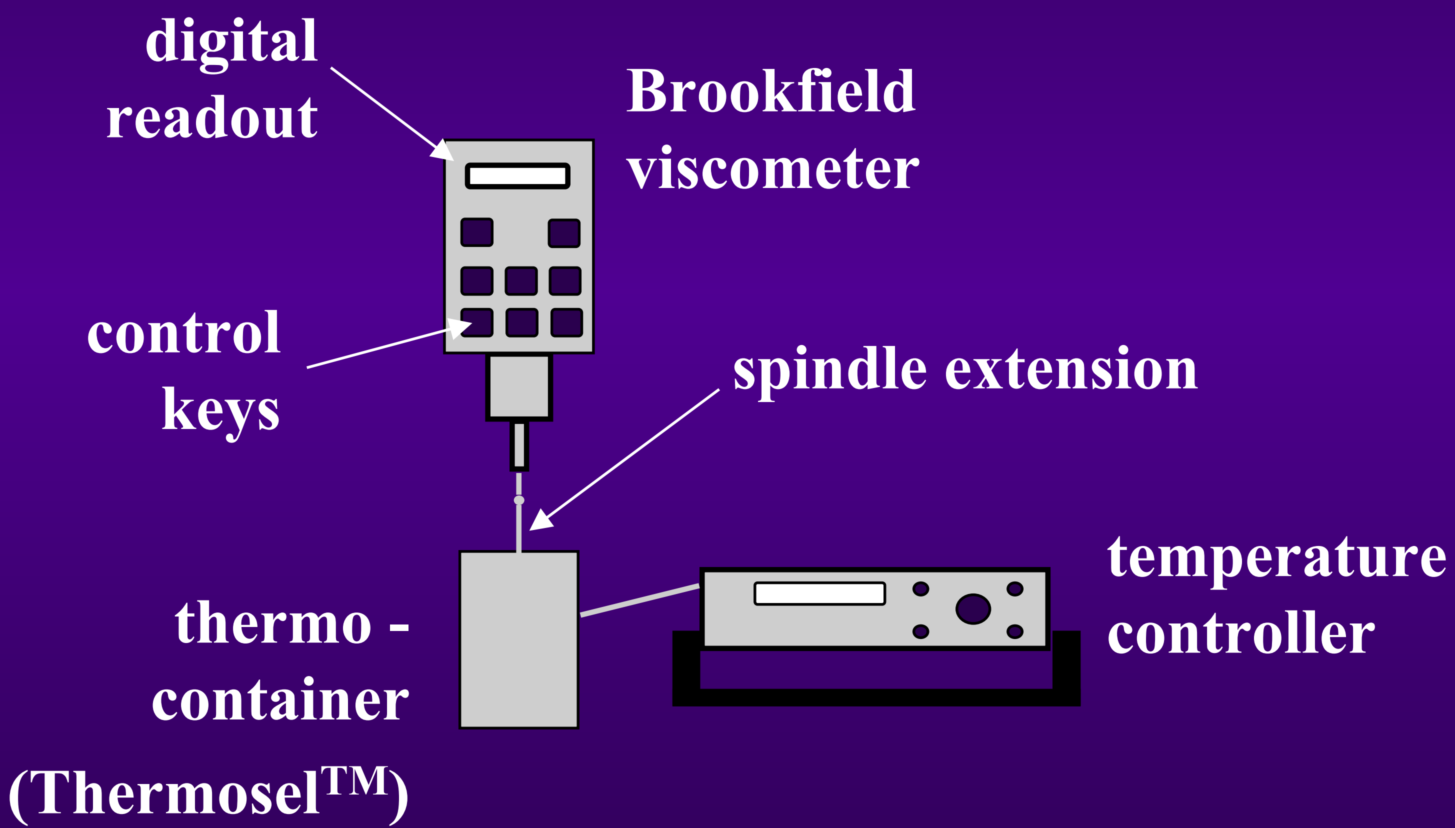
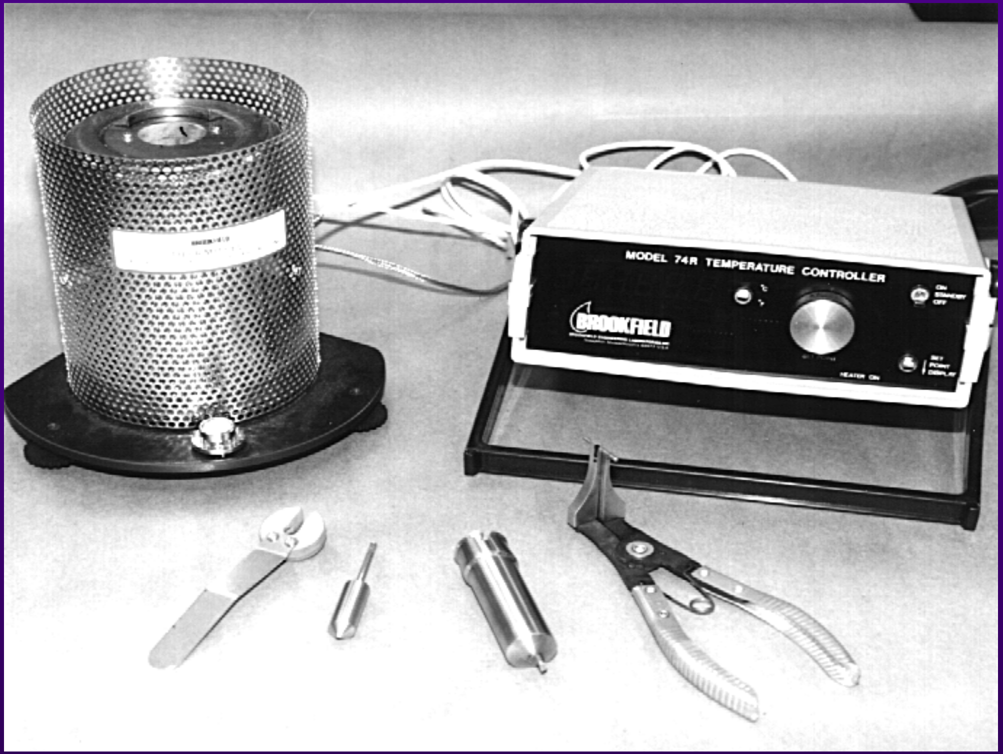
Rotational Viscometer



Rotational Viscometer



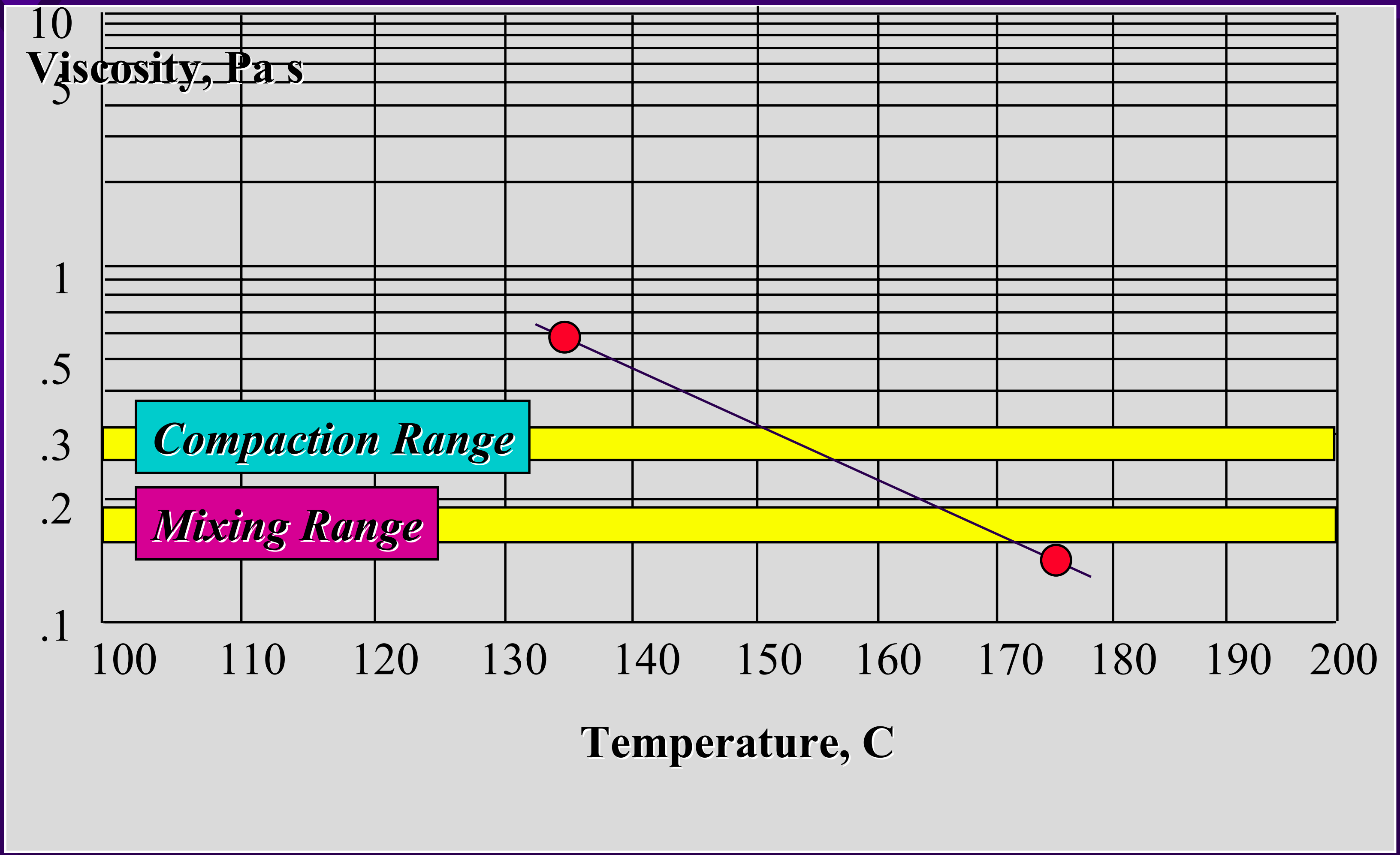
Rotational Viscometer



Rotational Viscometer Specification

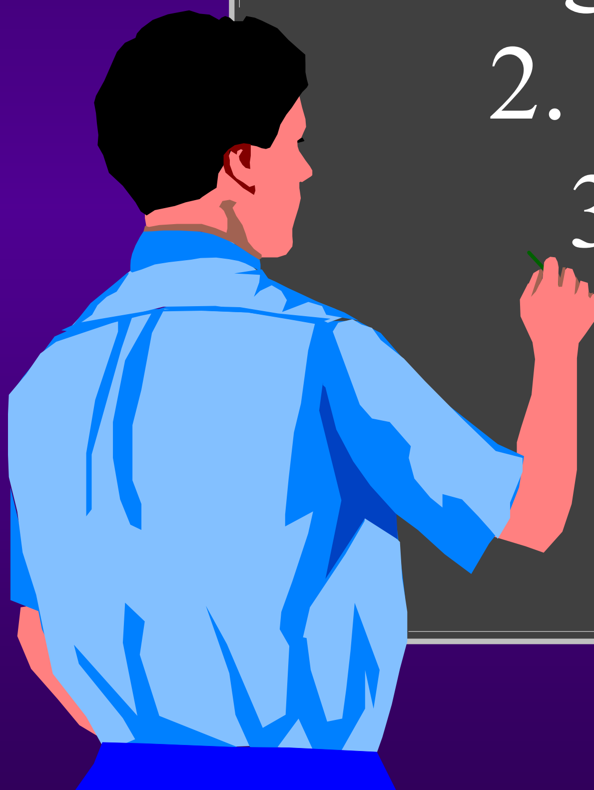
- Viscosity @ 135°C < 3.0 Pa-s
- Run viscosity at both 135°C and 165°C to determine laboratory mixing and compaction temperatures

Lab Mixing & Compaction Temperatures for Unmodified Asphalt

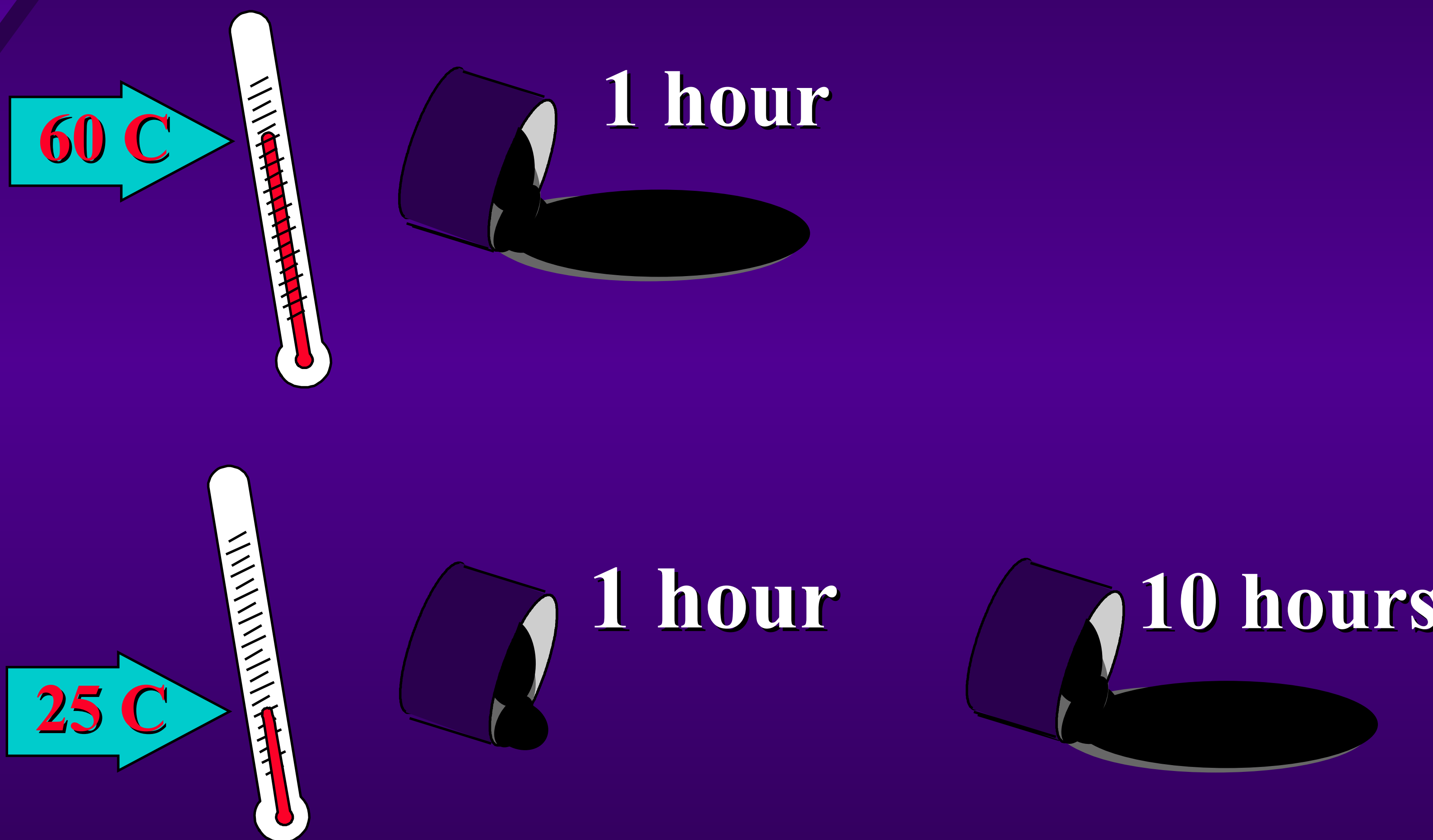


Asphalt binder's response to loading is a function of. . .

1. age
2. temperature
3. rate of loading



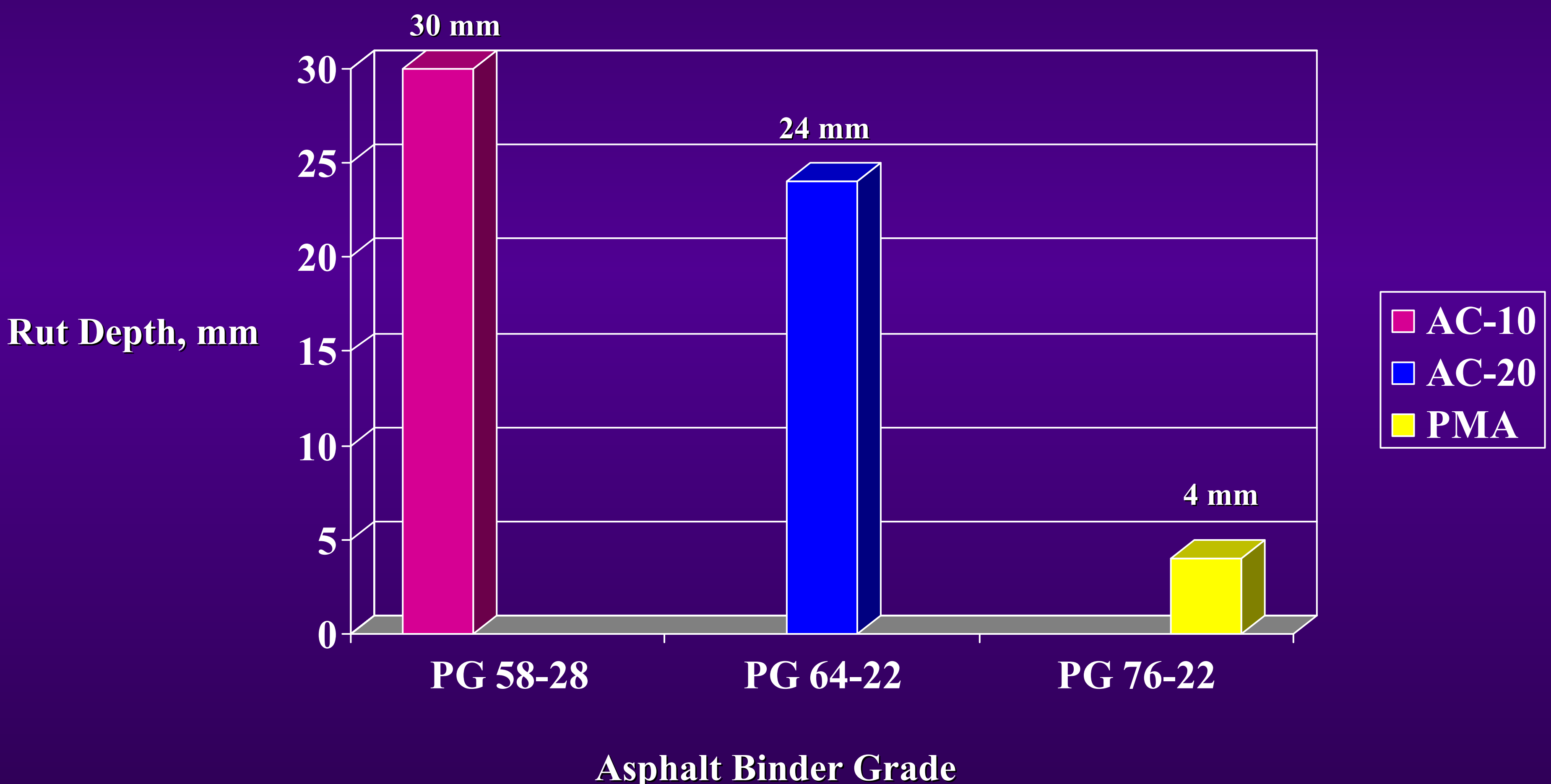
Time vs. Temperature



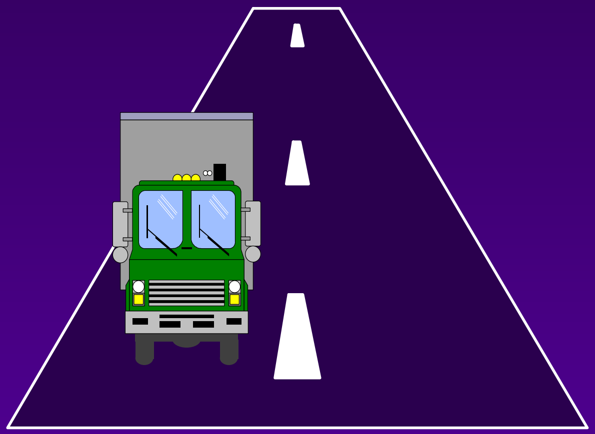

FHWA – ALF PG Binder Study

FHWA ALF Binder Study

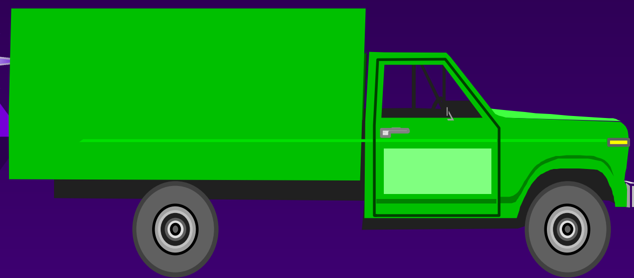
Rut Depth @ 5000 passes of ALF
11 mph @ 58ºC



Effect of Loading Rate on Binder Selection



- **Example**
  - **for 55 mph highway PG 64-22** ← ***Standard Grade***
  - **for 30 mph highway PG 70-22** ← **Slow - Bump one grade**
  - **for intersections PG 76-22** ← **Stopped - Bump one grade**

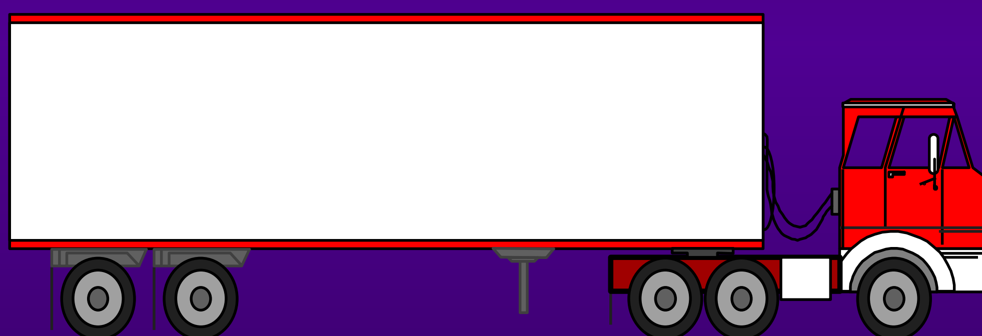


67 kN
15,000 lb
0.48 ESAL

+

27 kN
6,000 lb
0.01 ESAL

= **0.49 ESALs**



151 kN
34,000 lb
1.10

+

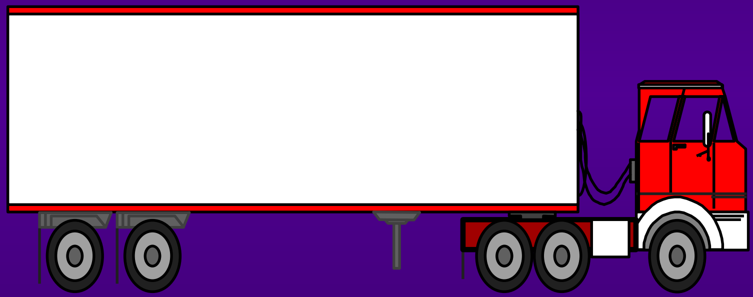
151 kN
34,000 lb
1.10

+

54 kN
12,000 lb
0.19

= **2.39 ESALs**

Effect of Traffic Amount on Binder Selection



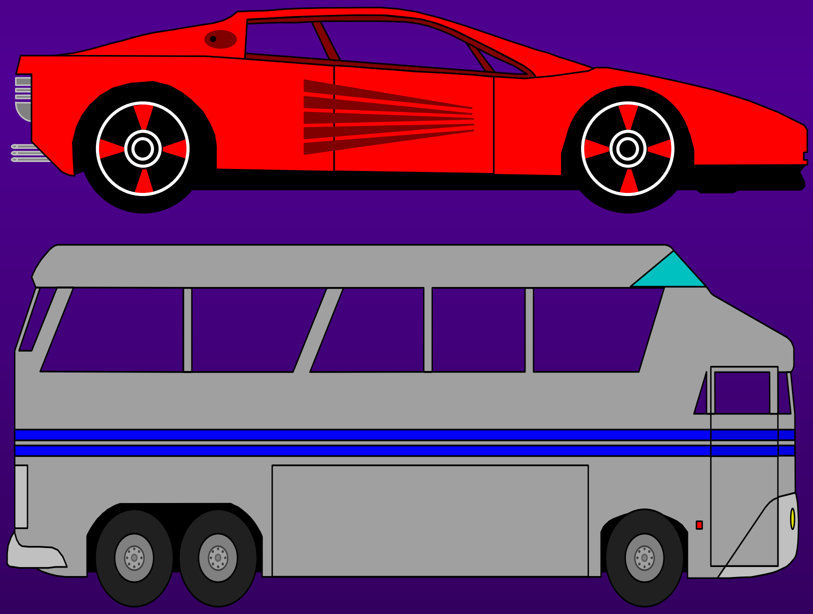
- **Traffic Loads on the pavement are measured in Equivalent Single Axle Loads (ESAL)**
- **20 year ESAL measurements are required in the SUPERPAVE system to correctly determine asphalt binder PG grade**

Effect of Traffic Amount on Binder Selection

> Equivalent Single Axle Loads

- $10 - 30 \times 10^6$ ESAL
  - Consider increasing - - one high temp grade
- $30 \times 10^6 +$ ESAL
  - Recommend increasing - - one high temp grade

SUPERPAVE Asphalt Binder Specification



- Selection is based on
  - Climate
  - Traffic speed
  - Amount of traffic - measured in ESALs
    - PG grade
    - Asphalt content of mix - durability

Rule # 1

PG 82
PG 76
PG 70
PG 64
PG 58

The higher the Grade, the stiffer the binder. The more rut resistance.

Rule # 2

PG - 22

- 28

-34

The lower the number, the more resistant to thermal cracking.

Rule # 3

Mix Cost + 15-20%

PG 82° ⟷ 22° (104°)

PG 76° ⟷ 22° (98°)

PG 70° ⟷ 22° (92°)

Mix Cost + 3 - 5%

PG 64° ⟷ 28° (92°)

PG 64° ⟷ 22° (86°)

PG 58° ⟷ 28° (86°)

The greater the difference the higher the cost.

Questions?