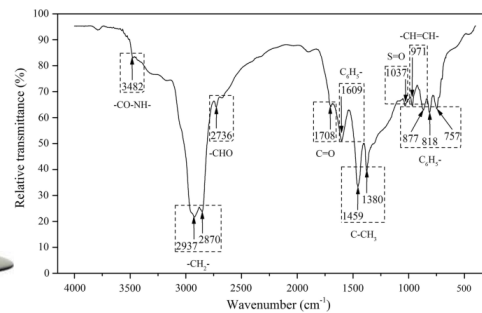
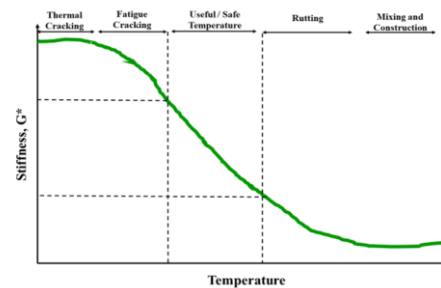


Global Trends in Designs & Construction of Durable Road Pavement

Chemo-Rheology Characterisation of Bitumen: A Pathway to Improved Quality Control for Nigerian Pavements



FTIR



DSR

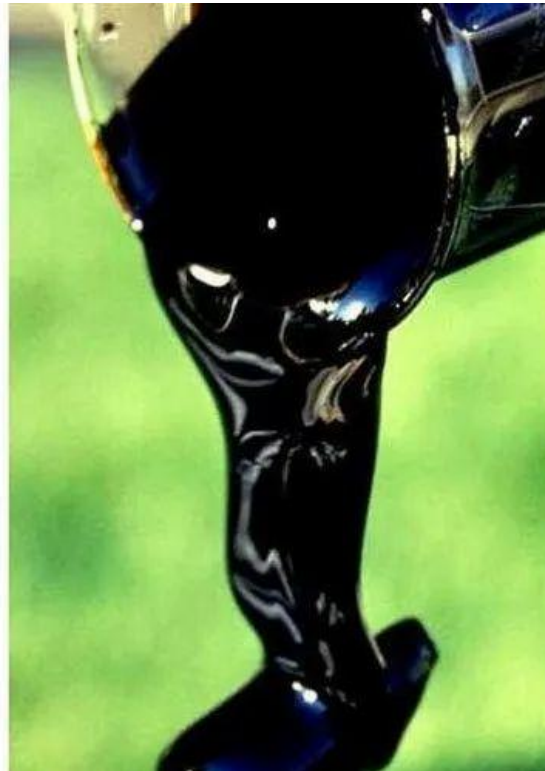
Adesola Afolabi
Research Scientist NBRRI

Bitumen

Waste from crude oil

Elastic material

Minor component of asphalt



The **binding glue** of asphalt

Viscoelastoplastic material

Major component of asphalt

Bitumen

Though a minor component in Asphalt, its chemical structure and rheological behavior controls:

Durability



Rutting resistance



Cracking performance



Moisture damage resistance



What is Chemo-Rheology?

Chemistry (Chemo):

Composition of bitumen → Saturates, Aromatics, Resins, Asphaltenes (SARA fractions)

Rheology:

How bitumen behaves under load, temperature, and time (viscosity, stiffness, elasticity)

Chemo-rheology:

How **chemical composition influences mechanical behavior.**

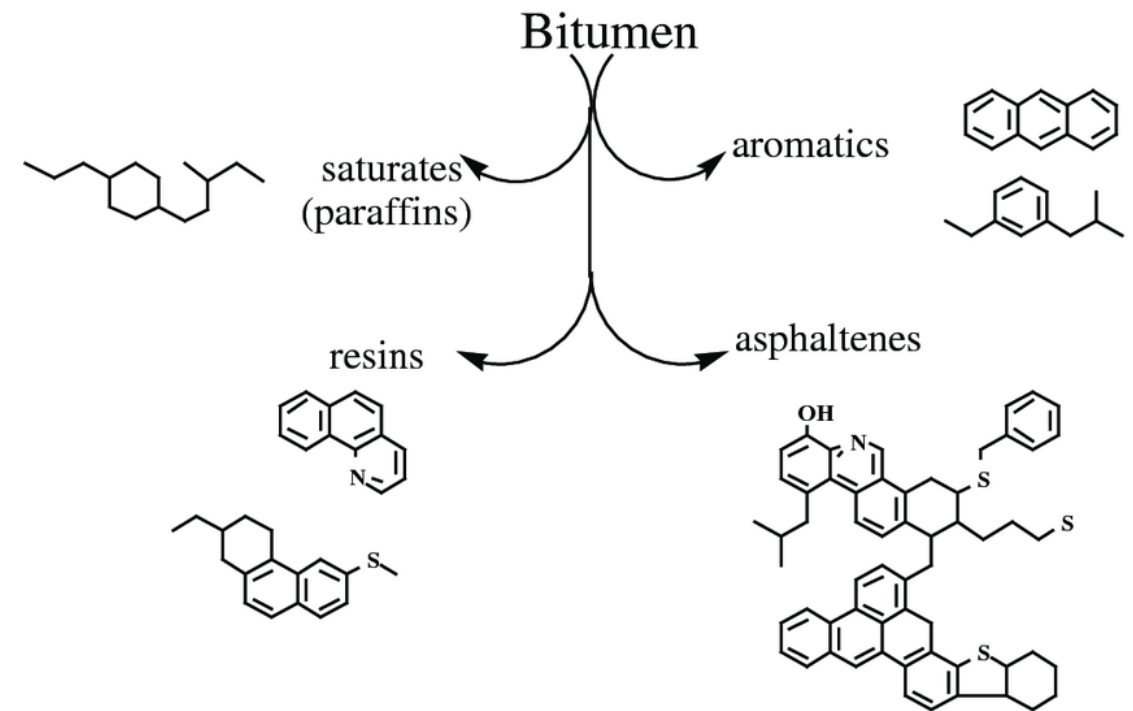
The Chemical Structure of Bitumen

Bitumen = complex mixture of hydrocarbons.

Key fractions:

- **Asphaltenes:** Provide stiffness and strength.
- **Resins:** Provide adhesion and ductility.
- **Aromatics:** Enable flexibility and flow.
- **Saturates:** Lubricating oils that help workability.

The ratio of these components determines performance grade.



Why Chemistry Affects Performance

High **asphaltene content** leads to stiffer bitumen

Rutting resistance  but Cracking resistance 

High **aromatics/resins** increase flexibility but lead to long-term ageing issues

Oxidation/Ageing increases stiffness but increases the risk of cracking

Rheological Properties That Matter

Measured using DSR, BBR, Penetrometer, Softening Point, and Viscometer.

- **Viscosity:** Workability during mixing/laying
- **Complex Shear Modulus (G^*):** Resistance to deformation
- **Phase Angle (δ):** Elastic vs. viscous nature
- **Stiffness Modulus (S):** Low-temperature cracking resistance
- **Jnr:** Resistance to permanent deformation (multiple stress creep recovery test)

Bitumen Aging (Short & Long Term)

Short-term aging (during mixing): simulated with RTFOT

Long-term aging (in service): simulated with PAV

Aging increases:

- Asphaltenes
- Stiffness
- Cracking probability

So, if we can control ageing, we get asphalt with better durability



What Determines Good Bitumen for Nigeria?

Must withstand:

- High temperatures (35–65°C pavement temperatures)
- Heavy axle loads
- Moisture susceptibility

Key indicators:

- High rutting resistance (low Jnr)
- Good elasticity (low phase angle δ)
- Adequate stiffness (higher G^*)
- Moisture resistance (via chemistry + additives)

Chemo-Rheology & Quality Control

Chemo-rheology provides a scientific explanation for:

- Why bitumen fails
- Which additives to use
- How to select bitumen suppliers
- How to verify quality on-site and in labs
- How to detect adulteration

Recommended QC Tests

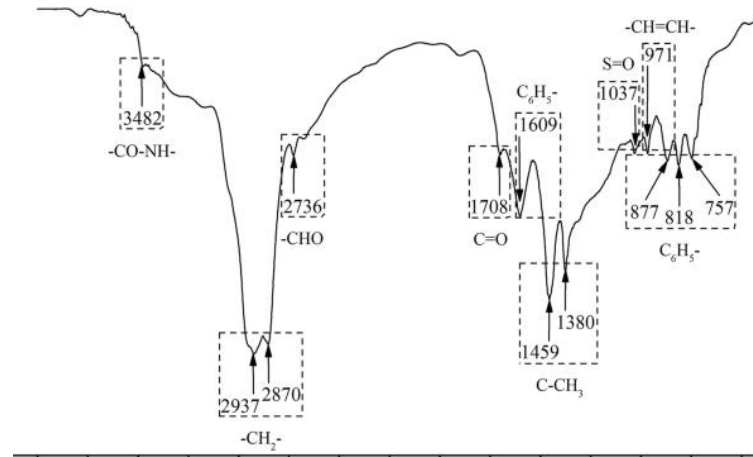
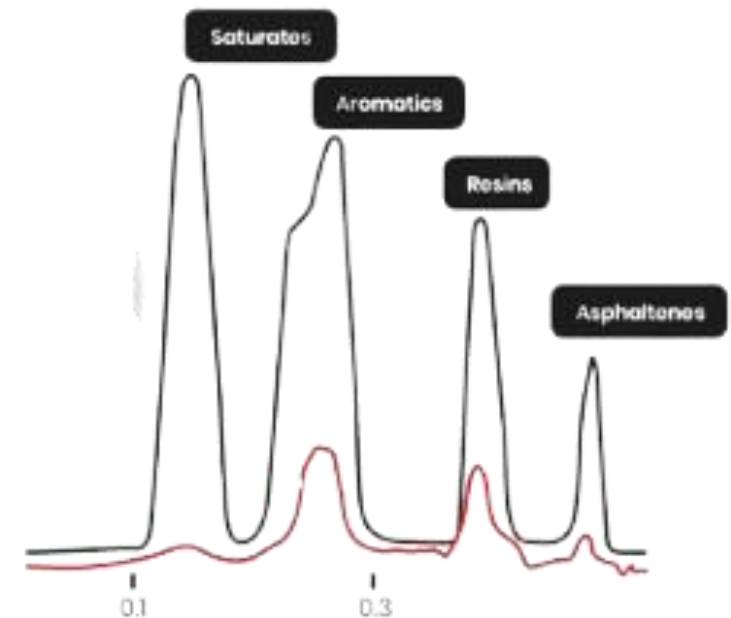
1. Conventional Tests

- Penetration
- Softening point
- Ductility
- Flash point

Recommended QC Tests

2. Chemical Tests

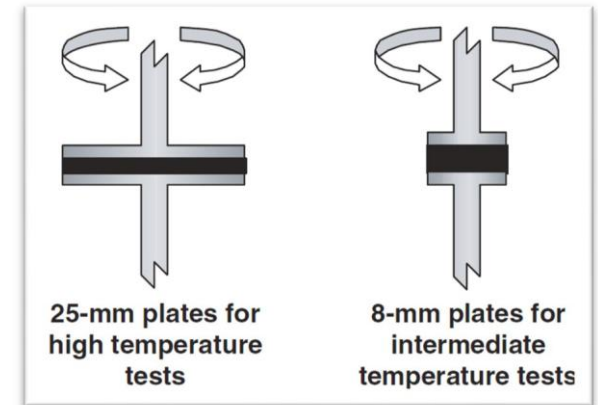
- SARA analysis
- FTIR for chemical fingerprints
- Elemental analysis (sulfur, metals in imported bitumen)



Recommended QC Tests

3. Rheological Tests

- Frequency sweep, Temperature sweep, Amplitude sweep (G^* , δ)
- MSCR (J_{nr} , % recovery)
- BBR for cold cracking
- Viscosity at 135°C & 165°C



Parallel plate for bitumen

Why FTIR Is Important in Bitumen Quality Control

Detects issues **that rheology alone cannot reveal:**

✓ **Adulteration detection**

- Diesel, kerosene, and waste oils create new absorption peaks.
- Reveals **DEFECTS** immediately, even when penetration or viscosity looks normal.

✓ **Verification of polymer modification**

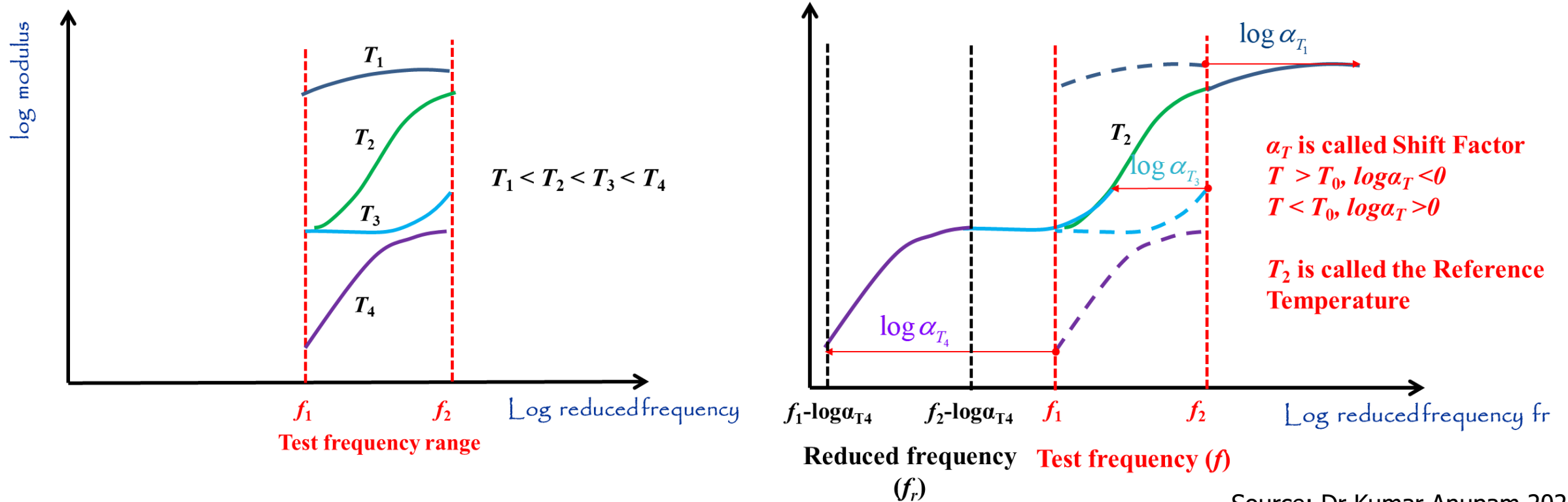
- Presence/absence of modifiers.
- Helps verify if a supplier actually delivered a “modified binder”.

✓ **Ageing measurement**

- Appearance of carbonyl (C=O) and sulfoxide (S=O) peaks.
- These peaks increase with oxidation and directly correlates with rheological stiffening.

How to make sense of the information obtained from the result of DSR?

Frequency sweep



Source: Dr Kumar Anupam 2024

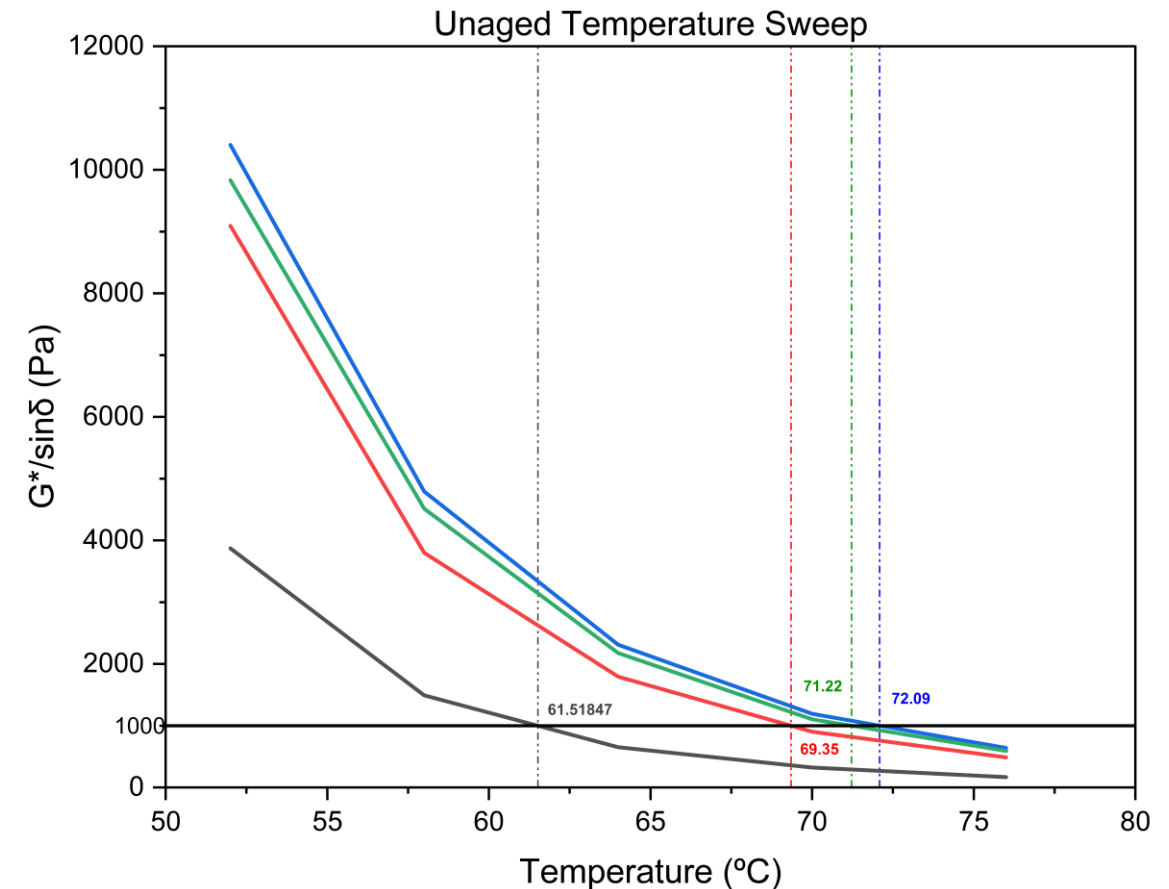
How to make sense of the information obtained from the result of DSR?

Temperature sweep

- Frequency is constant at 1.592 Rad/s
- Complex modulus (G^*) and phase angle (δ) are recorded at different temperatures
- The rutting parameter is calculated, using

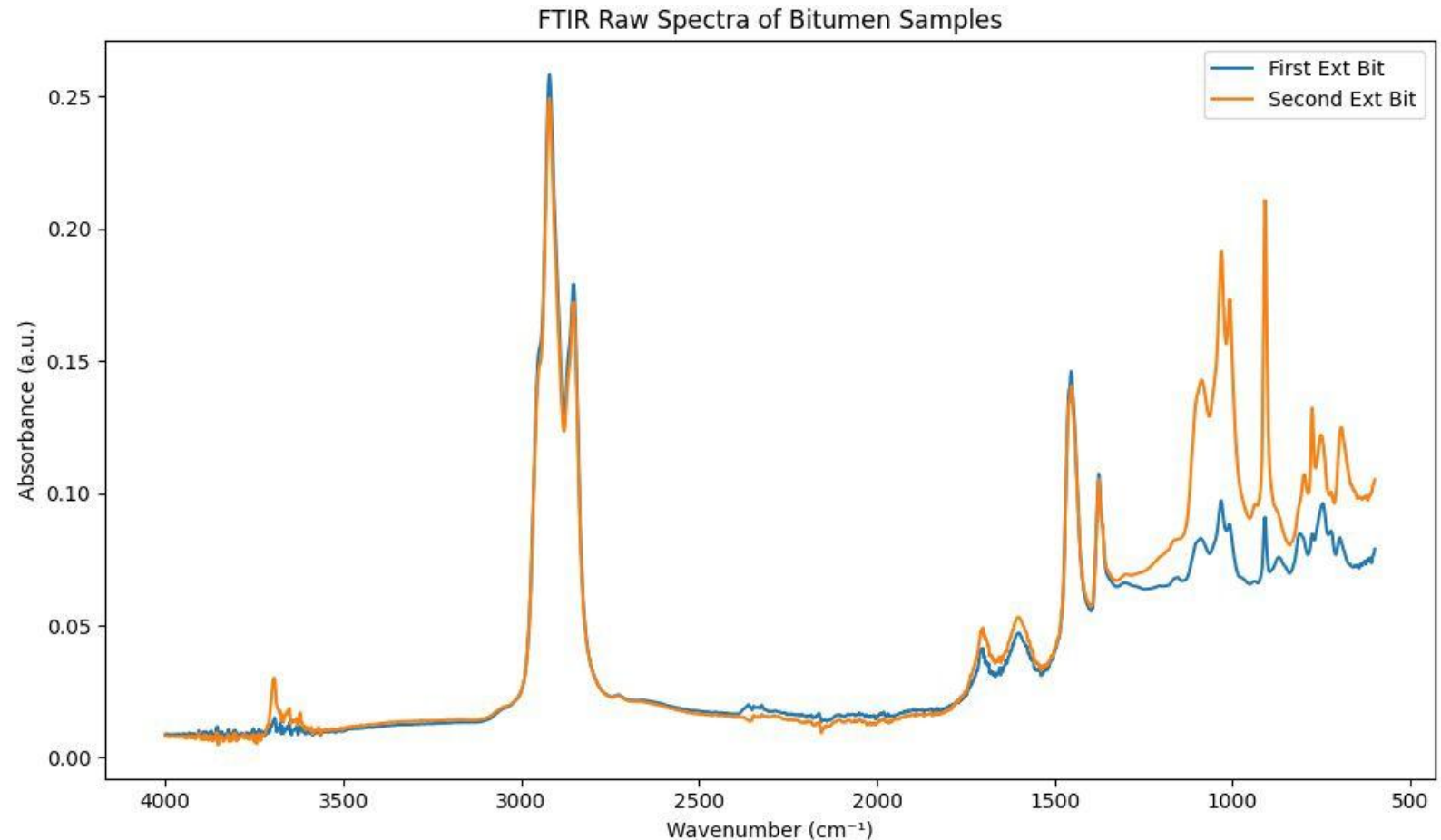
$$\frac{G^*}{\sin \delta}$$

- We then interpolate to get the exact temperature where the value falls below 1Kpa



How to make sense of the information obtained from the result of FTIR

➤ Look at the peaks that matter



FTIR Functional Groups that Matter

Bitumen shows key IR absorption bands:

Functional Group	Wavenumber (cm ⁻¹)	What It Means
Carbonyl (C=O)	1700	Aging & oxidation
Sulfoxide (S=O)	1030	Long-term aging
Aromatic C=C	1600	Indicates aromatic content
Aliphatic C-H	2850–2950	Base hydrocarbon structure
SBS Polymer bands	960–990, ~700	Confirms polymer modification
PE/PP Plastics	720–730	Plastic modification presence

Policy Recommendations

1. Adopt performance-based bitumen grades (PG system).
2. Require rheological tests for all bitumen used.
3. Establish state-level QC labs or regional hubs. (with DSR & FTIR)
4. Make chemical authentication (FTIR) mandatory for procurement.
5. Implement random sampling at the site & refinery depots.
6. Enforce clear penalties for suppliers delivering adulterated bitumen.
7. Encourage local bitumen research & modifier development.

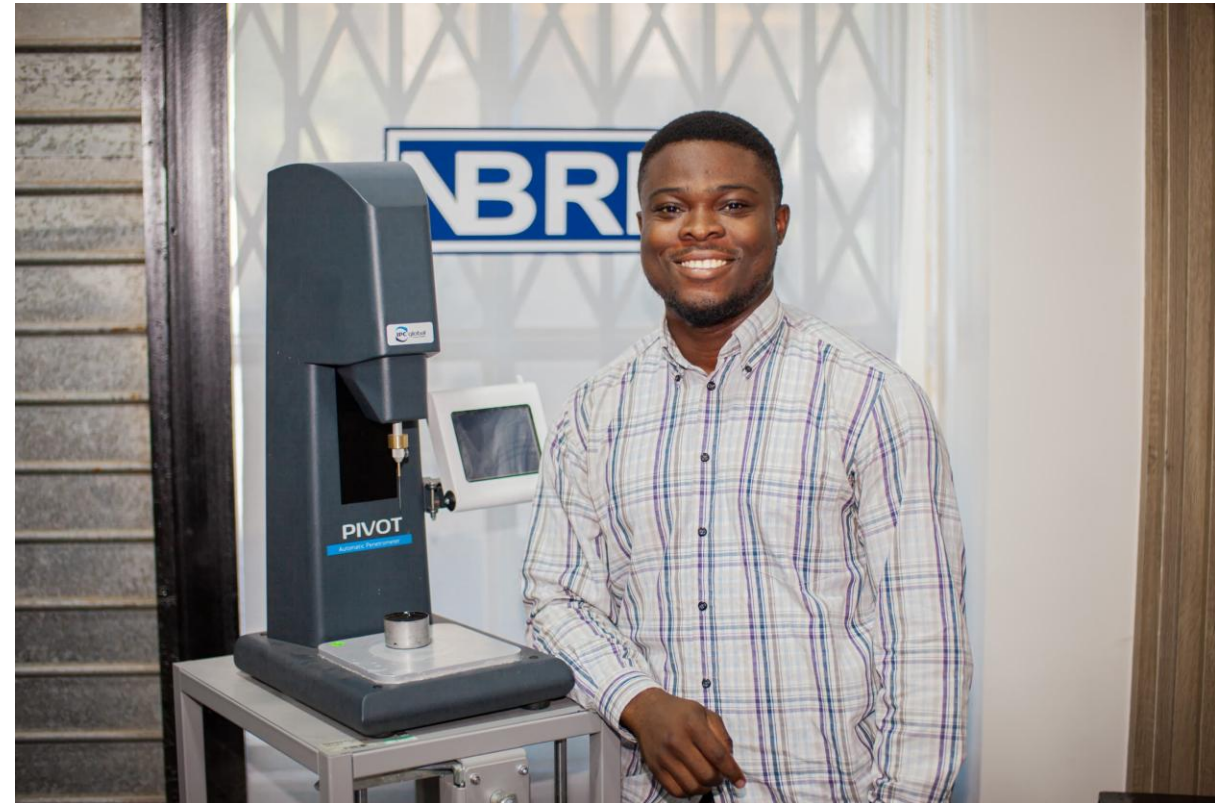
Summary

FTIR explains the chemistry

Rheology measures the mechanical effect.

Together, we have **chemo-rheology** for
durable road pavement.

Thank You



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