AF2903 Highway Construction and Maintenance

Laboratory: Binder rheology and ageing

Royal Institute of Technology, Stockholm

Prabir Kumar Das

Highway and Railway Engineering
Department of Transportation Science

What is Ageing

Ageing (British and Australian English) or **aging** (American and Canadian English) is the accumulation of changes in an organism or object over time.

Asphalt/bitumen properties change over time on exposure to high temperature and the atmosphere. This process is referred to as **ageing**.

What is Ageing

ageing is an effect of asphalt hardening with time caused by **oxidation, heat, UV light**.

Over the lifetime of the road, an asphalt binder oxidizes and subsequently hardens eventually causing failure of the road.

Why is it Important

- Transportation facilities are required for the economic development of a country

- Population growth and economic development result extensive development of asphalt-paved roadways

- Bitumen is used in pavement construction

Why is it Important

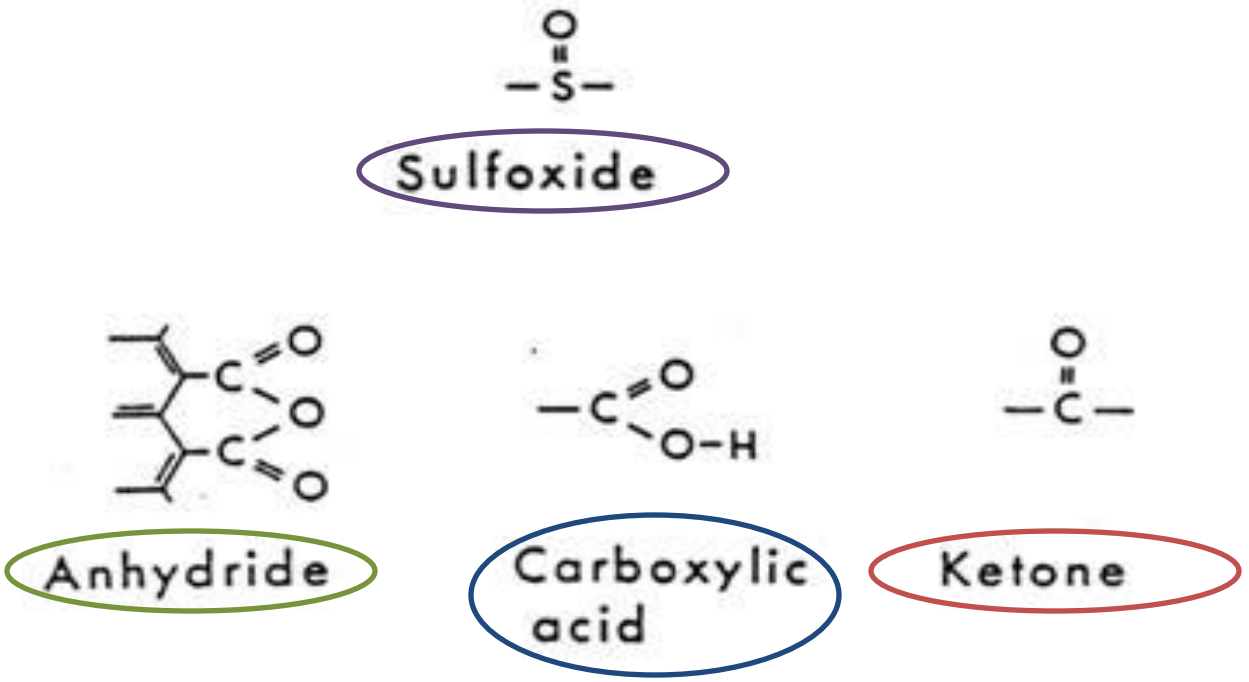
- Bitumen serves as a satisfactory binder in improvement of physical interlocking of aggregate bitumen mixes

- Its properties changes as it ages in bulk storage, transport and storage on site…..and rest of it's life

- The ageing of bitumen then leads to deterioration of pavement

Ageing Chemistry

The major oxygen-containing functionalities produced during aging include **ketones**, **carboxylic acids**, **anhydrides**, and **sulfoxides**.



Ageing Chemistry

- Among them, sulfoxide is produced at the beginning of aging for a short period of time
- Other three kinds of functionalities all have C=O present
- The carbonyl growth results from the creation of C=O containing functionalities.
- **Carbonyl formation** is a major product of oxidation

Ageing of Bitumen

Asphalt binder ageing is usually split up into two categories:

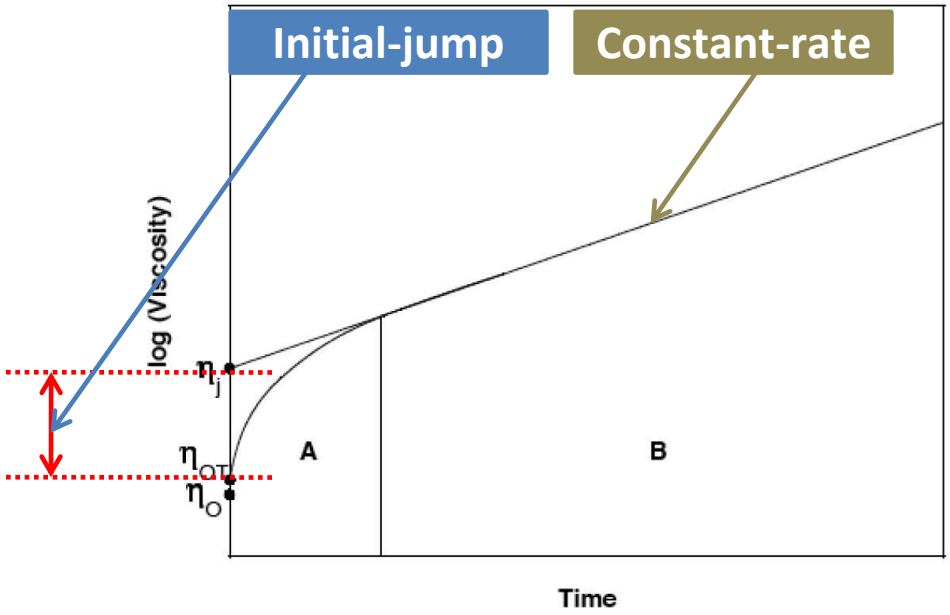
- ***Short-term ageing:*** This occurs when bitumen is mixed with hot aggregates i.e., ***during production and construction***

- ***Long-term ageing:*** This occurs after HMA pavement construction and is generally due to environmental exposure and loading i.e., ***during the life of the pavement***

Bitumen Oxidation Kinetics

At a given temperature and pressure, the asphalt oxidizes in **two stages**:

(1) a rapid-rate period followed by
(2) a long period with constant oxidation rate.



Laboratory Ageing Procedure

Typical ageing simulation tests are:

- Thin-Film Oven **(TFO)**
- Rolling Thin-Film Oven **(RTFO)**
- Stirred Air-Flow Test **(SAFT)**

Short-term ageing

- Pressure ageing Vessel **(PAV)** → **Long-term ageing**

Ageing Simulation Tests

The thin-film oven (TFO) :

Simulates **short-term** ageing by heating a film of bitumen in an oven for 5 hours at 163 ^{0}C (325 ^{0}F)

Bitumen is subjected to Heat and Air

Figure : Thin-Film Oven Test

Ageing Simulation Tests

Rolling Thin-Film Oven (RTFO): SUPERPAVE Specification

Simulates **short-term ageing** by heating a moving film of bitumen in an oven for **85 minutes** at 163 ^{0}C (325 ^{0}F)

Figure : Rolling Thin-Film Oven Test

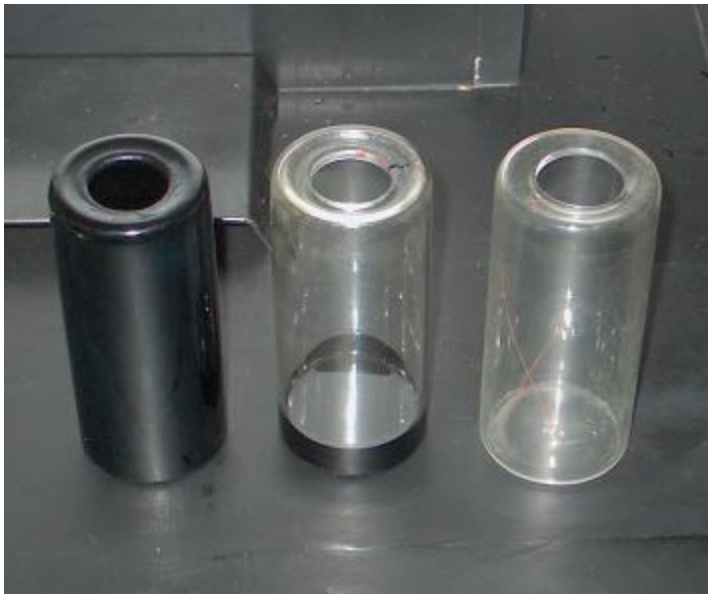


Figure : RTFO Samples
(left - after aging in the RTFO,
center - before aging in the RTFO,
right - empty sample jar)

Ageing Simulation Tests

Stirred Air-Flow Test (SAFT) :

The RTFOT and TFOT tests required a lengthy amount of time to properly age samples, SAFT expedites the process by using bitumen air blowing. The blowing air oxidizes the crude oil products in the asphalt and ages the samples at a faster rate.

Method	Time
Stirred Air-Flow Test (SAFT)	35 min.
Rolling Thin-Film Oven Test (RTFOT)	85 min.
Thin-Film Oven Test (TFOT)	5 hours

Figure : Stirred Air-Flow Test

Ageing Simulation Tests

Pressure Ageing Vessel (PAV) : SUPERPAVE Specification
simulate the effects of long-term bitumen ageing that occurs as a result of 5 to 10 years HMA pavement service

Figure : Pressure Ageing Vessel

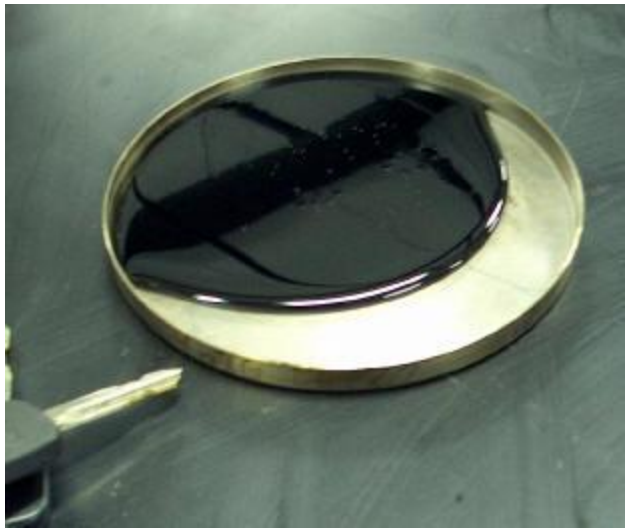


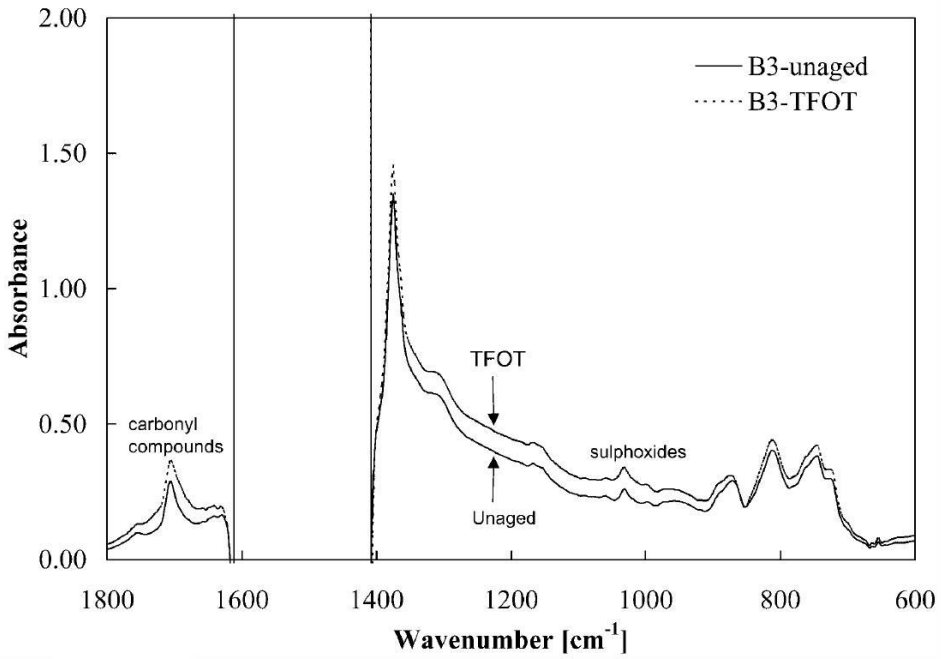
Figure: PAV Sample

Analytical Measurement

Equipment used to determine properties of aged bitumen to quantify ageing:

- *Dynamic Shear Rheometer (DSR)*
- *Fourier Transform Infrared (FT-IR) Spectroscopy*
- *Ductility and Force Ductility (FD)*
- *Corbett Analysis (CA)*

Fourier Transform Infrared (FT-IR) Spectroscopy



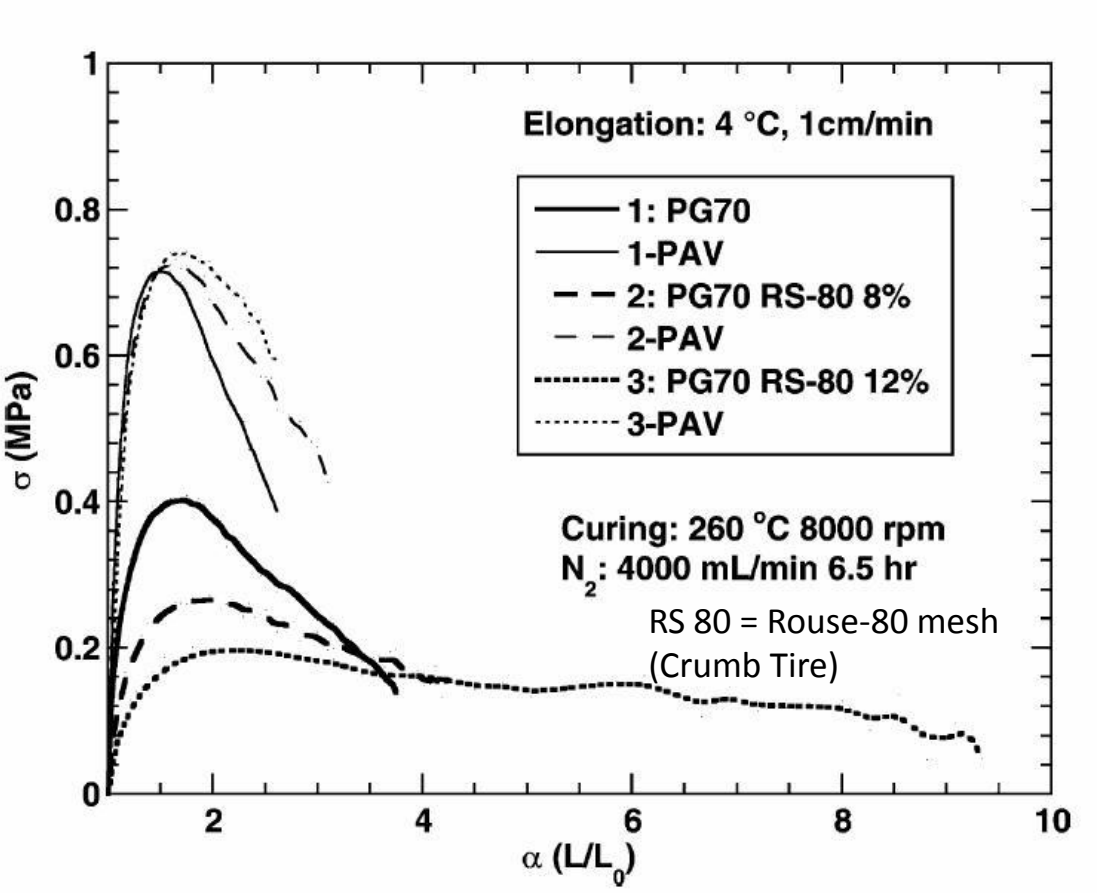
Effect of ageing on bitumen FTIR sepctrogram.

The absorbance bands

- at 1705 cm^{-1} are due to the C=O stretch in carbonyl compounds
- at 1030 cm^{-1} are due to the S=O stretch in sulfoxides

So, carbonyl compounds and sulfoxides increases due to ageing

Force Ductility



It’s a direct measurement of hardening

With the aging, the bitumen become stiffer.

Corbett Analysis (CA)

Conventional asphalt binders can be separated into four factions (ASTM D4124 - 09):

Asphaltenes
Saturates
Napthene Aromatics
Polar Aromatics

Corbett analysis is done by Gel Permeation Chromatography (***GPC***)

Corbett Analysis (CA) Result

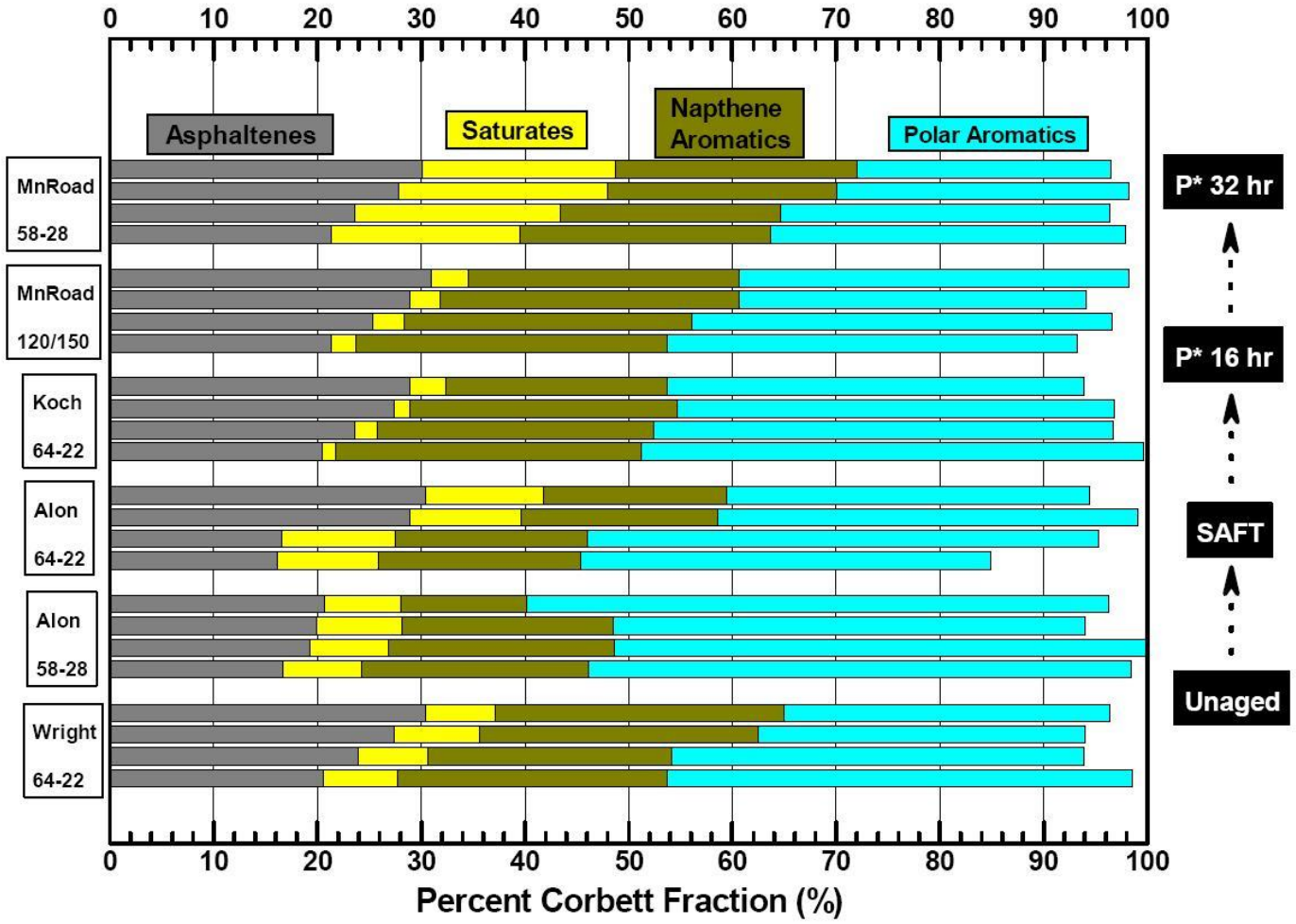


Figure: Corbett Analysis for Unaged and PAV* Aged PMAs and Base Binders (Wright through MnRoad)

Corbett Analysis (CA) Result

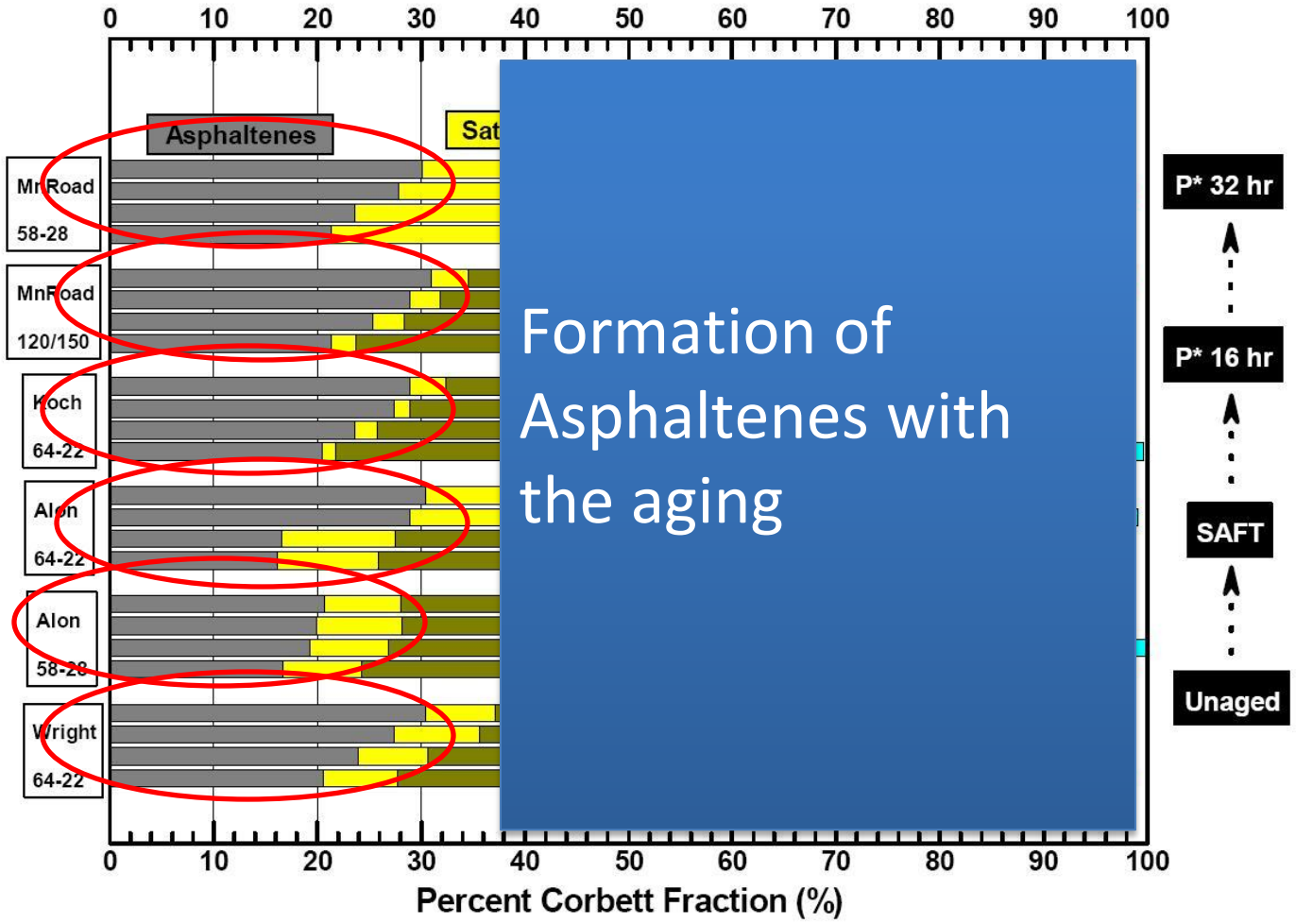
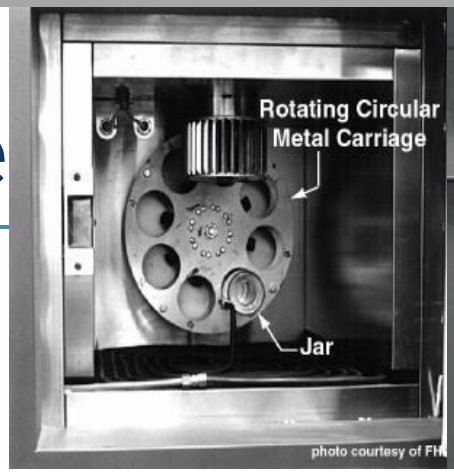


Figure: Corbett Analysis for Unaged and PAV* Aged PMAs and Base Binders (Wright through MnRoad)

Rolling Thin-Film Oven (RTFO)

RTFOT Test Procedure



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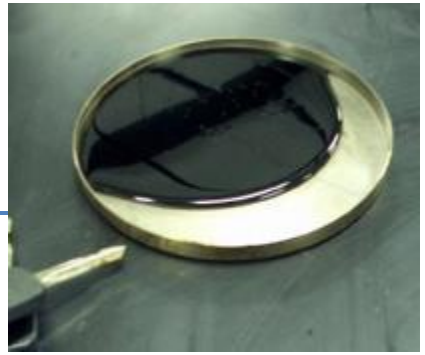
- Make the sample completely fluid but the oven temperature should not exceed 10°C below the test temperature (163 ± 1) °C
- Pre-heating the oven 1hour
- (35 ± 0.5) g of sample in each glass container
- Rotation rate (15 ± 0.2) r/min
- Air flow rate (4 ± 0.2) l/min
- 75 min from the time the temperature reaches 1 °C below the test temperature
- The test temperature should reach (163 ± 1) °C within 15 min

Pressure Ageing Vessel (PAV)

PAV Test Procedure



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- Pre-heat to the PAV conditioning temperature (typically 85°C, 90°C, 100°C and 110°C)
- Pre-heating the vessel up to 15°C above the conditioning temperature
- (50 ± 0.5) g of sample in each container
- Air pressure 2.1 ± 0.1 MPa
- The test temperature should reach within 2 hours after application of pressure
- Typical ageing time for 90°C, 100°C and 110°C is 20 h ± 10 min and for 85°C is 65 h ± 30 min
- At the end of the test, slowly release the internal pressure and
- Place the filled containers into a pre-heated oven set to 170 ± 5°C for 30 ± 1 min.

Thank You

Question?