BITUMEN 1
(ASPHALT CEMENT)

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Definition

A black or dark brown non-crystalline solid or viscous material, composed principally of high molecular weight hydrocarbons, having **adhesive** properties, derived from petroleum either by **natural** or **refinery** processes and substantially soluble in carbon disulphide.

**Adhesion** (Cementing action)

Bituminous materials adhere to clean dry surfaces.
Origin of Bitumen

Asphalt materials have been utilized since 3500 B.C. (lining of water retaining structures) in building and road construction. Their main uses have been as adhesives, waterproofing agents, and as mortars for brick walls.

These early asphalt materials were natural asphalt. These asphalts were found in pools and asphalt lakes. For example, Trinidad and Bermudez lake deposits (asphalt lake).
Historical Developments

- First US hot mix asphalt (HMA) constructed in 1870’s
  - Pennsylvania Ave.
  - Used naturally occurring asphalt from surface of lake on Island of Trinidad

- Two sources
  - Island of Trinidad
  - Bermudez, Venezuela

- Demand for paved roads exceeded the supply of lake asphalts in late 1800, leading to use of petroleum asphalts
Lake Bitumen
Petroleum Bitumen

- Petroleum bitumen is simply the residue left over from petroleum refining.

- Asphalt is waste product from refinery processing of crude oil
  - Sometimes called the “bottom of the barrel”

- Properties depend on:
  - Refinery operations
  - Composition crude source-dependent
Refinery Operation

Diagram showing the process of refining crude oil to various products at different temperatures:
- Crude oil enters the furnace at 20°C.
- At 150°C, Petroleum Gas is produced.
- At 200°C, Gasoline (petrol) is produced.
- At 300°C, Kerosene is produced.
- At 370°C, Diesel, Industrial fuel oil, and Lubricating oil, paraffin wax are produced.
- At 400°C, Asphalt is produced.
Bitumen Components

- Asphaltene
- Resins
- Oils
Native bitumen
The primary asphalt product produced by the distillation of crude oil. They are produced in various *viscosity grades*. 
Cont. Types of Bitumen/Classifications

Cutbacks
Describes a mixture of a binder and a light volatile oil. They are liquid at low temperatures until the volatile oil evaporates.

Environmental Aspect
Due to the release of solvents into the Atmosphere they are now rarely used.
Emulsions

When mixed with water binders will generally settle out. An emulsifier must be added to give a stable solution. The water evaporates and the bitumen remains on the surface. The current types of cold rolled materials are based on emulsions.
Modified Bitumen

- More stable under heavy loads, braking and accelerating forces;
- Shows increased resistance to permanent deformation in hot weather.
- It resists fatigue loads;
- Better adhesion between aggregates and binders

Types of modifiers / Advantages [Google]
- Sulphur
- Rubber (natural and discarded tyres)
- Polymers (ethylene vinyyle, polypropylene)
Other Types of Bitumen

Oxidised Bitumen

- Bitumen, the properties of which are modified by blowing air through it at a comparatively high temperature and pressure.
- Used in wide variety of industrial application including roofing, flooring, pipe coating, etc

Foamed Bitumen

created by injection of a pre-determined amount of cold water (usually around 2.5%) into hot bitumen in the mixing chamber of a pavement recycling unit. [Google search]
Aging (Ageing) of Bitumen

- Results due to exposure of bitumen to atmosphere.

**Oxidation**: Oxygen molecules from the air combine with the resins forming asphaltenes (high weight molecules)

**Loss of Volatiles**: Low weight molecules evaporates due to increase in temperature during production of asphalt concrete and thereafter.

**Consequence**

Aging = hardening
= becoming brittle
BUT
✓ what is wrong of being **brittle**?!

**Oxidation**: Oxygen molecules from the air combine with the resins forming asphaltenes (high weight molecules)

**Loss of Volatiles**: Low weight molecules evaporates due to increase in temperature during production of asphalt concrete and thereafter.
Bitumen Behavior

- Bitumen is **visco-elastic** meaning that it can exhibit both elastic and viscous properties in the same time.

- Behaviour of bitumen depends on:
  - Temperature (discuss latter)
  - Time (duration) of loading (rate of loading)
  - Aging properties

- Bitumen is **thermoplastic** material meaning that it soften as temperature rises but become hard again when temperature fall.

Temperature susceptibility = change in viscosity with temperature
BITUMEN 2
Testing
Penetration grade Specifications

- Flash point test
- Ductility
- Solubility
- Penetration
- Ductility
- Softening
Penetration Testing

- Sewing machine needle
- Specified load, time, temperature

100 g

Penetration in 0.1 mm

100 g

Initial

After 5 seconds
Penetration Grades

Five Grades

- 40 - 50
- 60 - 70
- 85 - 100
- 120 - 150
- 200 - 300

*Penetration test* is a 1mm diameter needle is loaded with a weight of 100g and the distance it drops into a bitumen sample in 5 seconds is measured *(at 25°C)*. A bitumen is referred to as 70 pen if the penetration is 7mm.
Flash point
Temperature at which Vapour starts.

Bitumen vapour
Carcinogenic!

Fire point
Temperature at which Bitumen starts to burn
Ductility

- Ability to stretch without breaking

Distance in cm to which a standard specimen will elongate before breaking is pulled apart at a specified speed and a specified temperature.
Solubility

This test method is a measure of the solubility of binder in toluene. The portion that is soluble in toluene represents the active cementing constituents.
Softening Point

The softening-point is reported as the mean of the temperatures at which two disks of bitumen soften enough to allow each ball to fall a distance of 25 mm.

Why the softening temp. is so important in KSA?

- Grades asphalt near average in-service temp.
- Fast
- Can be used in field labs
- Low capital costs
- But can Temp. susceptibility be determined?
Disadvantages of Pen. Spec.

- Empirical test
- Shear rate
  - High
  - Variable
- Mixing and compaction temp. information not available
- Similar penetrations at 25C (77F) do not reflect wide differences in asphalts
Viscosity: the ratio between the applied shear stress and the rate of shear.

\[ \eta = \frac{\tau}{\dot{\gamma}} \]

The viscosity of a liquid is the property that retards flow so that, when a force is applied to liquid, the higher the viscosity, the slower will be the movement.
Types of Viscosity Tubes

Asphalt Institute Tube

Zietfuchs Cross-Arm Tube
Viscosity Testing- Absolute

- Absolute viscosity
  - U-shaped tube with timing marks & filled with asphalt
  - Placed in $60^\circ$C bath
  - Vacuum used to pull asphalt through tube
  - Time to pass marks
  - Viscosity in Pa s (Poise)
Viscosity Testing - Kinematic

- Cross arm tube with timing marks & filled with asphalt.
- Placed in 135°C bath
- Once started gravity moves asphalt through tube
- Time to pass marks
- Viscosity in mm² / s (centistoke)
Mixing/Compaction Temps

Viscosity, Pa s

Temperature, °C

- **Compaction Range**
- **Mixing Range**
Advantages of Viscosity Grade Spec.

- Fundamental property
- Wide range of temperatures
- Based on max. pavement surface temp.
- Wide range of instruments
- Test method precision established
- Temperature susceptibility is controlled
- Information on mixing & compaction temps.
Disadvantages of Viscosity Grade Spec.

- More expensive
- Longer testing time
- More technician skill needed
- Wide range of properties for same grade
Where Must I Go from Here

Should look for a binder specifications That addresses:
- Permanent deformation
- Low temperature cracking
- Fatigue cracking

SHRP = Strategic Highway research Program

Superior Performing Asphalt Pavements
SUPERPAV
SUPERPAVE BINDER SPECIFICATIONS
Superpave Performance Graded Specifications was developed to address the **shortcoming** seen in traditional bitumen specifications

@25 degree Celsius! Fits both conditions in Canada and KSA??

- Relationship between performance and Pen. / Visc. Spec. is missing OR has to be gained from experience!

- Long-term **aging** not considered in Both Pen. and viscosity specifications

- Entire range of temperature was not included in the Pen (only at 25°C)/ Visc (only at 60 & 135°C) Spec. !!

Same specification grade, but might be different behavior with respect to temperature?
Superpave – Performance Grade (PG) Specifications

Advantages:

- Fundamental properties related to pavement performance.
- Environmental factors included.
- In-service & construction temp. are taken into account.
- Short and long term aging is considered.

PG 64 - 22

Performance Grade

Min pavement temperature (on the surface)

Average 7-day max. pavement temperature (20 mm below surface)

Pavement temp = f (air temp, depth, latitude)
## SUPERPAVE Binder Tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rolling Thin Film Oven (RTFO)</td>
<td>simulates short-term aging (aging from hot mixing and construction)</td>
</tr>
<tr>
<td>Pressure Aging Vessel (PAV)</td>
<td>simulates long-term aging (aging of 7 to 10 years)</td>
</tr>
<tr>
<td>Dynamic Shear Rheometer (DSR)</td>
<td>measure binder properties at high and intermediate temp.</td>
</tr>
<tr>
<td>Rational Viscometer (RV)</td>
<td>measure binder properties at high temp.</td>
</tr>
<tr>
<td>Bending Beam Rheometer (BBR)</td>
<td>measures binder properties at low temp.</td>
</tr>
<tr>
<td>Direct tension Tester (DTT)</td>
<td>measures binder properties at low temp.</td>
</tr>
</tbody>
</table>
Rolling Thin Film Oven

Outside of Oven

Pan

Rotating Shelf

Thermometer
Dynamic Shear Rheometer (DSR)

Shear flow varies with gap height and radius
Non-homogeneous flow

Rheology = study of flow and deformation

\[ G^*/\sin\delta \]
\[ G^*\sin\delta \]

Rutting
Fatigue
Discuss?!
Rational Viscometer

- Torque Motor
- Inner Cylinder
- Thermosel Environmental Chamber
- Digital Temperature Controller
Bending Beam Rheometer

- Air Bearing
- Load Cell
- Deflection Transducer
- Fluid Bath
Direct Tension Test

Load

\[ \Delta L \]

\[ \Delta L_e \]

\[ \text{Stress } \sigma = \frac{P}{A} \]

\[ \sigma_f \]

\[ \varepsilon_f \]

Strain
High Temperature Behavior

- High in-service temperature (KSA)
  - Desert climates
  - Summer temperatures
- Sustained loads
  - Slow moving or parked trucks
  - Intersections

Can additives reduce / alleviate such effect?

Bitumen behaves like viscous liquid

Shear stress vs. Shear strain

Hot asphalt (Newtonian)

Rutting?

Plastic

Permanent Deformation!
Low Temperature Behavior

- Low Temperature
  - Cold climates
  - Winter
- Rapid Loads
  - Fast moving trucks
  - Parking trucks

Elastic Solid

Too brittle
cracks at excessive load

Like rubber band?

Hooke’s Law applies

Drop in temp. 
contraction 
Tensile stress >>> material strength 
Thermal Cracks
# Performance Grades

<table>
<thead>
<tr>
<th>Avg 7-day Max, °C</th>
<th>PG 46</th>
<th>PG 52</th>
<th>PG 58</th>
<th>PG 64</th>
<th>PG 70</th>
<th>PG 76</th>
<th>PG 82</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-day Min, °C</td>
<td>-40</td>
<td>-40</td>
<td>-40</td>
<td>-40</td>
<td>-40</td>
<td>-40</td>
<td>-40</td>
</tr>
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</table>

| ≥ 230 °C | Flash Point | FP |
| ≤ 3 Pa·s @ 135 °C | Rotational Viscosity | RV |
| ≥ 1.00 kPa | Dynamic Shear Rheometer | DSR \( G^*/\sin \delta \) |

<table>
<thead>
<tr>
<th>(ROLLING THIN FILM OVEN)</th>
<th>RTFO</th>
<th>Mass Loss &lt; 1.00 %</th>
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<tr>
<td>≥ 2.20 kPa</td>
<td>Dynamic Shear Rheometer</td>
<td>DSR ( G^*/\sin \delta )</td>
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<tr>
<th>(PRESSURE AGING VESSEL)</th>
<th>PAV</th>
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<tr>
<td>20 Hours, 2.07 MPa</td>
<td>90</td>
</tr>
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| ≤ 5000 kPa               | Dynamic Shear Rheometer | DSR \( G^* \sin \delta \) |
| S ≤ 300 MPa & \( m \geq 0.300 \) | Bending Beam Rheometer | BBR “S” Stiffness & “m”-value |
| 31, 28, 25, 22, 19, 16, 13, 10, 7, 4, 25, 22, 15, 10, 1, 46, 52, 58, 64, 70, 76, 82 |

<table>
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<tr>
<th>Report Value</th>
<th>≥ 1.00 %</th>
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<tr>
<td>(Bending Beam Rheometer)</td>
<td>BBR</td>
</tr>
<tr>
<td>(Direct Tension)</td>
<td>DT</td>
</tr>
<tr>
<td>90, 90, 100, 100, 100 (110), 100 (110), 110 (110)</td>
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How the PG Spec Works

### Spec Requirement Remains Constant

<table>
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<tr>
<th>Avg. Test Temperature</th>
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### Test Temperature Changes

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</tr>
<tr>
<td>S &lt; 300 MPa, m ≥ 0.300</td>
<td>46</td>
<td>52</td>
<td>70</td>
<td>76</td>
<td>82</td>
</tr>
</tbody>
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### How PG Spec Works

- **...(Bending Beam Rheometer) BBR “S” Stiffness & “m”-value**
- **...(Direct Tension) DT**
KSA Ministry of Transport has established PG zones

Ras - Tanura produces PG64 - 22

How can we get PG70 - 10 for Riyadh Roads?!?!
Questions