Superpave Binder Specification

Why, When, What, How, and Where?

Workshop

Federal Highway Administration

Version 2.2 - Basic Intro

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Why a
specification ?

Superpave Binder Specification
Why, When, What, How, and Where?

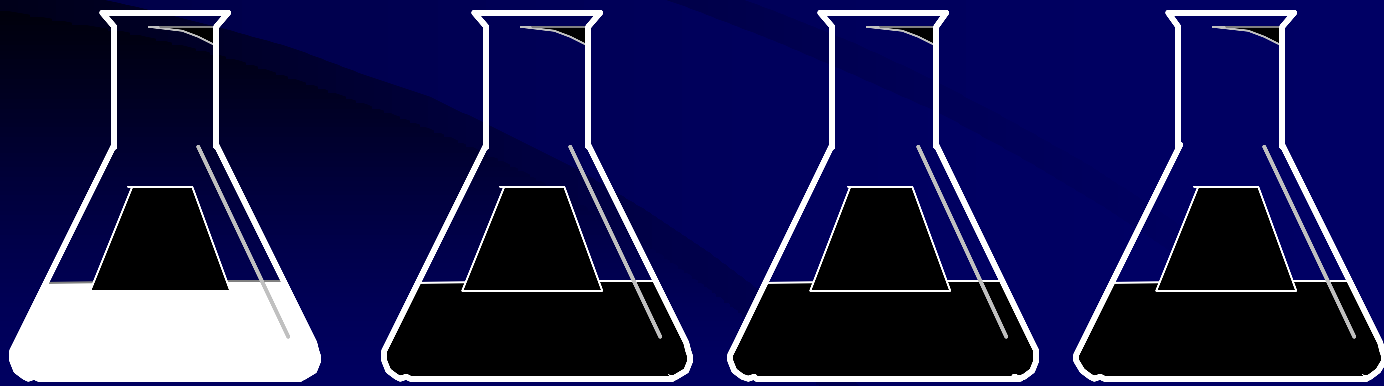
- Why?
  - **Q.** The goal of a specification is. . ?

Superpave Binder Specification
Why, When, What, How, and Where?

- Why?
  - **Q.** The goal of a specification is. . ?
  - **A.** To determine what materials provide acceptable performance.

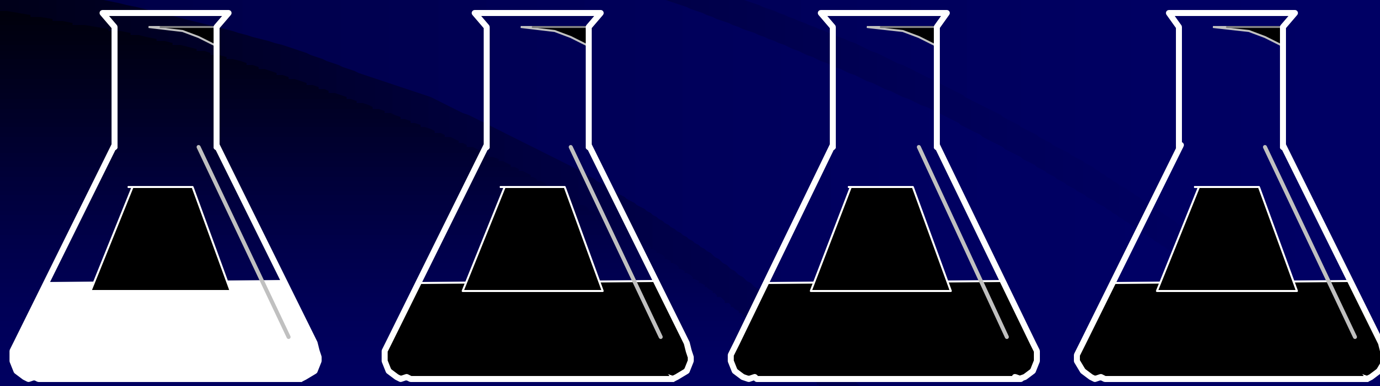
So we have four asphalt binders

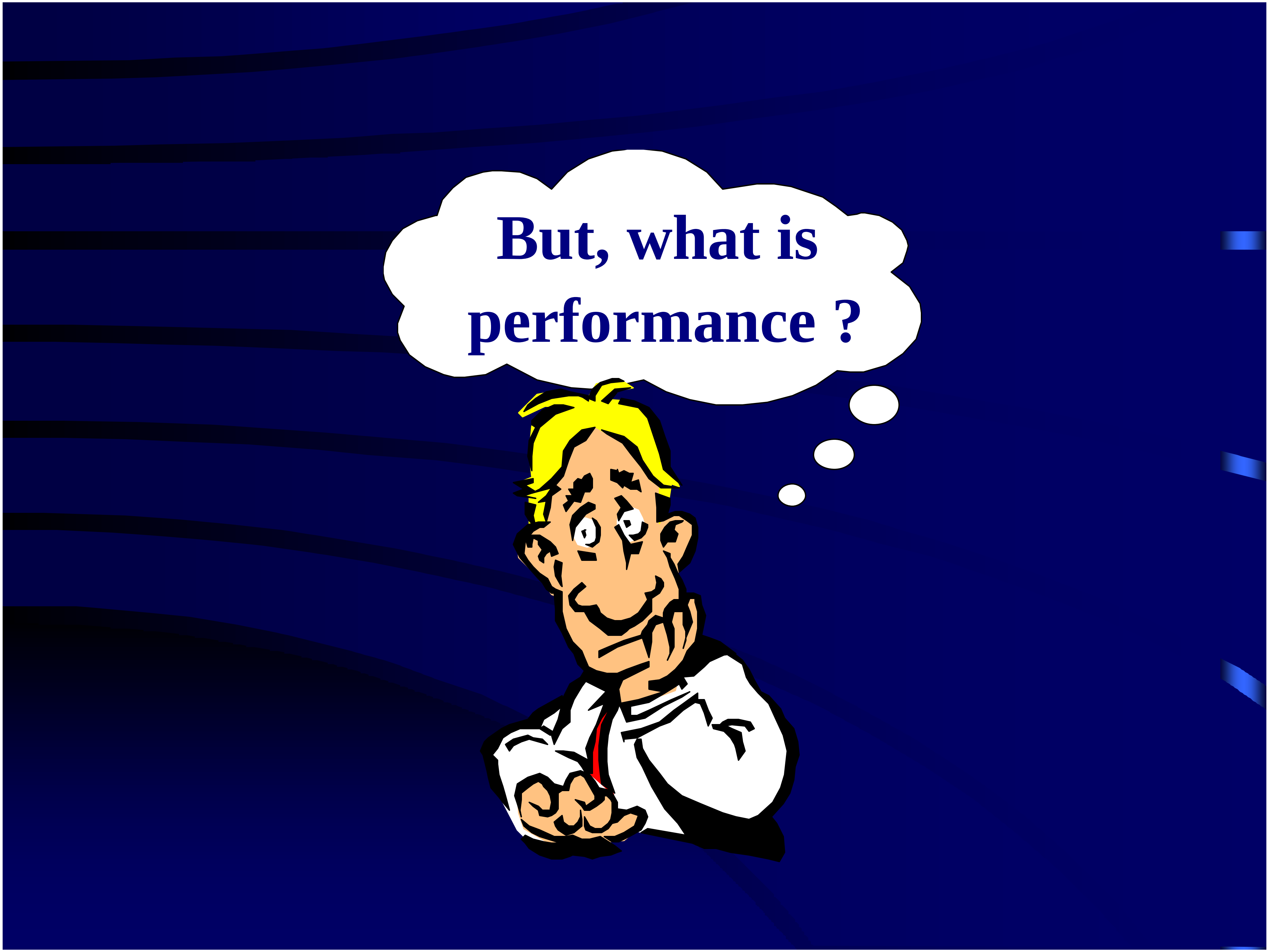
- **Q.** How do we determine which asphalt binder is best for our project?



So we have four asphalt binders

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




But, what is
performance ?

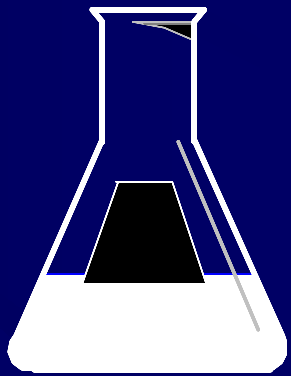
What is performance ? Is it. . .

15 to 20 years of service under traffic with minimal maintenance.

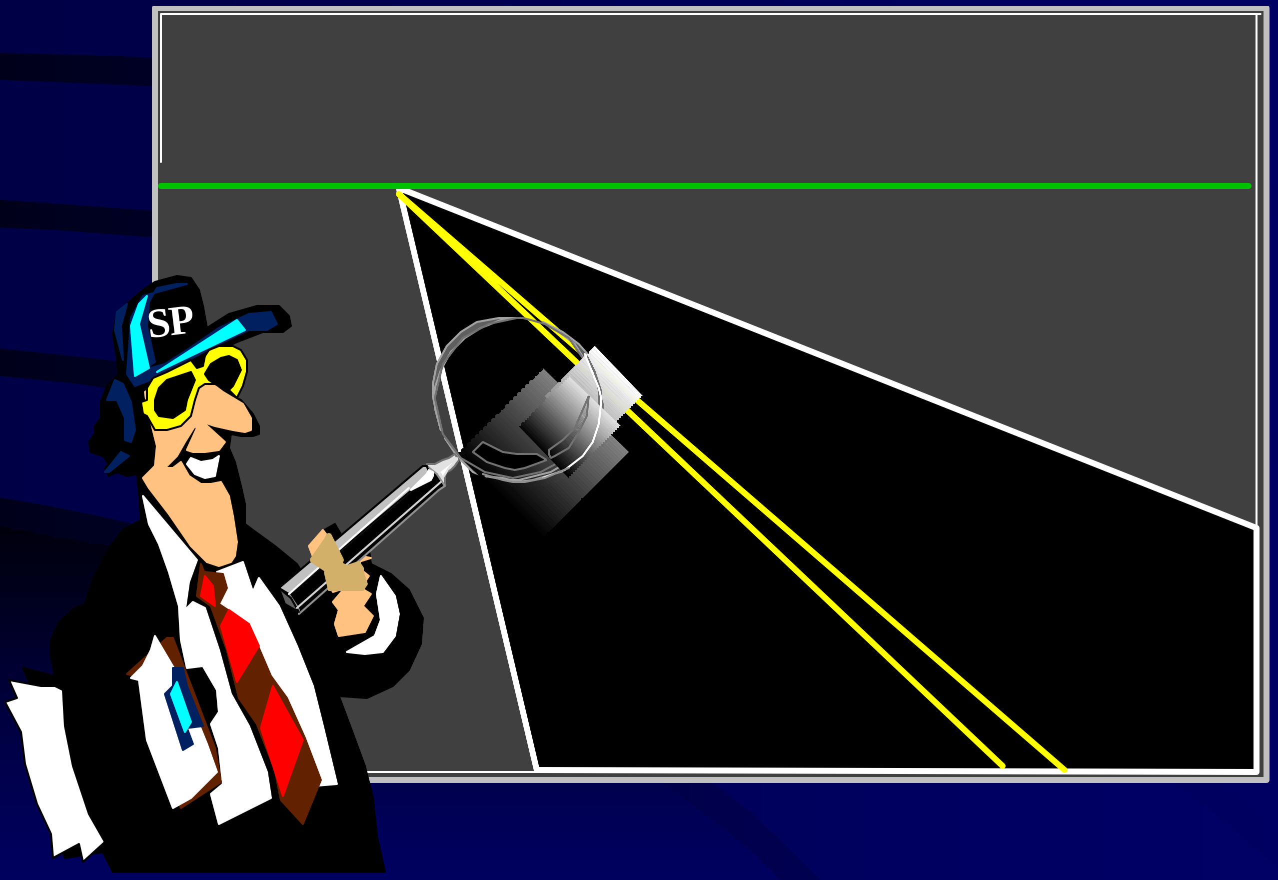
Performance ?

- **Q.** What areas of poor performance do we want to address ?

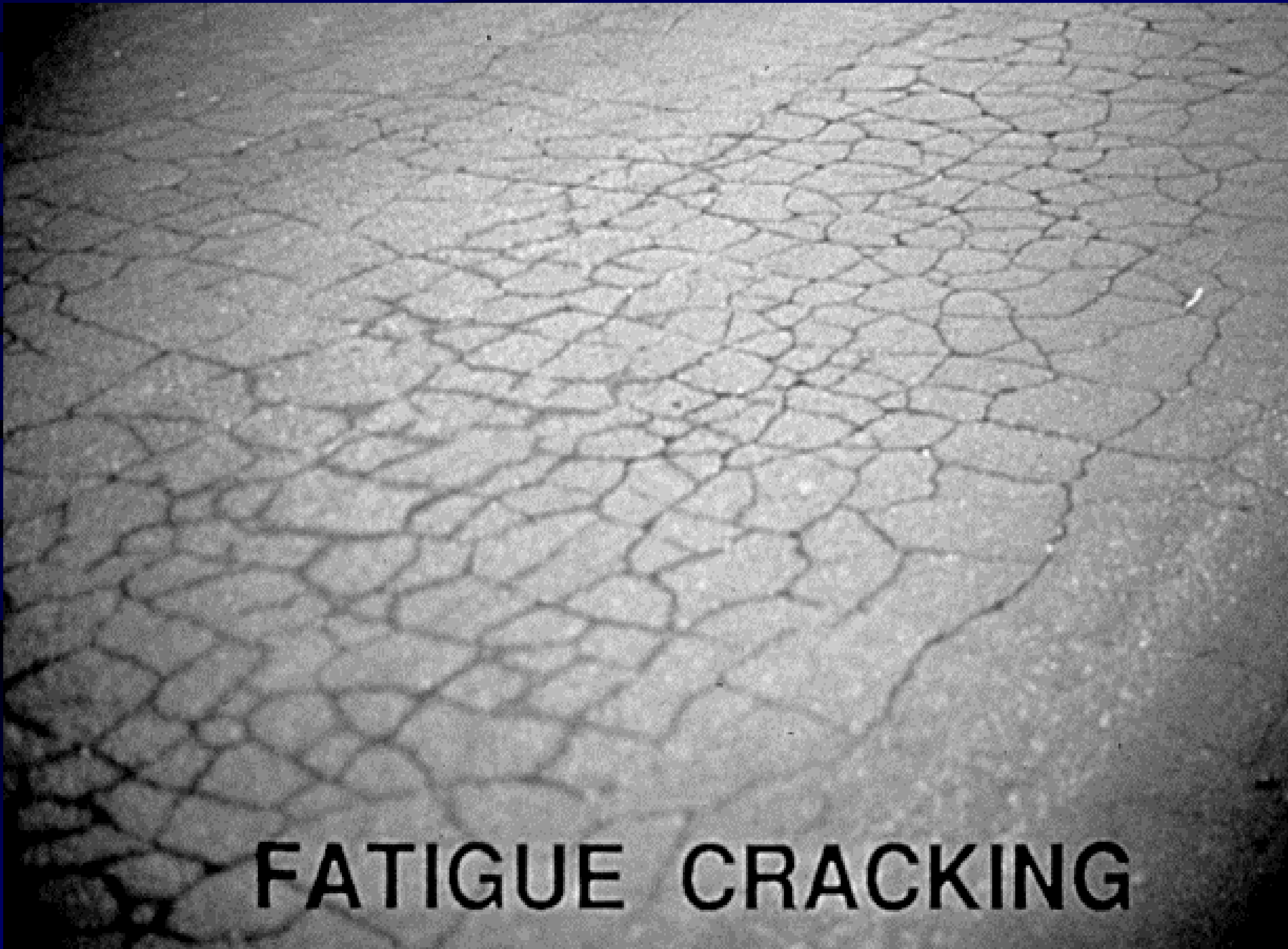
- Or, in other words, how do our asphalt pavements fail ?

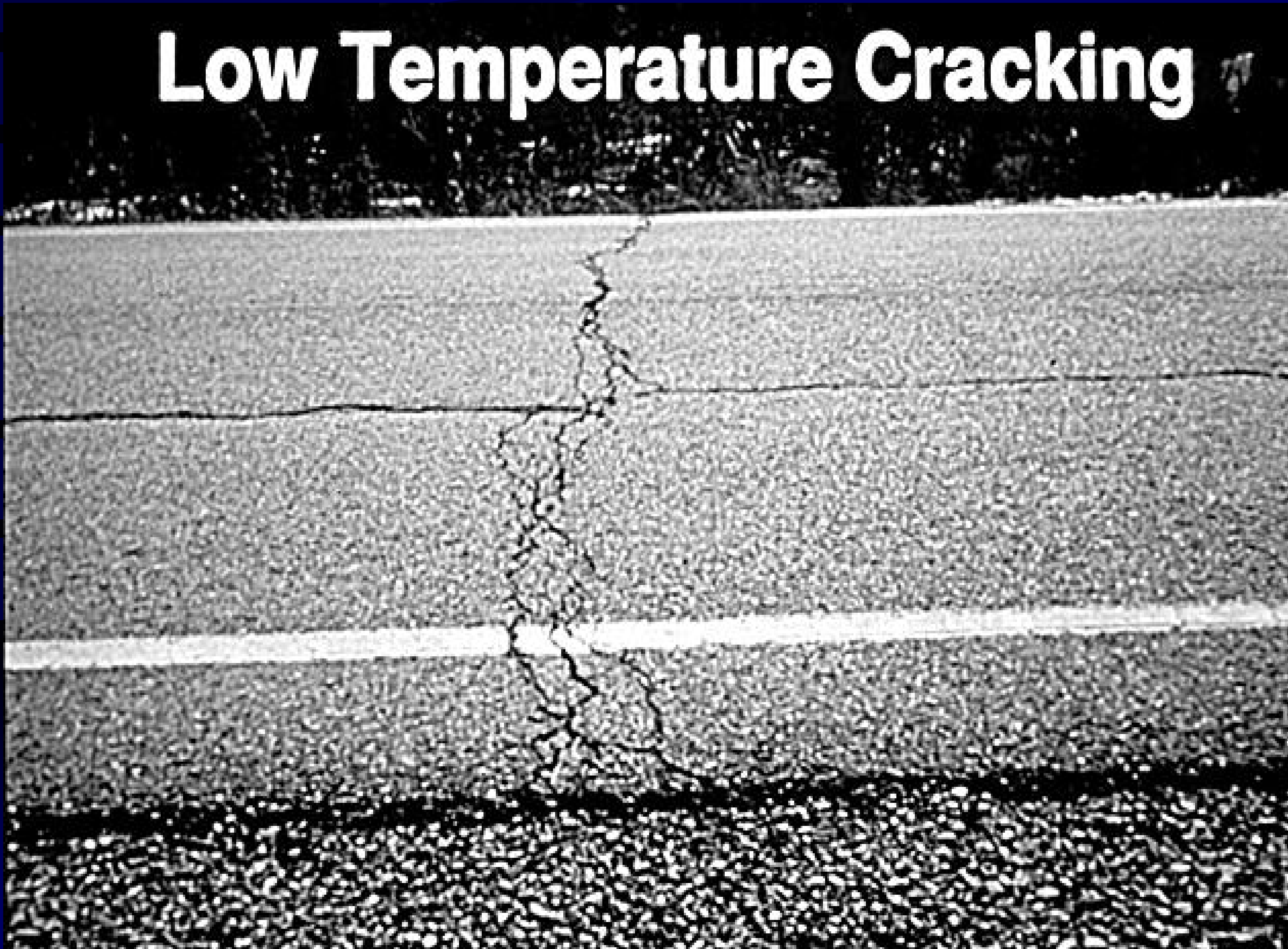


How do asphalt pavements fail ?




Rutting


FATIGUE CRACKING


Low Temperature Cracking

How do asphalt pavements fail ?

1. **Rutting**

   (Permanent Deformation)

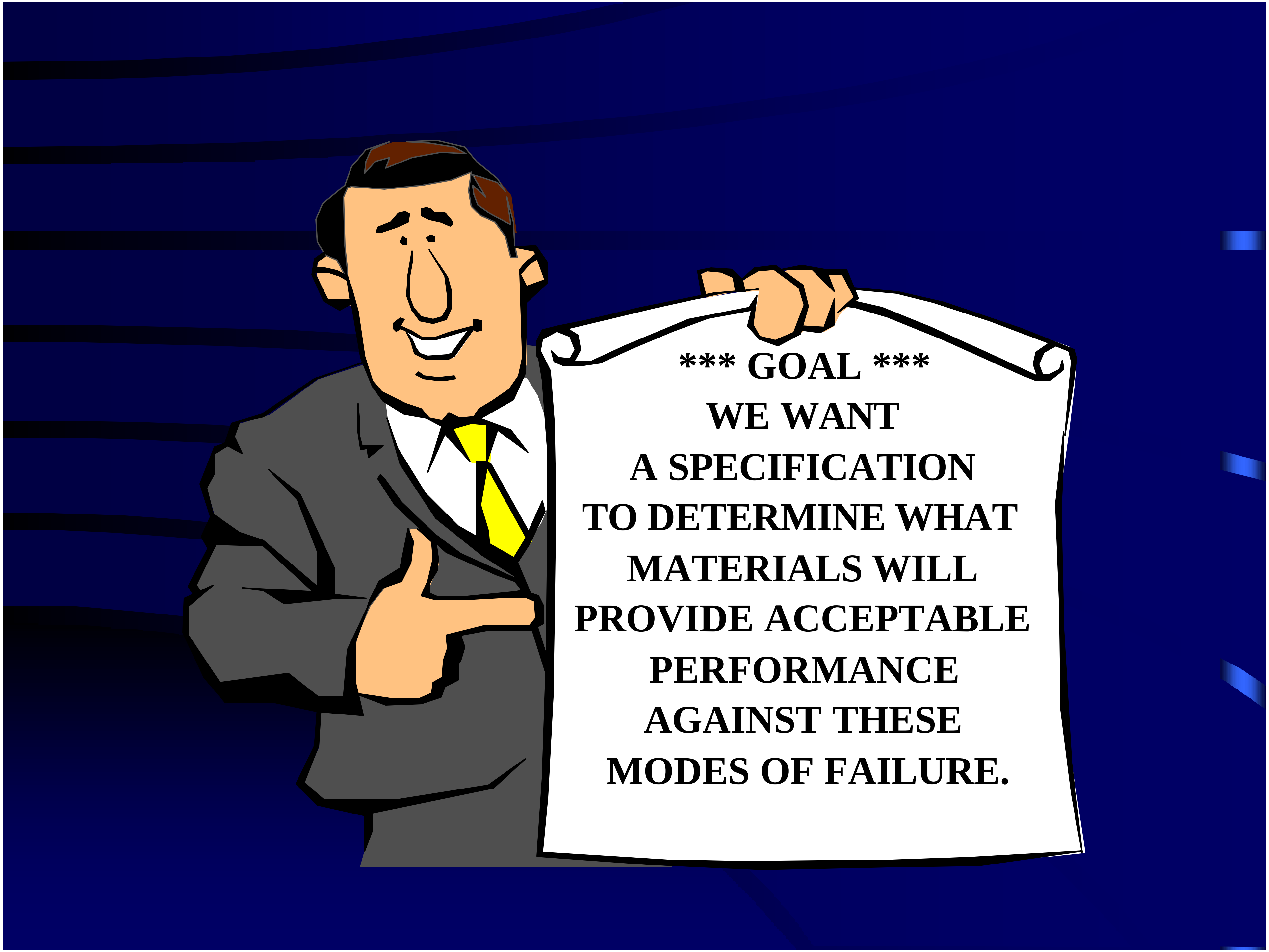
2. **Alligator or Fatigue Cracking**

3. **Low Temperature Cracking**

   Shoving

   Bleeding

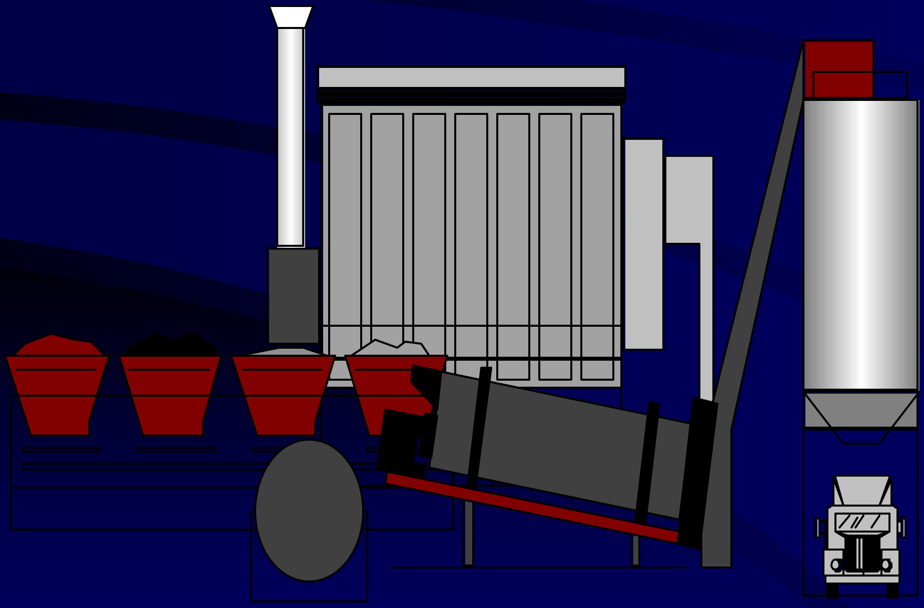
   Raveling

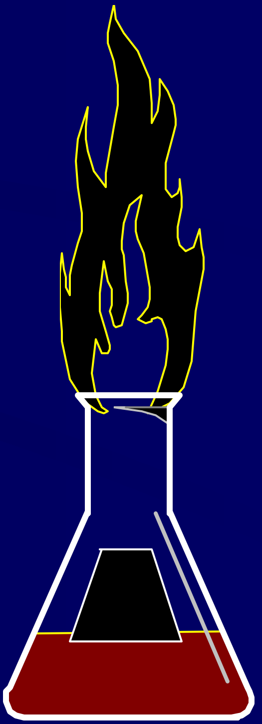

*** GOAL ***
WE WANT
A SPECIFICATION
TO DETERMINE WHAT
MATERIALS WILL
PROVIDE ACCEPTABLE
PERFORMANCE
AGAINST THESE
MODES OF FAILURE.

What other concerns should the specification address ?

Other concerns. . .

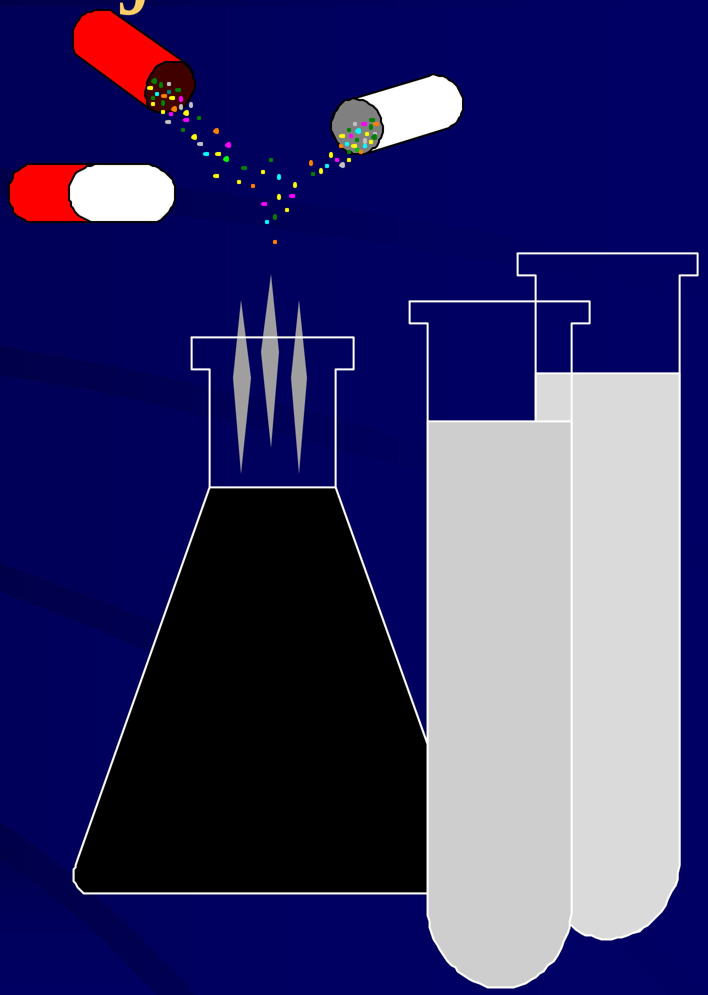
- Safety, and
- Construct-ability





Original SHRP Research Objective

- Chemical Specification for Asphalt Binders



Advanced Morphology

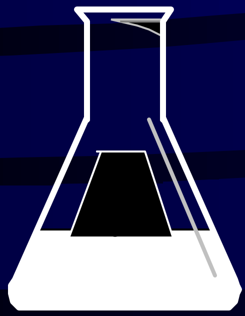
- Schopenhauer's Law of Entropy:

- If you put a spoonful of wine in a barrel full of sewage, you get sewage. If you put a spoonful of sewage in a barrel full of wine, you get sewage.

  – from The Complete Murphy's Law, Bloch

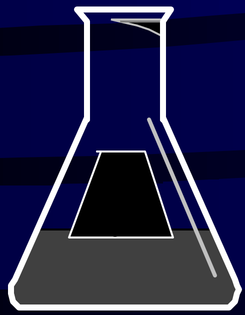
Final SHRP Research Product

- Performance-related specification based on physical characterization of asphalt binders.



Asphalt binders

- **Q.** Are the properties of asphalt binders constant over a pavements performance life?



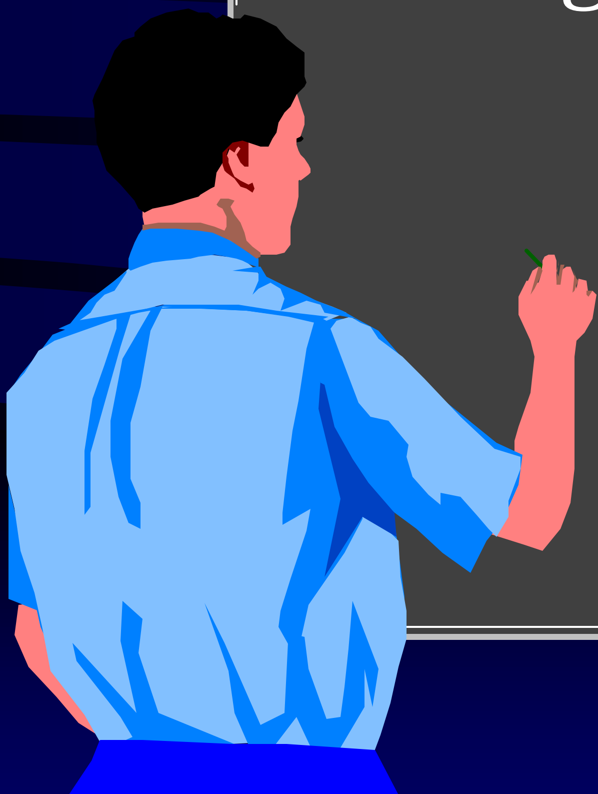
Asphalt binders

- **Q.** Are the properties of asphalt binders constant over a pavements performance life?

- **A.** NO! An asphalt binder's response to loading is a function of three factors. . .

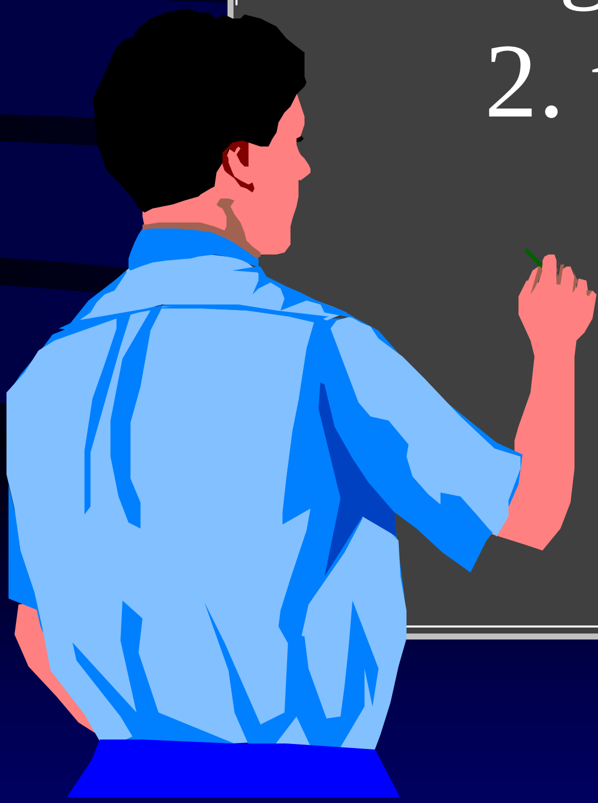
Asphalt binder's response to loading is a function of. . .

1. age



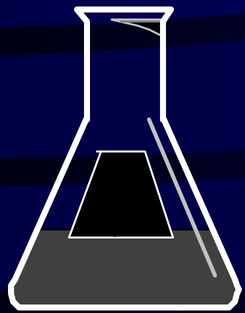
Asphalt binder's response to loading is a function of. . .

1. age
2. temperature



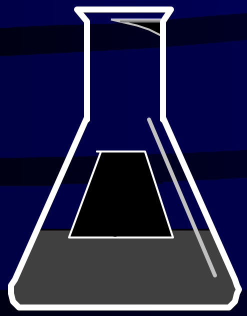
Asphalt binder's response to loading is a function of. . .

1. age
2. temperature
3. rate of loading



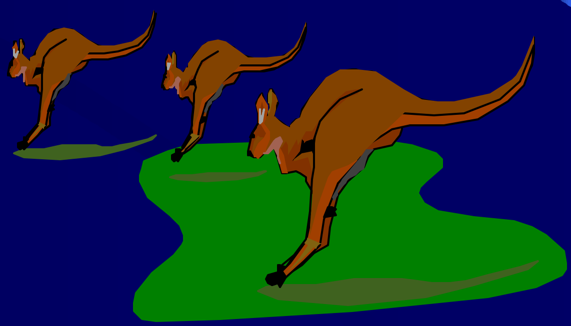
Aging

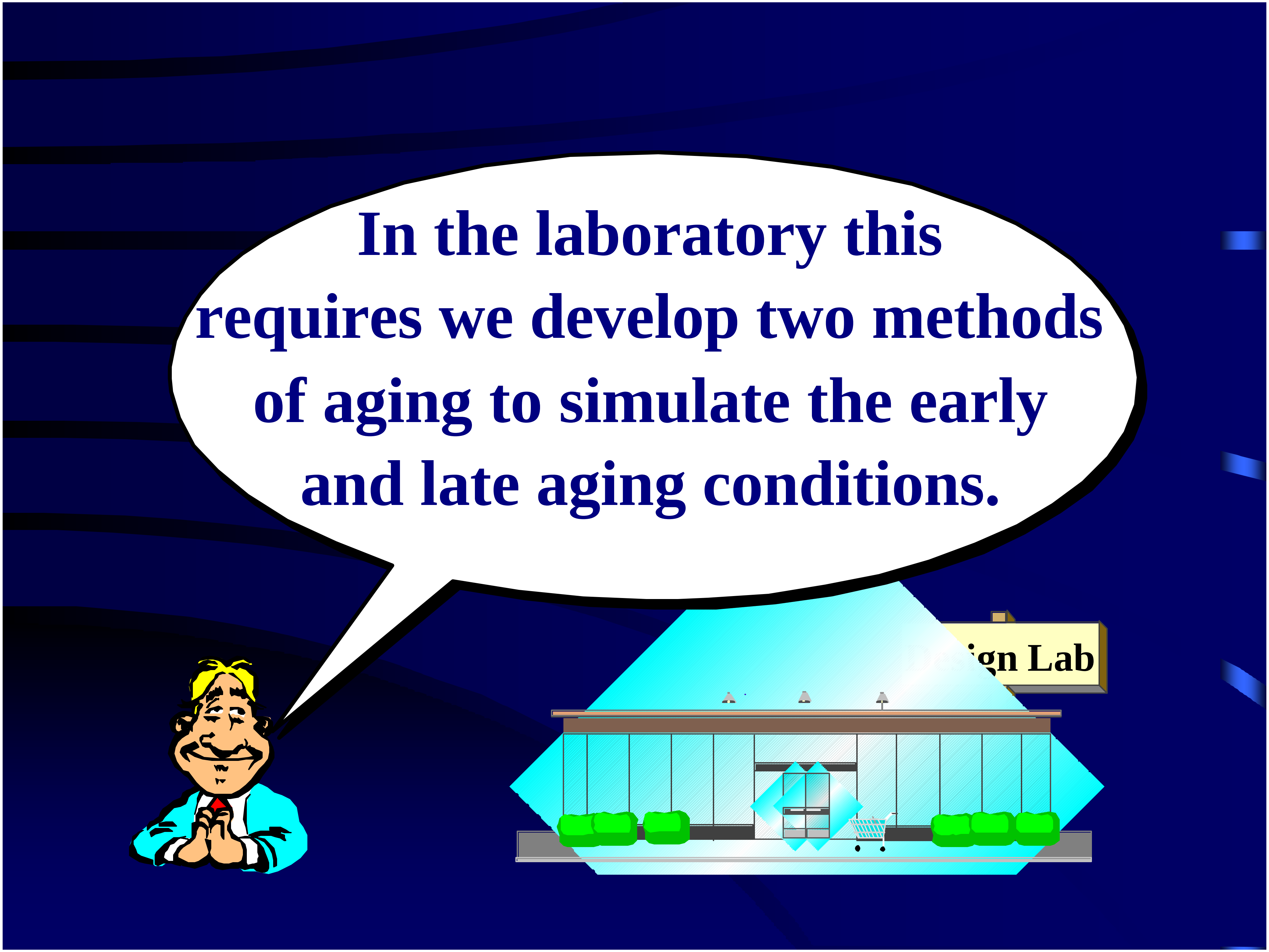
- Asphalt binders undergo aging through the loss of volatiles *(a.k.a. loss of light ends)* and oxidation.
- From the standpoint of accessing an asphalt binder's performance there are three key ages we need to address.



Key Aging

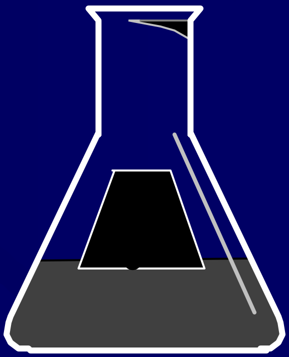
- During construction
- Early in the pavement's life
  - Post construction to roughly two years
- Late in the pavement's life
  - Seven plus years of service



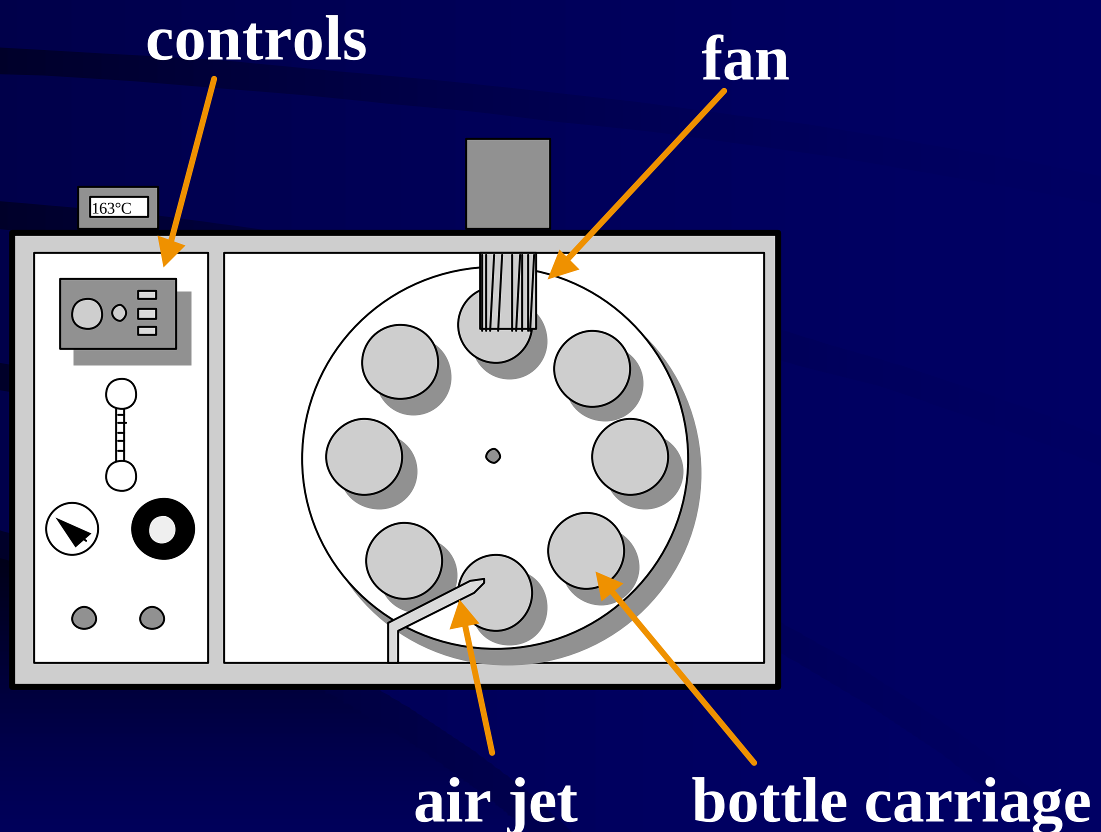

In the laboratory this
requires we develop two methods
of aging to simulate the early
and late aging conditions.

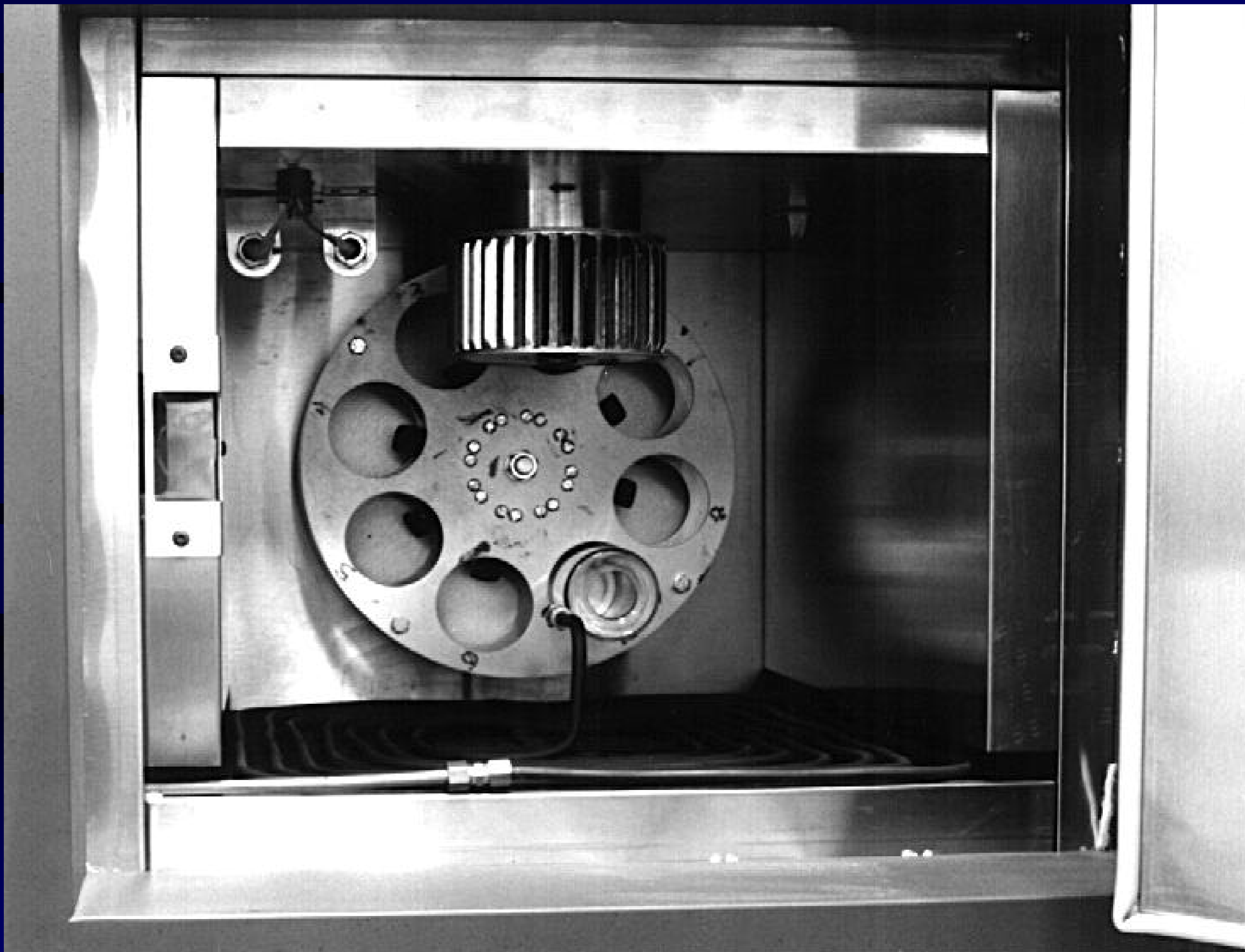
Aging - How ?

- **Early:** To simulate the aging that occurs due to construction and initial service, we are going to employ the Rolling Thin-Film Oven *(RTFO)*. This is a standard AASHTO test method, T 240.
  - Spec.: 85 minutes, 163°C,
    400 ml of air per minute, 15 rpm

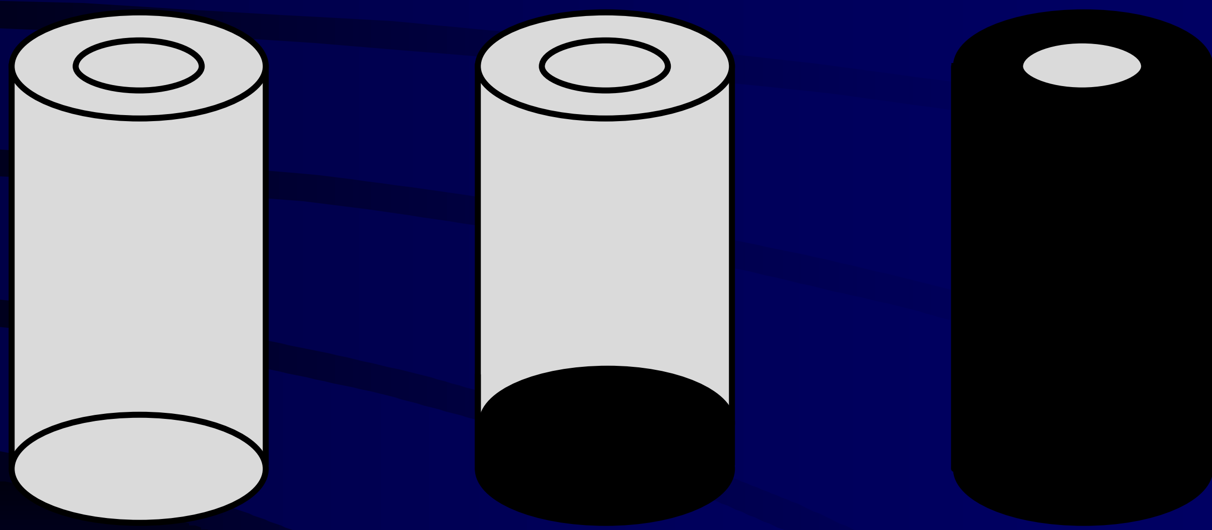


Rolling Thin Film Oven





Rolling Thin Film Oven Sample Bottles



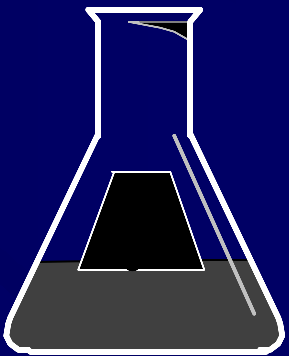
Clean Bottle Before Loading

After Loading

Coated Bottle After Testing

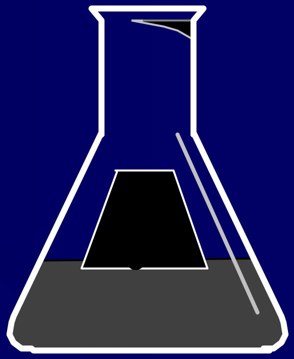
Aging - How ?

- **Late:** To simulate the aging that occurs due to oxidation over a pavement's life, we are going to subject the RTFO residue to time, temperature, and pressure. For this we are going to develop a pressure aging vessel, *(PAV)*.

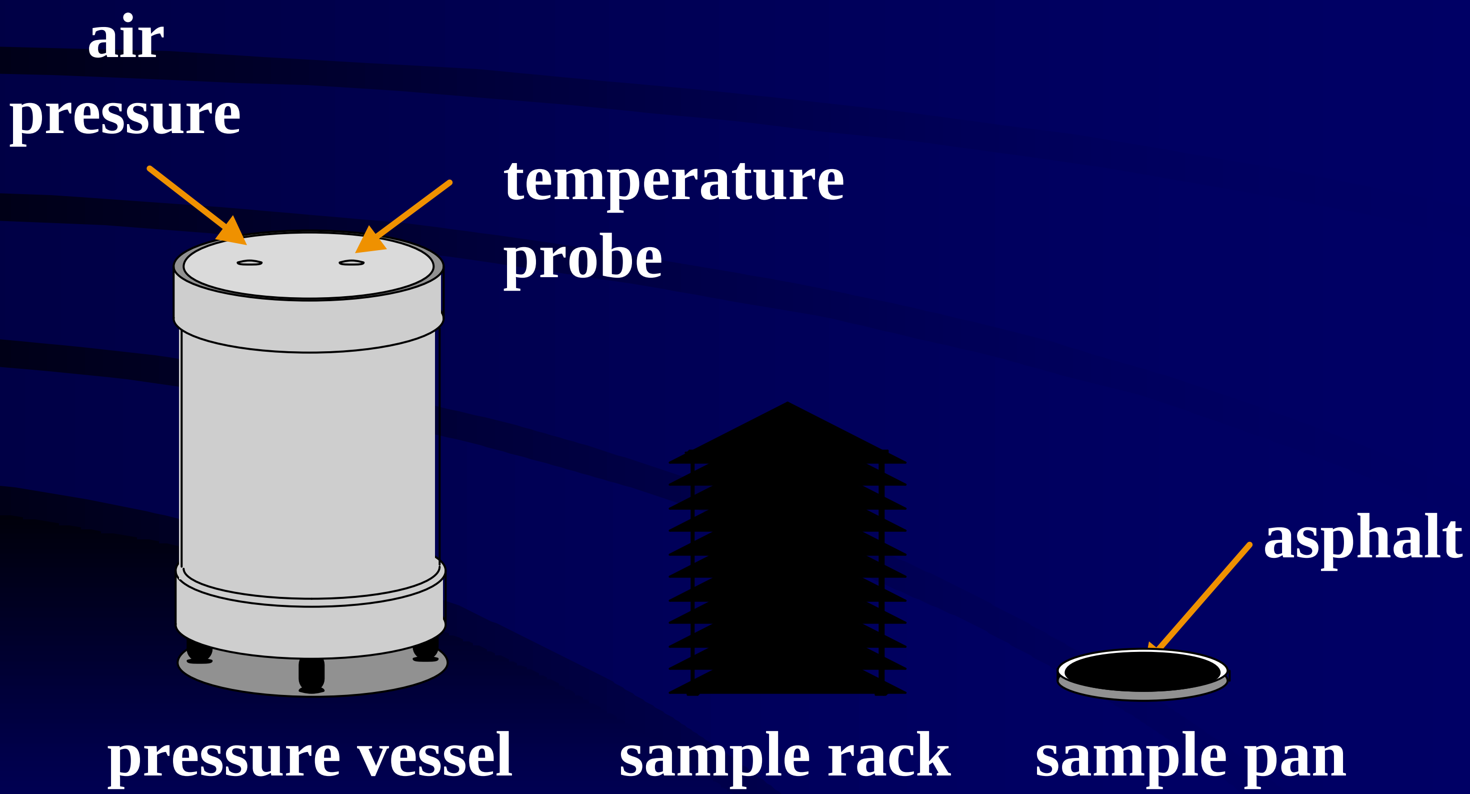


Aging - How ?

- **Late, Spec.:** We need to develop a provisional procedure for this, AASHTO PP1.
- According to PP1, our RTFO residue is subjected to:
  - Time: 20 hours
  - Temperature: 90 to 110°C
  - Pressure: 2.1 kPa



Pressure Aging Vessel



Superpave Binder Specification

Why, When, What, How, and Where?

- When ?
- **Q.** When do the 3 modes of failure occur in a pavements life?
  - – Rutting
  - – Fatigue Cracking
  - – Low Temp. Cracking

Superpave Binder Specification

Rutting, Fatigue and Low-Temp. Cracking

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

Superpave Binder Specification

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Rutting, Fatigue and Low-Temp. Cracking

WHEN	WHAT	HOW	WHERE
Construction			
Early *(RTFO)*	Rutting		
Late *(+PAV)*	Fatigue Low Temp		

Superpave Binder Specification

Why, When, What, How, and Where?

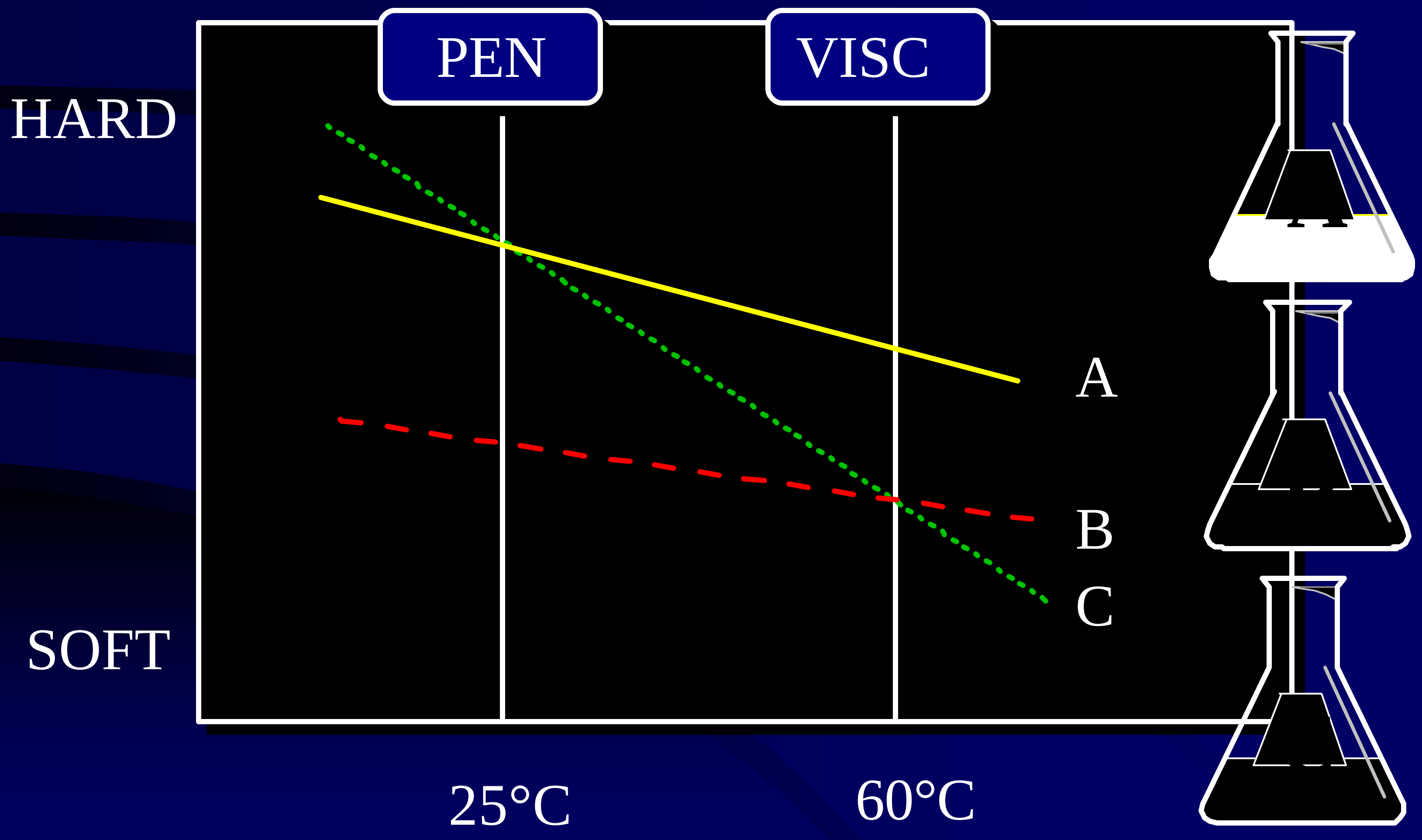
- How ?
- **Q.** How can we characterize an asphalt binder's response to time and temperature ?

Superpave Binder Specification

Why, When, What, How, and Where?

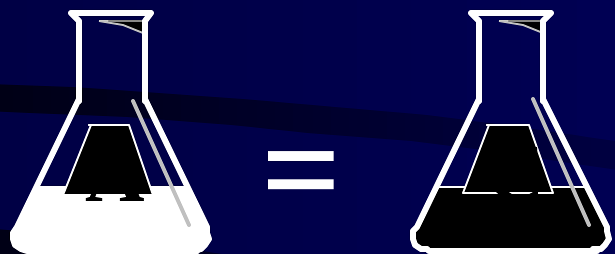
- How ?
- **H.** Historically, we have characterized binders through the use of the Penetration test and the Viscosity test. However these tests only characterize or grade binders at one temperature and one rate of loading...

Problem with one temperature grading

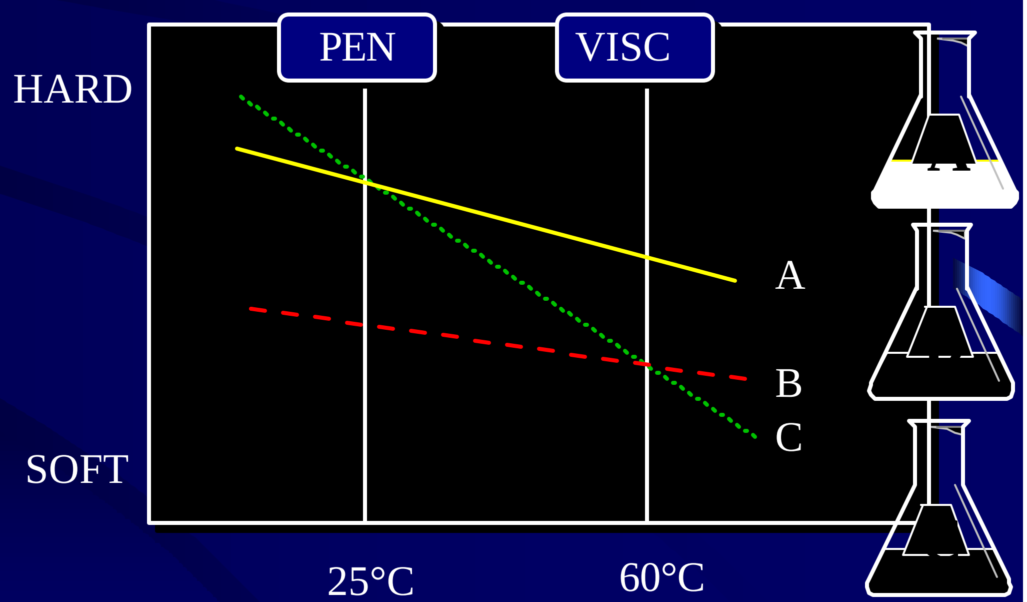


Problem with one temperature grading

- According to the Penetration system:



- According to the Viscosity System:



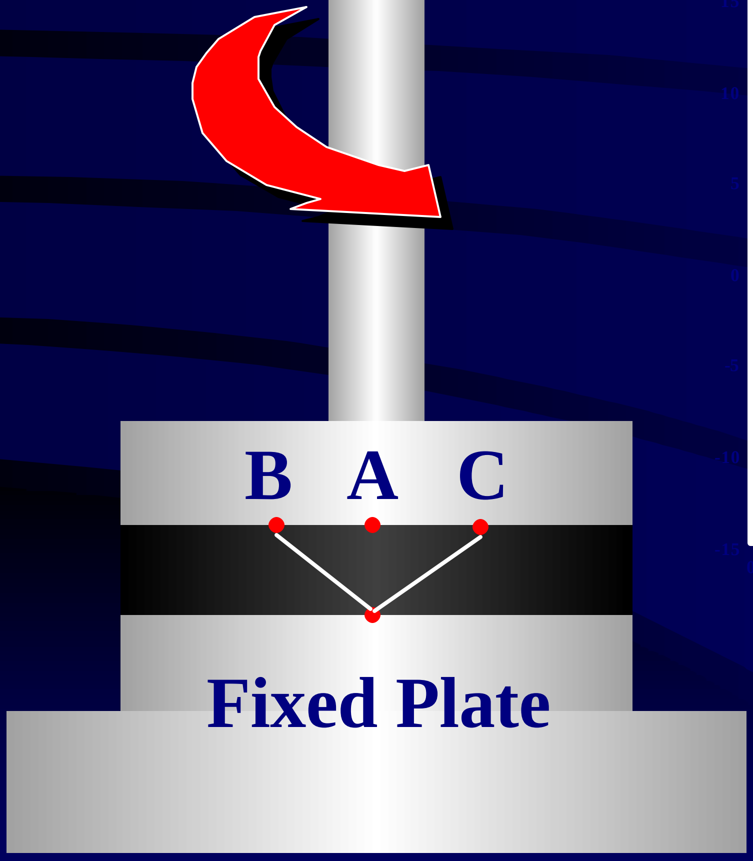
Superpave Binder Specification

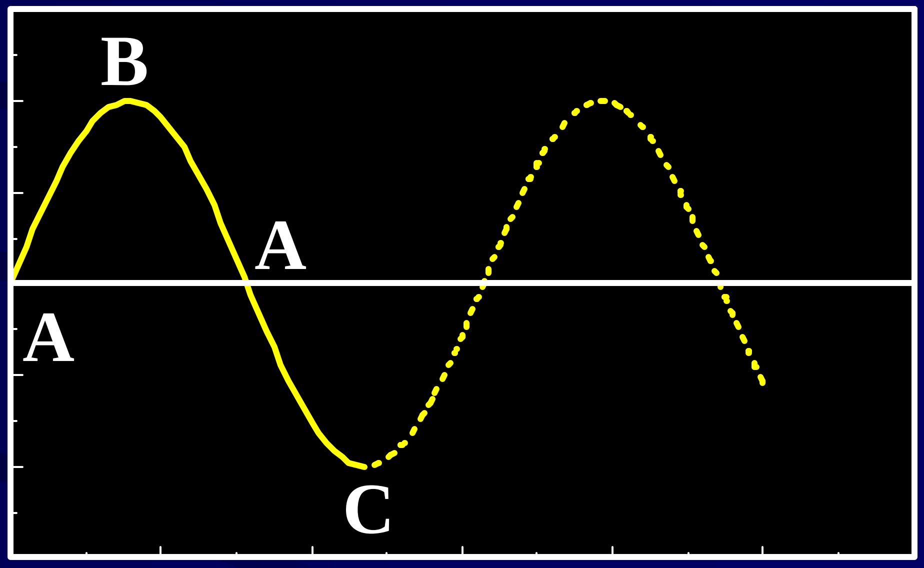
Why, When, What, How, and Where?

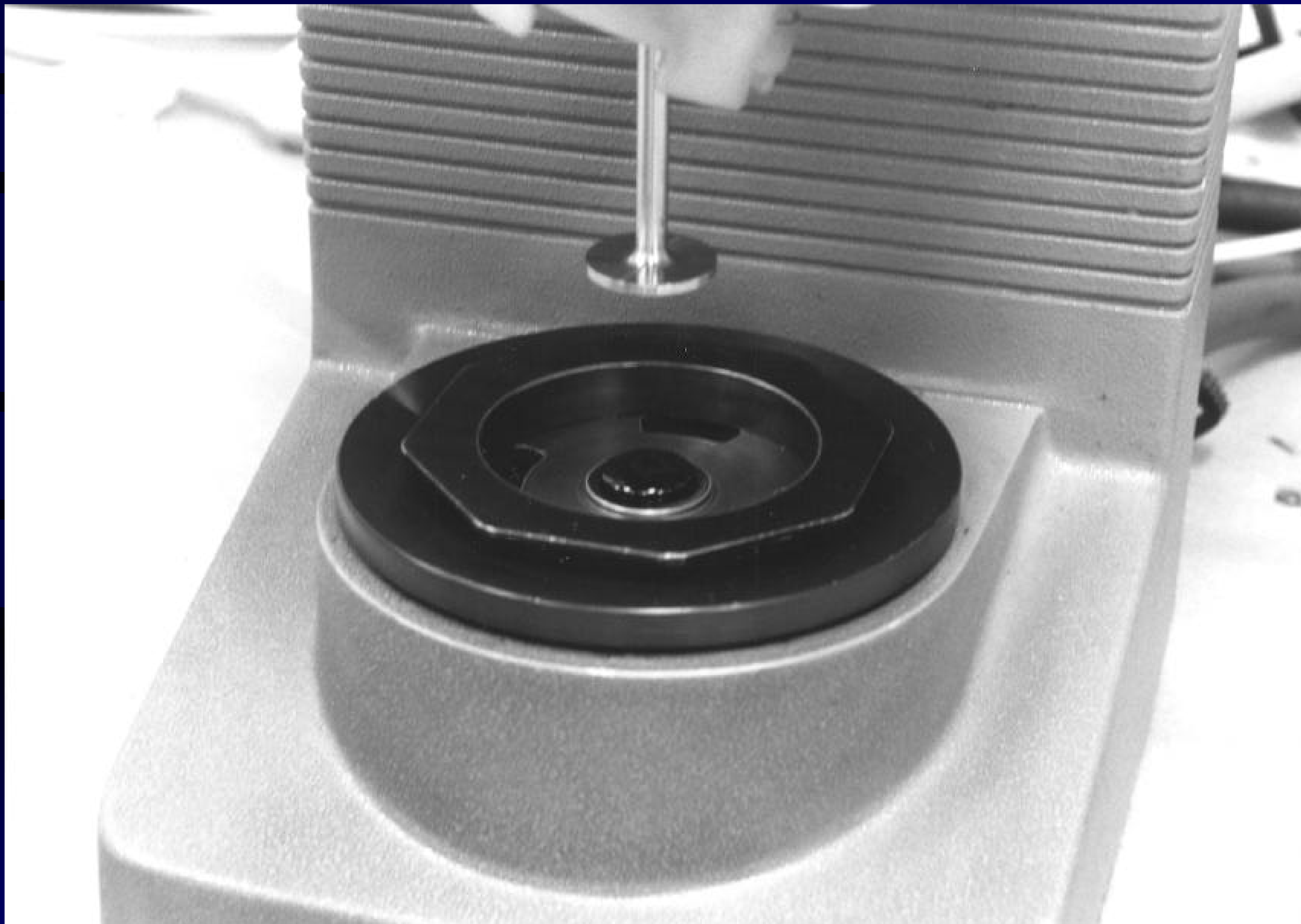
- How ?
- **Q.** How can we characterize an asphalt binder's response. . .

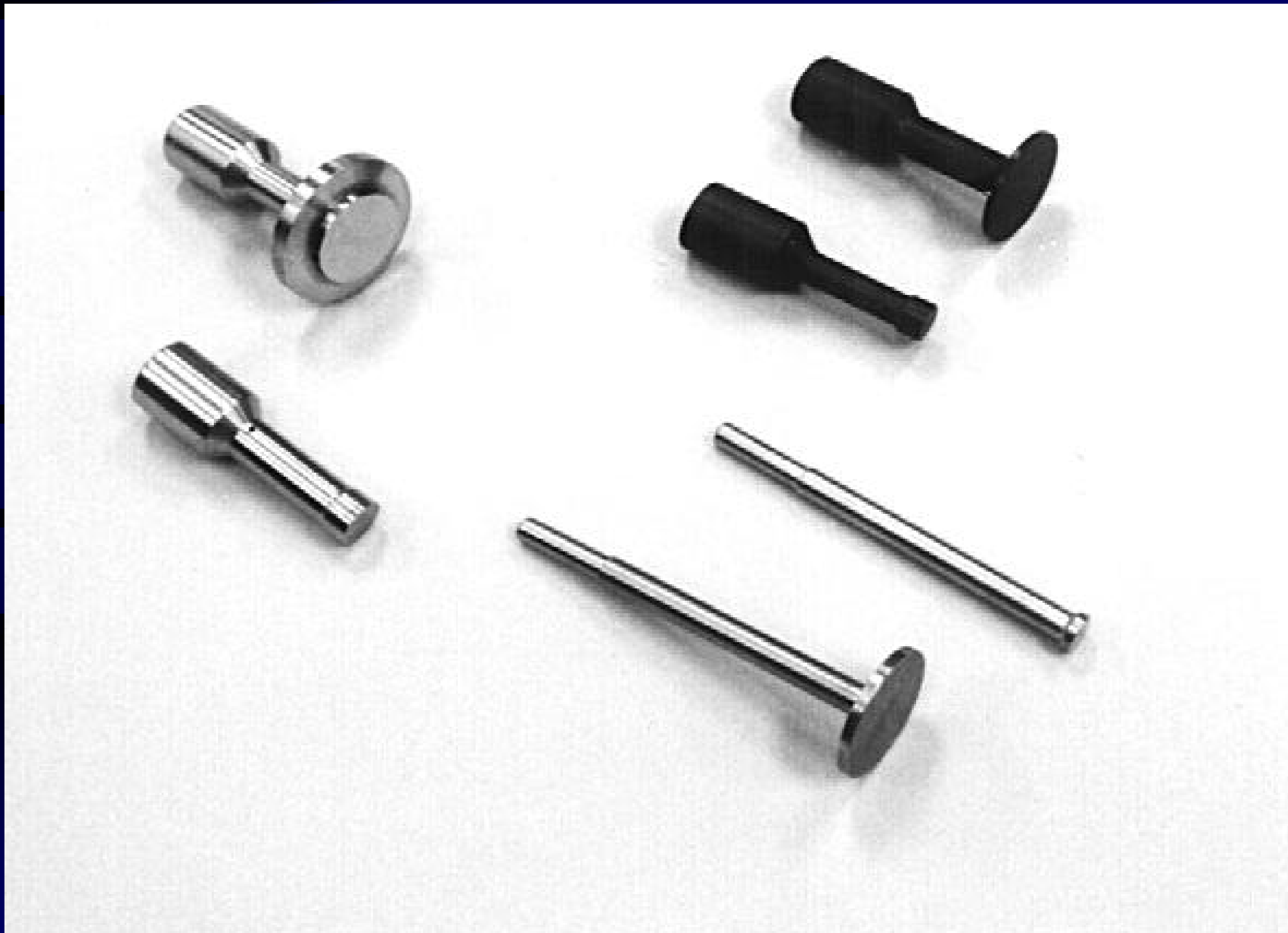
- **A.** To address the visco-elastic properties of asphalt binders we are going to employ a dynamic shear rheometer, *(DSR)*.

Dynamic Shear Rheometer, DSR









DSR provides G^* and δ

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

- $G^* / \sin \delta$
  - Correlates to rutting resistance.
- $G^* \sin \delta$
  - Correlates to fatigue resistance.

Superpave Binder Specification

Rutting, Fatigue and Low-Temp. Cracking

WHEN	WHAT	HOW	WHERE
Construction			
Early *(RTFO)*	Rutting	$G^* / \sin \delta$	
Late *(+PAV)*	Fatigue Low Temp	$G^* \sin \delta$	

Superpave Binder Specification
Why, When, What, How, and Where?

- **Where ?**
  - **Q.** Where to perform a test is not a simple question. . .

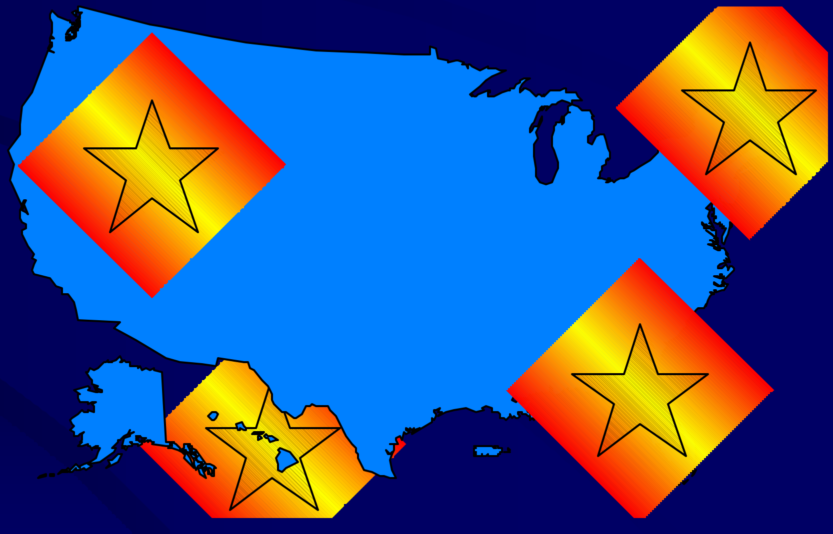
Superpave Binder Specification

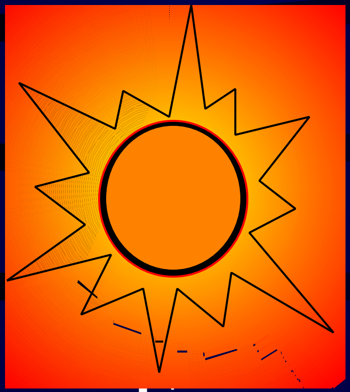
Why, When, What, How, and Where?

- **Where ?**
- We can either perform the test at a standard specified temperature and vary our criteria from location to location, or. . .

Superpave Binder Specification
Why, When, What, How, and Where?

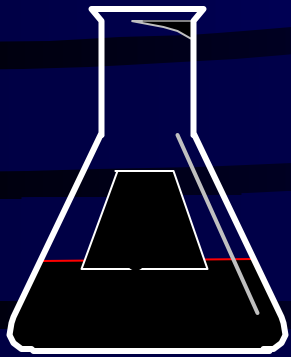
- **Where ?**
- We can vary our test temperature based on our project location and standardized our criteria.





Where ?

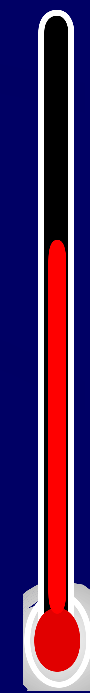
- For our specification, lets choose to standardized our criteria for each test and base test temperatures on project weather data.

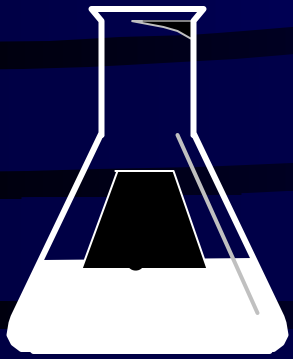


Temperatures

- **Q.** What temperatures do we need to address ?

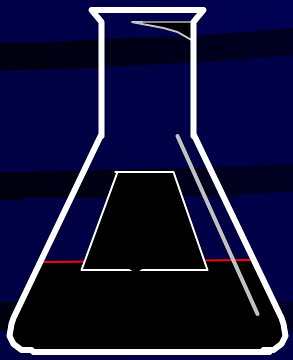
- 1. Rutting occurs at. . .
- 2. Fatigue Cracking occurs at. . .
- 3. Low Temperature Cracking occurs at. . .





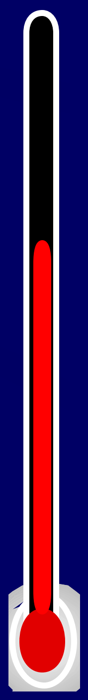
Temperatures

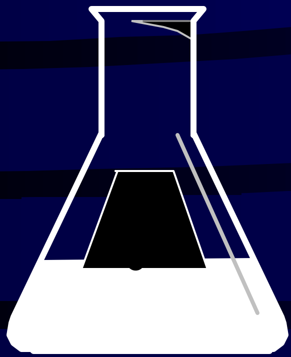
- 1. Rutting occurs at high pavement temperatures, $T_{(high)}$
- 2. Fatigue Cracking occurs at intermediate pavement temperatures, $T_{(inter)}$, and
- 3. Low Temperature Cracking occurs at low pavement temperatures, $T_{(low)}$.



Temperatures

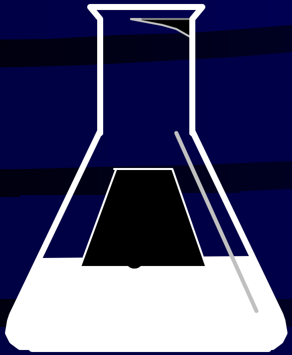
- **Q.** Where do we get high, intermediate, and low pavement temperatures for our project ?





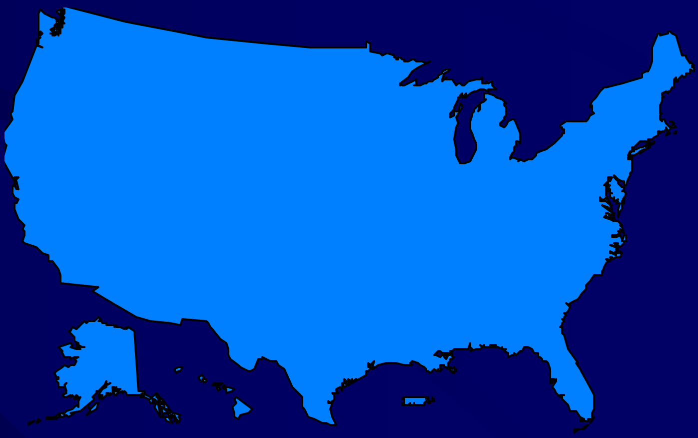
Temperatures

- **Q.** Where ?
- **A.** The National Weather Service has been monitoring environmental data on a national basis for over 50 years. This historical record of air temperatures can be used to estimate pavement temperatures over a pavement's life.



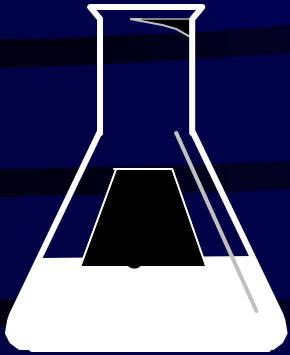
Temperatures

- **For Example. . .**
- In Reno, Nevada there is a weather station located at:
  - 119.49° longitude, and
  - 39.46° latitude.



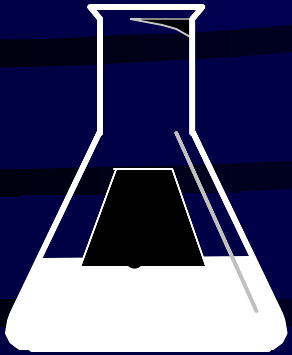
Temperatures
Reno, Nevada

- From this weather station the following is determined:
  - The average minimum air temperature is -18°C, and
  - The 7-day average maximum air temperature is 36°C.



Temperatures

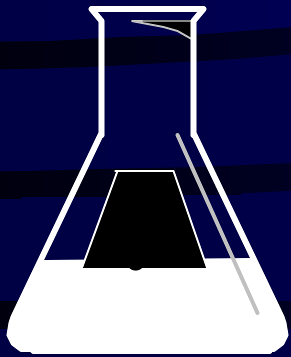
- During the SHRP research program, an algorithm was developed by Dr. Tom Kennedy to convert maximum air temperatures to maximum pavement temperatures *(at a depth of 20 mm)*.



Temperatures
Reno, Nevada

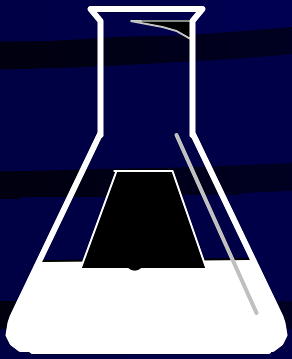
- Based on Dr. Tom's equation:

- The 7-day average maximum pavement temperature is 56°C.



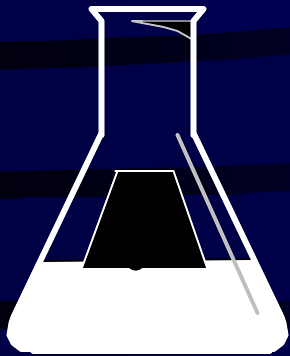
Temperatures

- **Q.** Why 7-day average ?



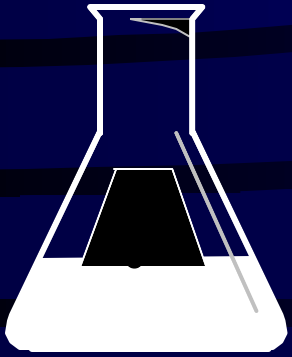
Temperatures

- **Q.** Why 7-day average ?
- **A.** The SHRP researchers observed rutting failures typically occur during extended heat waves. It was felt using a 1-day maximum temperature would be too conservative and also inappropriate.



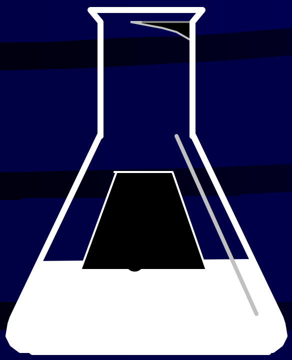
Temperatures

- **Q.** Okay, what do we do for our minimum pavement temperatures ?



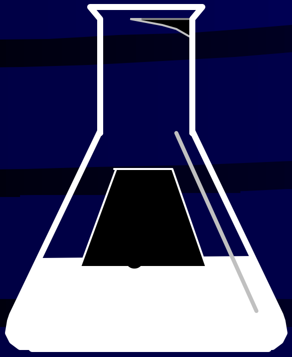
Temperatures

- **Q.** Okay, min. pavement temperatures ?
- **A.** Low temperature cracking occurs when tensile stresses develop between the asphalt layer and the supporting layer. When an asphalt layer cools, like most materials, it contracts causing tension between the asphalt and supporting layers. . .



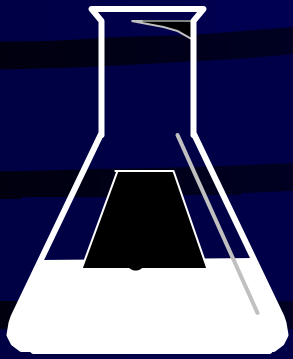
Temperatures

- **Q.** Okay, min. pavement temperatures?
- **A.** . . . When the tensile stress in the asphalt exceeds its tensile strength, we get a crack. Since this does not require repetitive loading, like rutting, we use the average (1-day) minimum air temp. as the average minimum pavement temperature.



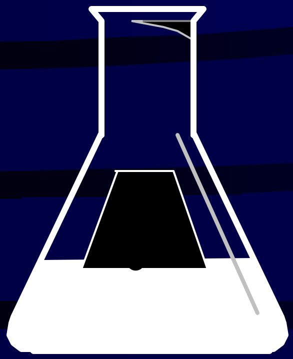
Temperatures

- **Q.** Should we distinguish grades by one degree increments ?



Temperatures

- **Q.** Should we distinguish grades by one degree increments ?
- **A.** Well that wouldn't be very practical, not to mention the oil companies might come after us. . .



Temperatures

- **Q.** Should we distinguish grades by one degree increments ?
- **A.** . . . We are going to establish grades in 6°C increments.
  - – Typically for asphalt binders, if you decrease the test temperature by 6°C you will find the viscosity has doubled.

Performance Grade Increments

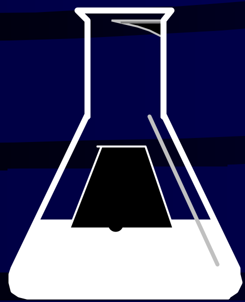
Average 7-day Maximum Pavement Temperature						
46	**52**	**58**	**64**	**70**	**76**	**?**

Average 1-day Minimum Pavement Temperature						
+2	**-4**	**-10**	**-16**	**-22**	**-28**	**?**

Temperatures
Reno, Nevada

- **Q.** Our min and max pavement temperatures are -18°C and +56°C. What performance grade should we select?

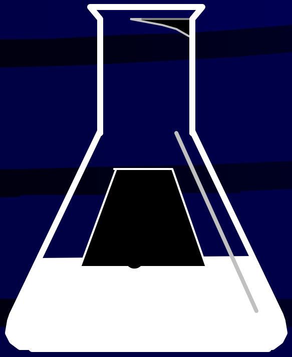
46	**52**	**58**	**64**	**70**	**76**	**?**
+2	**-4**	**-10**	**-16**	**-22**	**-28**	**?**



Temperatures
Reno, Nevada

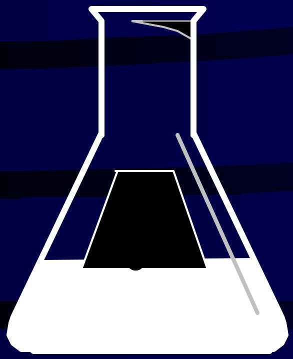
- **A.** PG 58-22

46	**52**	**58**	**64**	**70**	**76**	**?**
+2	**-4**	**-10**	**-16**	**-22**	**-28**	**?**



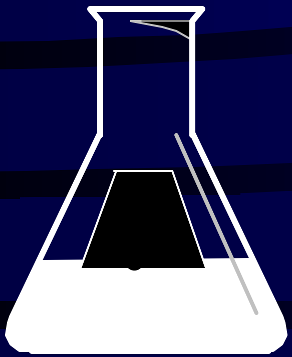
Temperatures

- **Q.** What do you think happens when the maximum and minimum pavement temperatures grow further and further apart ?



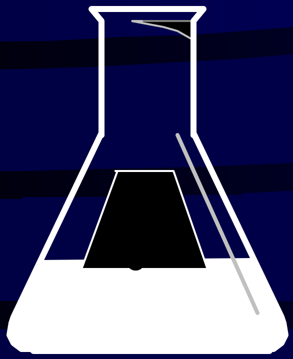
Temperatures

- **Q.** What do you think. . .
- **A.** Typically if the difference is greater than 90°C modification of the asphalt is required.
- **Q.** In Reno, would we expect a modified asphalt binder is required?
- **A.** PG 58-22, 58°+22° = 80° < 90°



Temperatures

- **Q.** Okay, we know our max and min pavement temperatures, how do we determine our intermediate pavement temperature for accessing fatigue.
- **A.** Well the obvious answer would be to take the average of the two temperatures. . .
- (58-22) / 2 = 18



Temperatures

- **However:** during the SHRP research, Dr. Dave Anderson established the intermediate test temperature should be slightly higher based upon field observations, such that. . .

- $T_{(inter)} = [(58\text{-}22) / 2] + 4 = 22°C$

Superpave Binder Specification

Why, When, What, How, and Where?

- We know what we are testing for:
  - Rutting,
  - Fatigue Cracking, &
  - Low Temp Cracking. . .

- We know what temperatures to test our asphalt binders.

Superpave Binder Specification
Low Temperature Characterization

- **Q.** So what test equipment should we use for accessing Low Temperature Cracking ?

- **A.** DSR?

Superpave Binder Specification

Low Temperature Characterization

- You could use a DSR if you wanted to spend a lot of money. However, Dr. Dave and gang at Penn State came up with two new tests to address the low temperature properties:

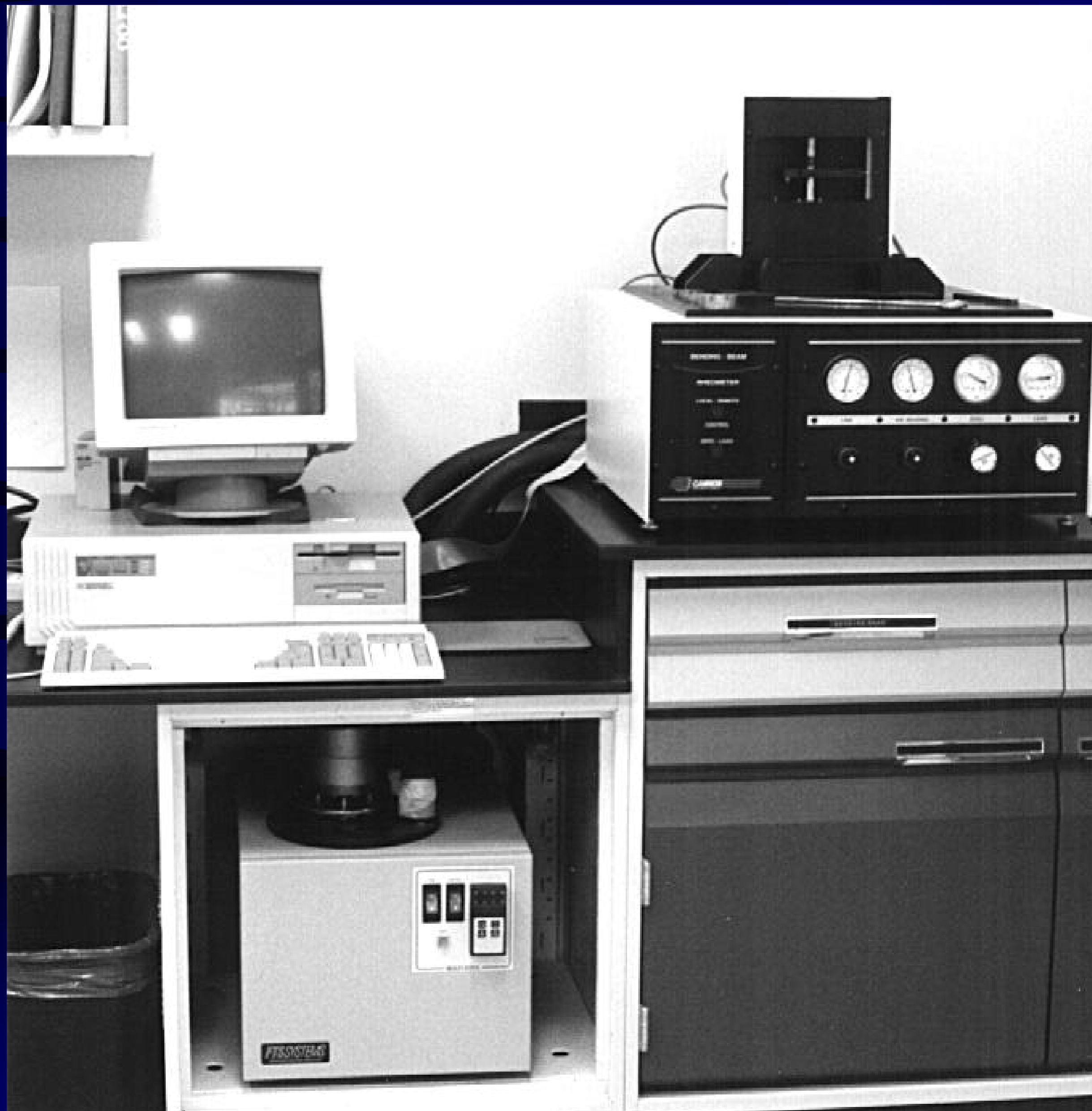
- Bending Beam Rheometer, BBR
- Direct Tension Tester, DTT

Superpave Binder Specification

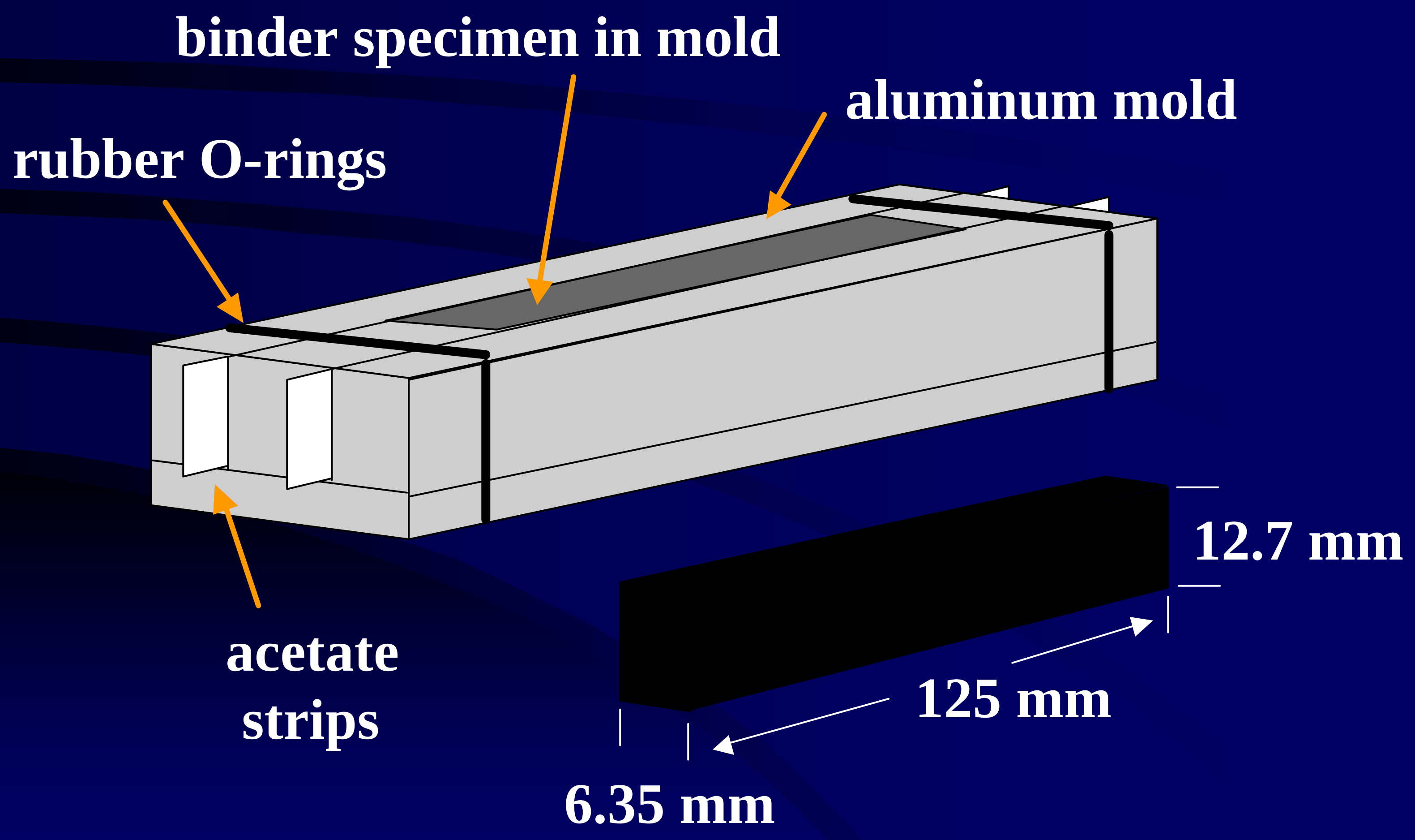
Low Temperature Characterization

- The BBR, developed by Penn State, determines the Creep Stiffness (S) of an asphalt binder at low temperatures.

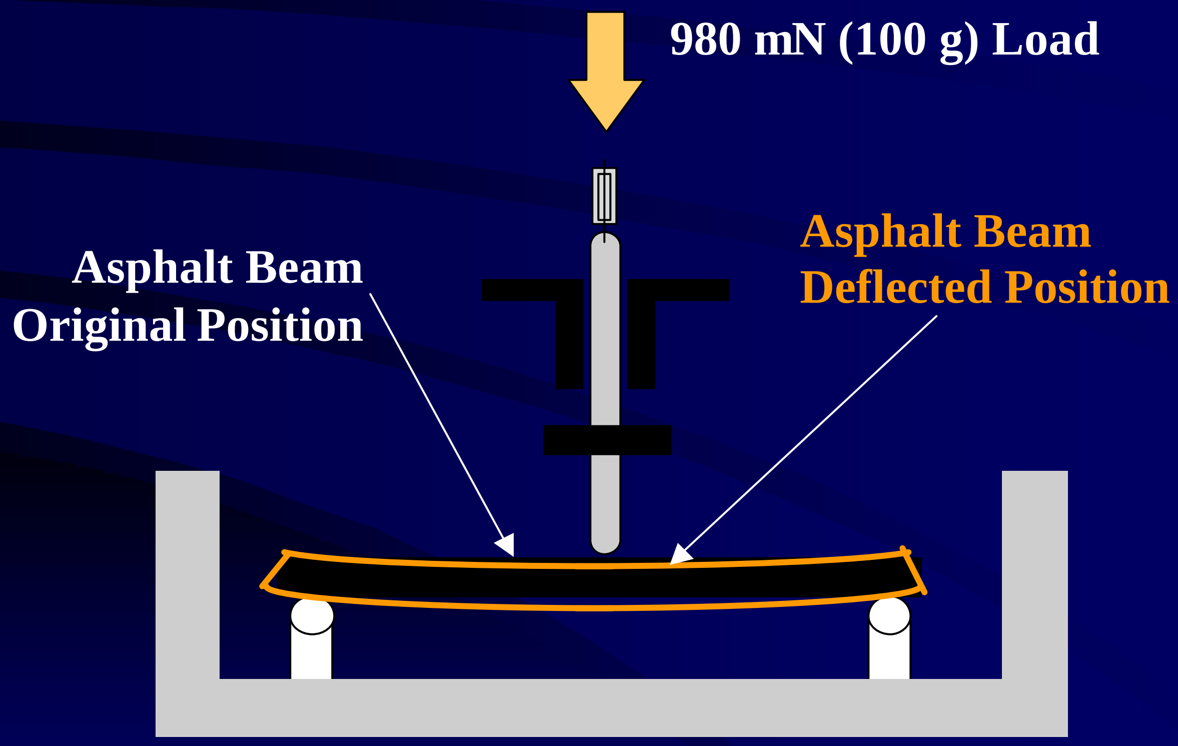
- If a binder is too stiff at service temperatures, you can expect low temperature cracking.

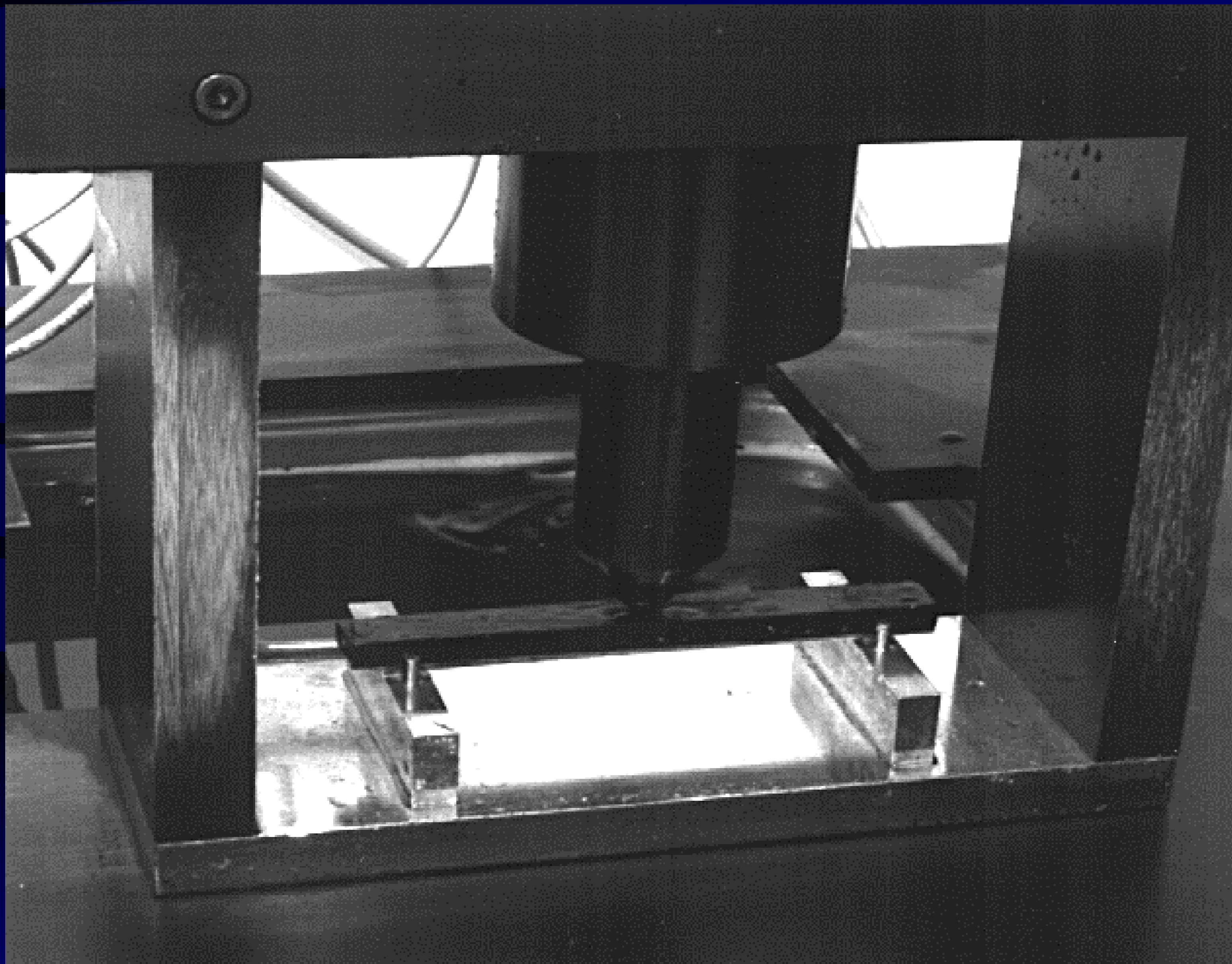


Bending Beam Rheometer, BBR



Bending Beam Rheometer, BBR

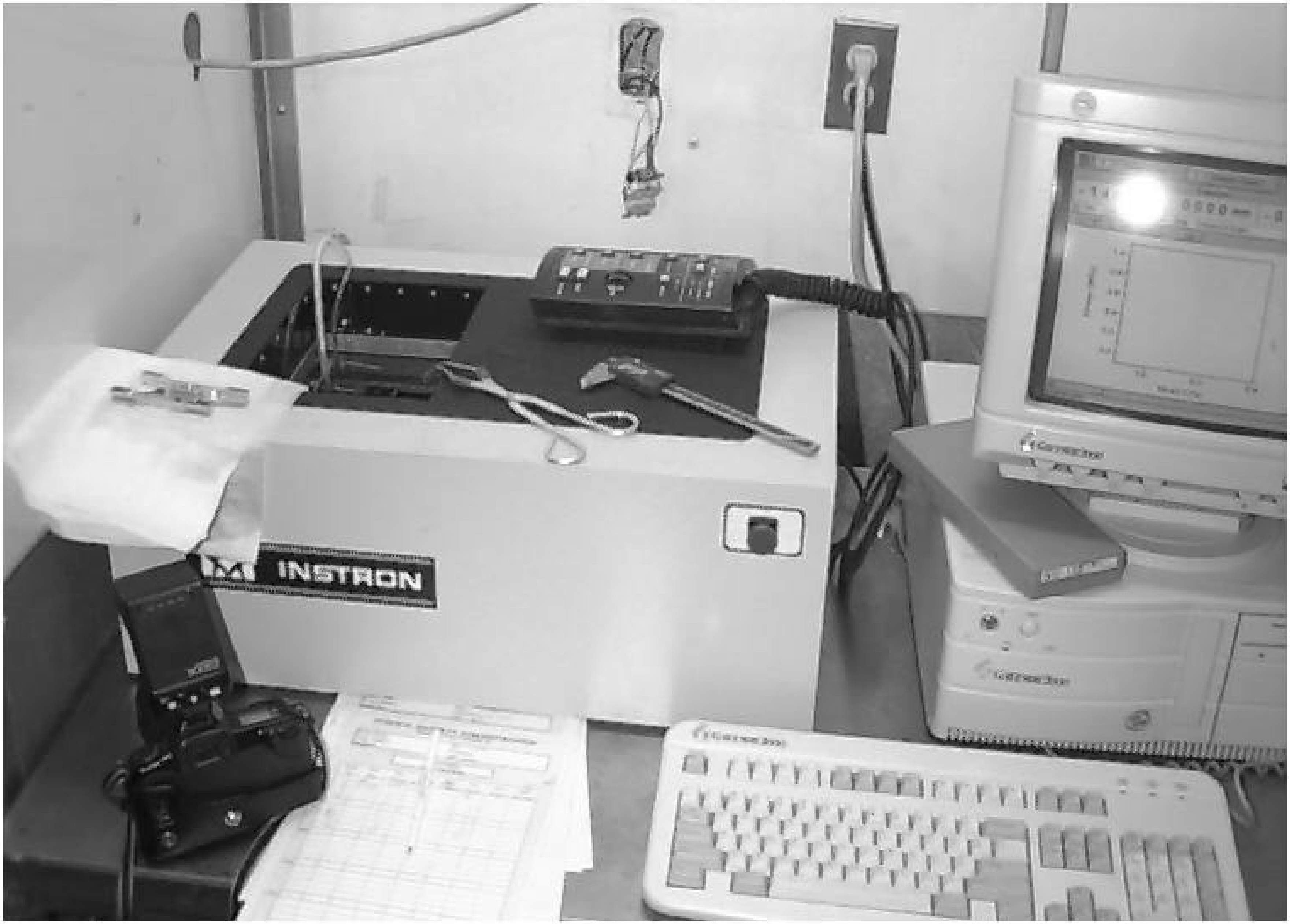




Superpave Binder Specification

Low Temperature Characterization

- **Q.** Okay, why do we need two low temperature tests, BBR and DTT ?
- **A.** Good question. For unmodified systems the BBR is all that is required for PG grading. However, for some modified systems we find they have very high creep stiffness at low temperatures, but also have very high low temperature strengths.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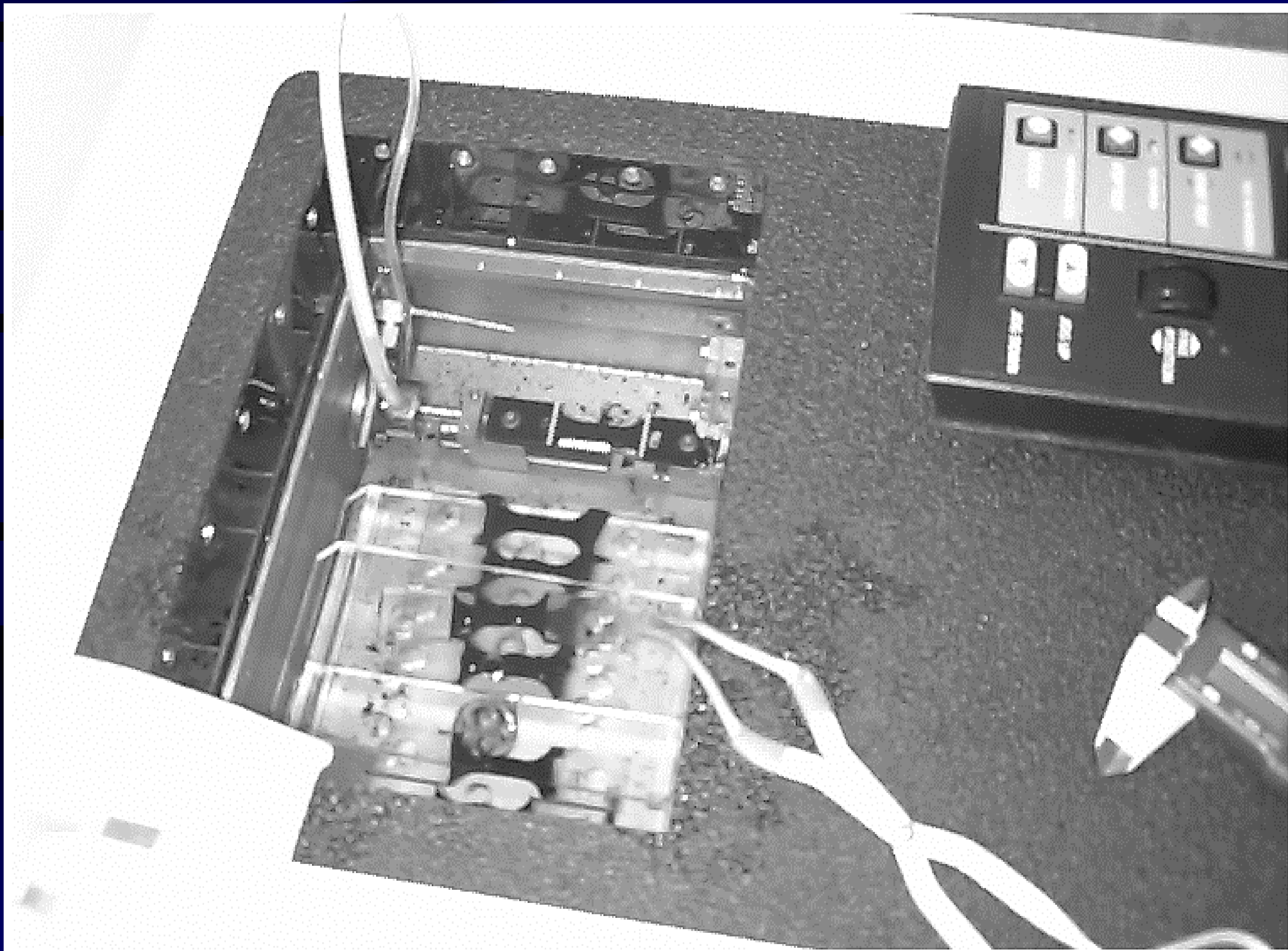


Superpave Binder Specification

Low Temperature Characterization

- **Q.** So for the BBR and DTT we test our asphalt binders at $T_{(min)}$?
- **A.** You could, but Dr. Dave and the gang used the concept of time/temp superposition to reduce the test times and minimize the cost of the equipment.
  - In the BBR, an asphalt at T(min) tested for 2 hours will have the same creep stiffness at T(min) + 10°C tested for 60 seconds.

Superpave Binder Specification

Low Temperature Characterization

- **A.** Such that both the BBR and DTT tests are conducted at $T_{(min)} + 10°C$

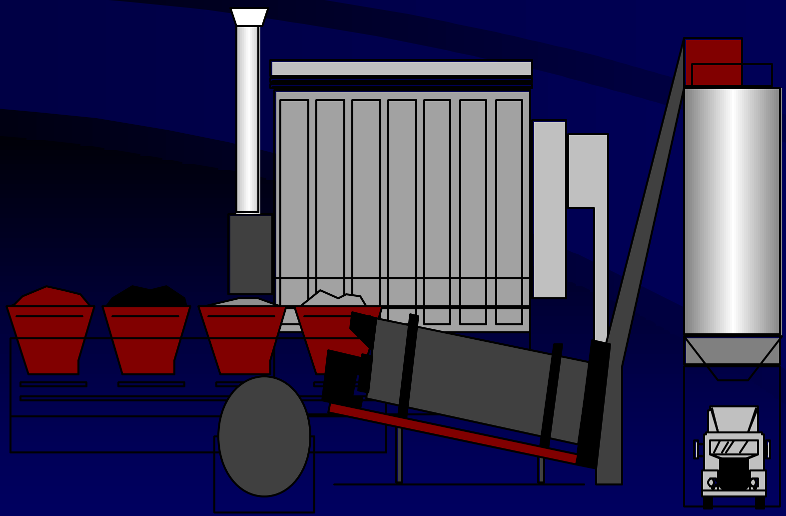
Superpave Binder Specification

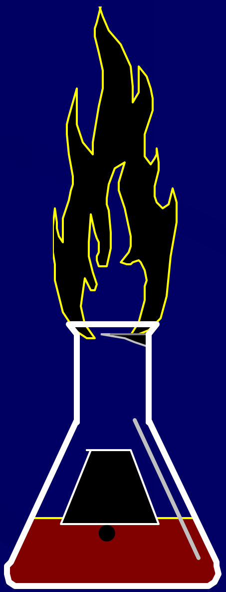
Rutting, Fatigue and Low-Temp. Cracking

WHEN	WHAT	HOW	WHERE
Construction			
Early *(RTFO)*	Rutting	$G^* / \sin \delta$	T(high)
Late *(+PAV)*	Fatigue Low Temp	$G^* \sin \delta$ BBR/DTT	T(inter) T(low)+10

Other concerns. . .

- **Q.** Okay, what about. . .
  - Safety and
  - Construct-ability

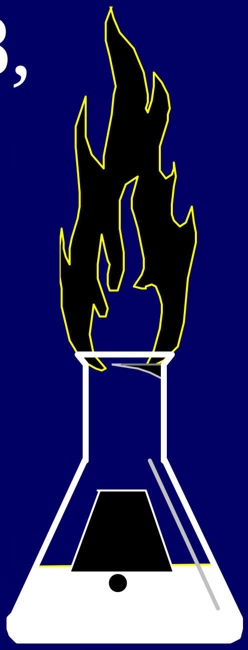




Other concerns. . .

- **Q.** What about Safety ?

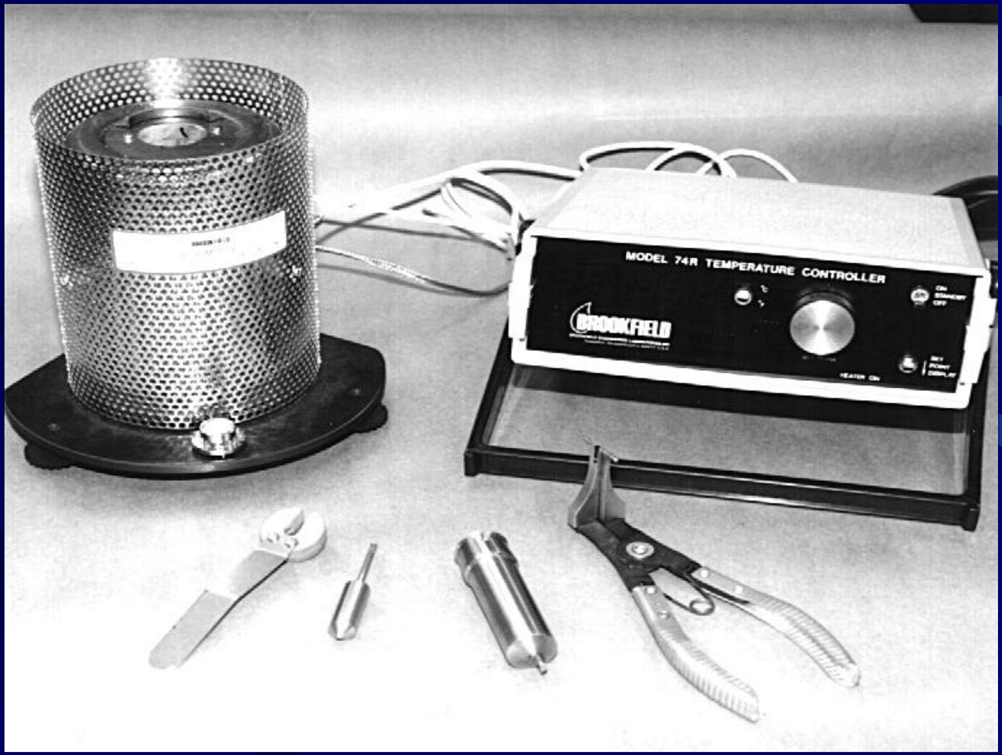
- **A.** We are going to use AASHTO T 48, Flash Point, with a minimum of 230°C.



Other concerns. . .

- **Q.** What about Construct-ability ?
- **A.** A better word might be Pump-ability. A concern raised during SHRP was the need to address modified systems. Heavily modified systems can literally burn-out pumps. To address this, we will use ASTM D 4404, "Brookfield Rotational Viscometer."

Rotational Viscometer



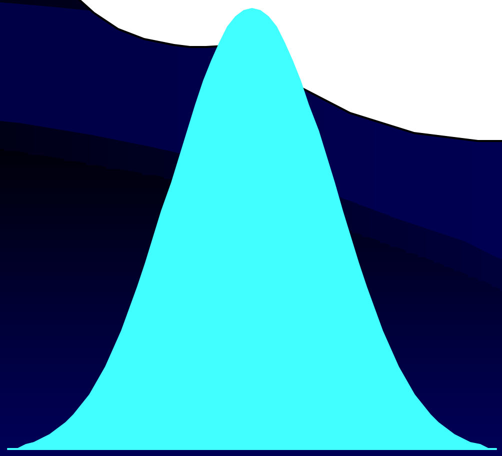

BROOKFIELD
THERMOSEL
BROOKFIELD ENGINEERING LABORATORIES

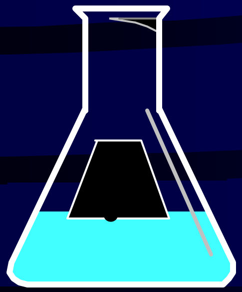
Superpave Binder Specification

Rutting, Fatigue and Low-Temp. Cracking

WHEN	WHAT	HOW	WHERE
Construction	Safety Pumpability	Flash Point Rot Visc	230 min 3 Pa-s max
Early *(RTFO)*	Rutting	$G^* / \sin \delta$	T(high)
Late *(+PAV)*	Fatigue Low Temp	$G^* \sin \delta$ BBR/DTT	T(inter) T(low)+10

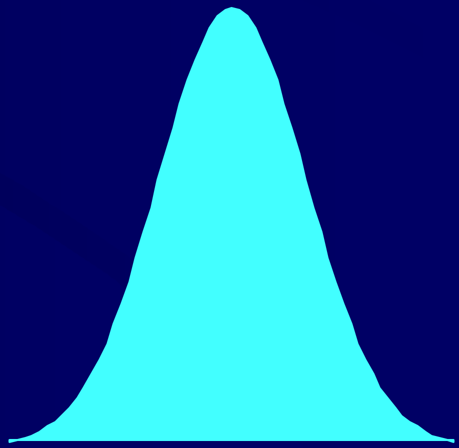
How can we incorporate a factor of safety in our performance grading system ?





Factor of Safety

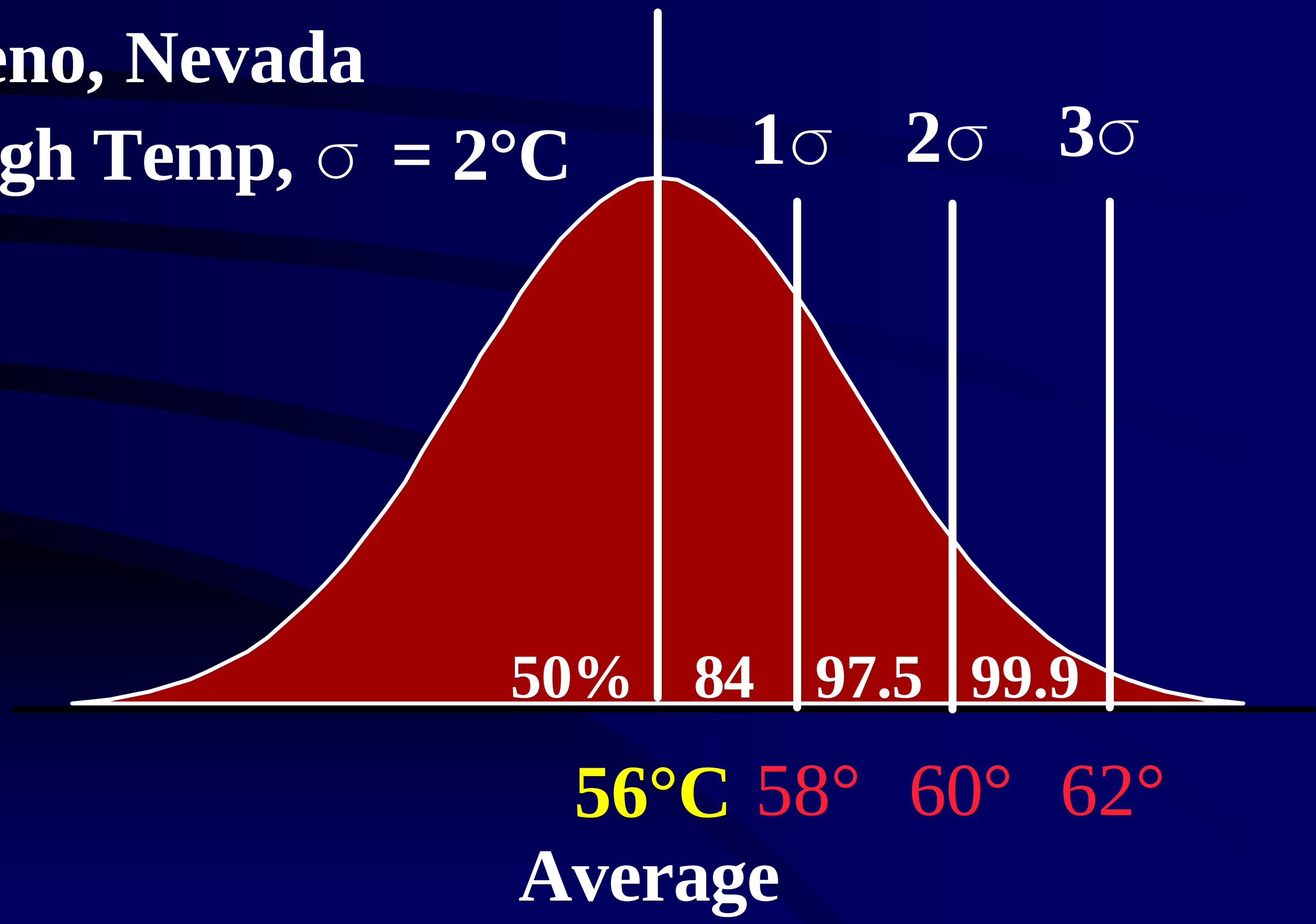
- **A.** Using the weather data we can apply levels of reliability to our temperature data by using their associated standard deviations.



Factors of Safety

Reno, Nevada

High Temp, σ = 2°C

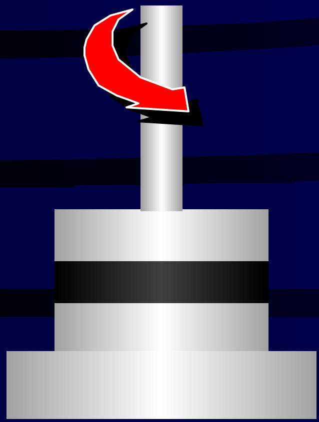


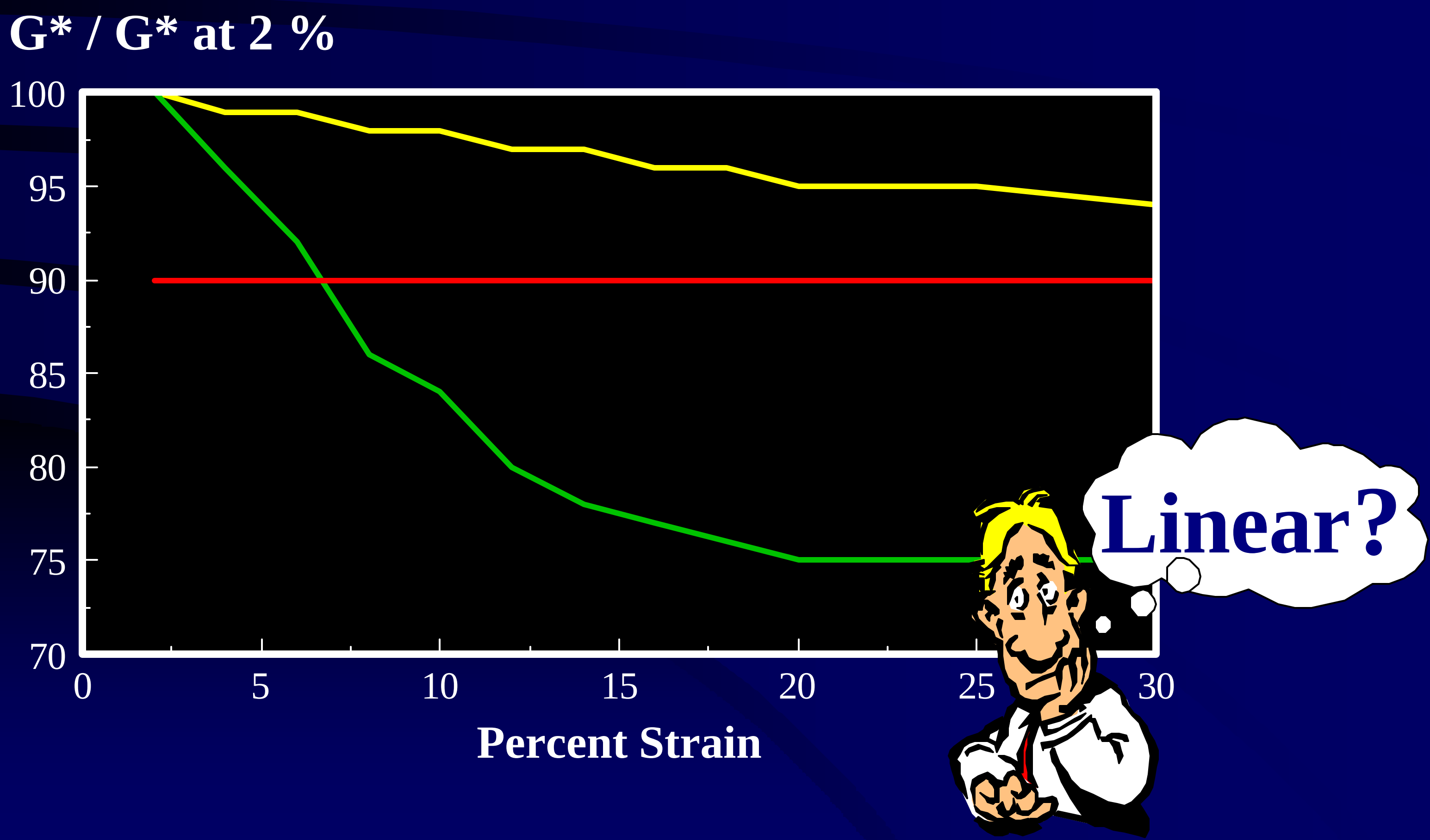

can I performance grade any asphalt binder ?
NO, CALVIN.

Are all binders performance grade-able ?

No, an asphalt binder must meet the theory behind the tests (DSR, BBR, & DTT). It has to be linear in the visco-elastic range and can not be a filled system.

Linearity Check





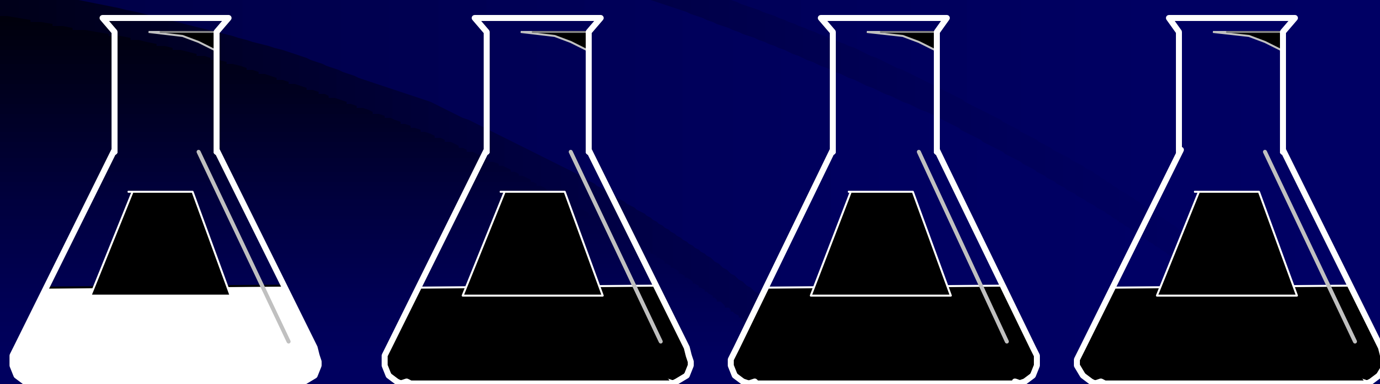
Superpave Binder Specification

Rutting, Fatigue and Low-Temp. Cracking

WHEN	WHAT	HOW	WHERE
Construction	Safety Pumpability Rutting	Flash Point Rot Visc $G^* / \sin \delta$	230 min 3 Pa-s max T(high)
Early *(RTFO)*	Rutting	$G^* / \sin \delta$	T(high)
Late *(+PAV)*	Fatigue Low Temp	$G^* \sin \delta$ BBR/DTT	T(inter) T(low)+10

So we have four asphalt binders

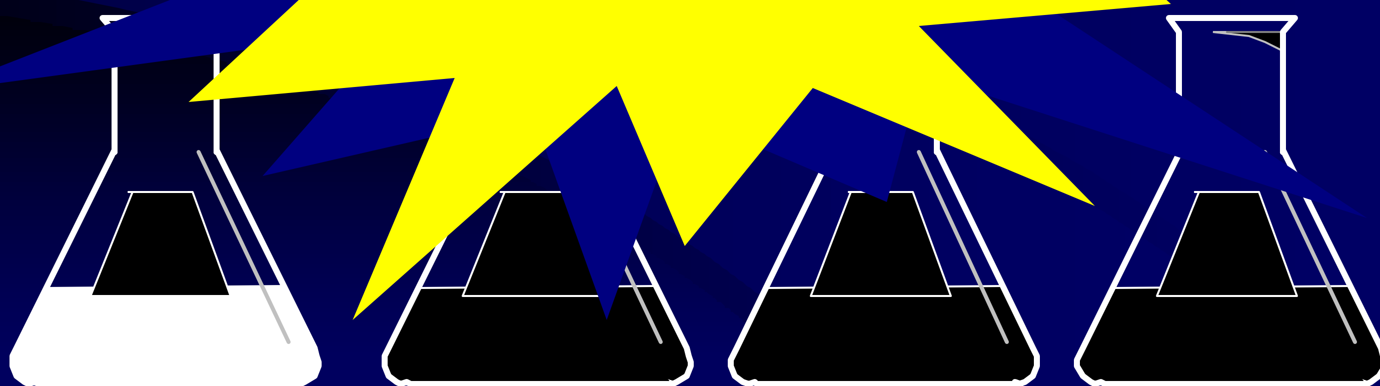
- **Q.** How do we determine which asphalt binder is best for our project?



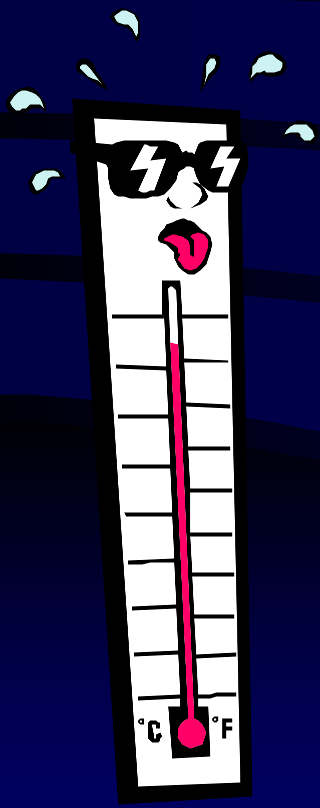
So we have four asphalt binders

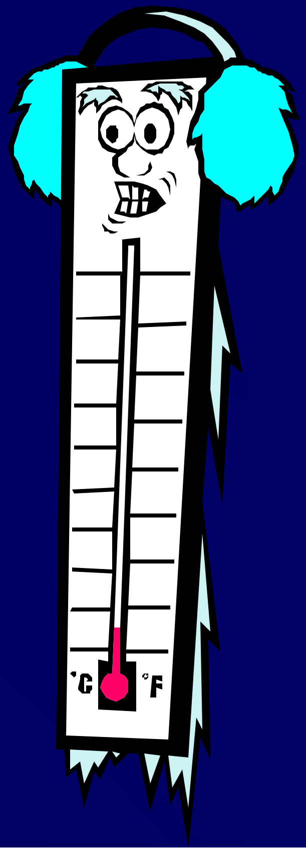
- **Q.** How … o we deterr … n … which asphalt binder … ject?

Performance Based !



Binder Grade is a function of environment and traffic level





Superpave Asphalt Binder Specification

Grading system and selection based primarily on climate

PG 64-22

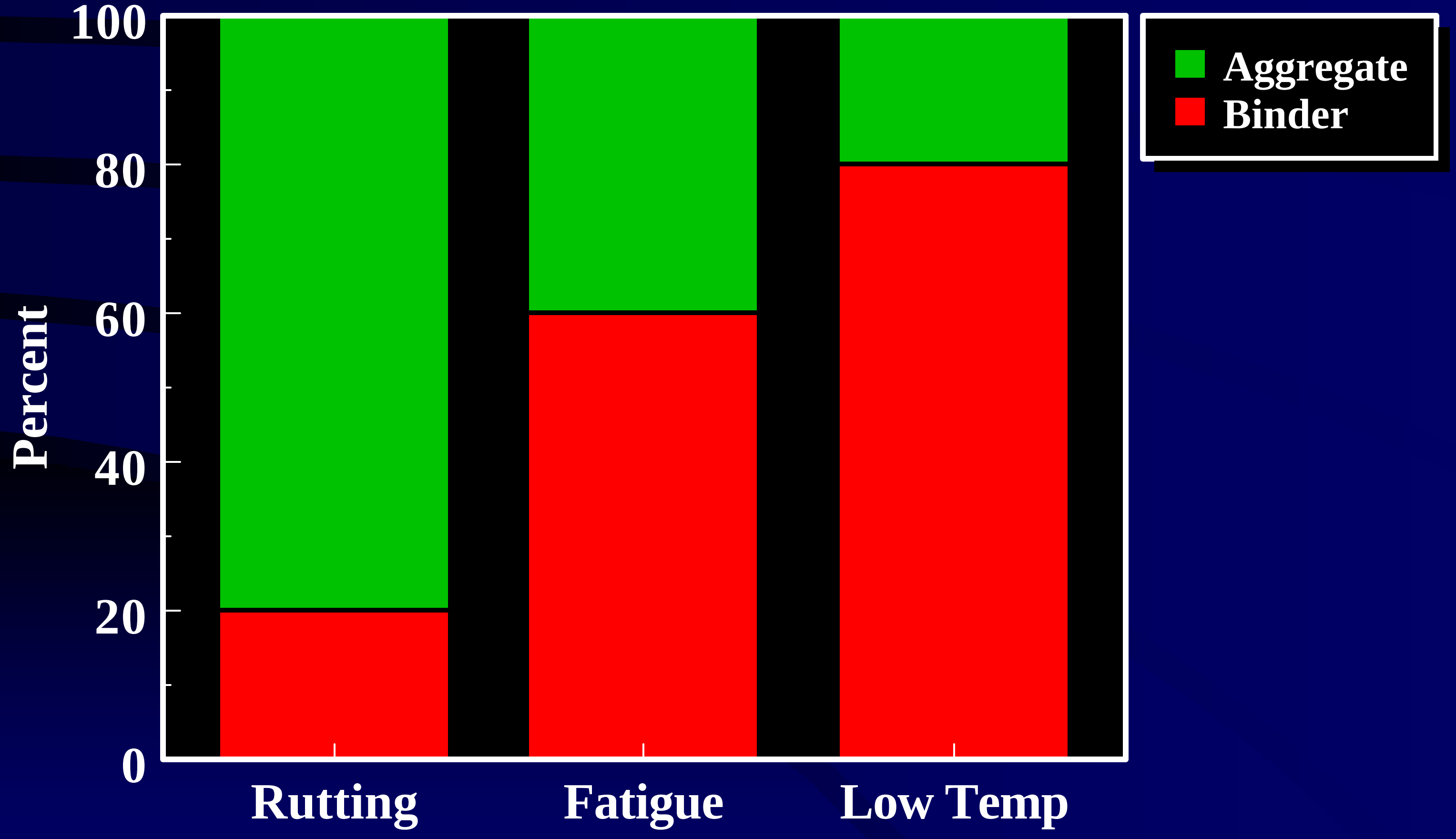
Performance Grade

Average 7-day max pavement design temp

Min pavement design temp


PG's will solve it all !
but what about aggregates ?

Pavement Performance



Remember,
Superpave
is a
system !


Thank you.