Module 3

Specifications and test methods

Purpose of Specifications for bituminous binders

To ensure that:

- Binders are manufactured to accepted, uniform standards that will ***ensure satisfactory performance;***
- Binders quality - not adversely affected during normal handling, transport and storage, even when heated
- Changes in binder properties during correctly controlled application will not exceed certain limits.

Context of this module

- Current national specification for bitumen: SANS 4001-BT1
  - Mandatory
  - Basis for SABS mark scheme
- PG spec being implemented
  - SABS technical specification SATS 3208
  - Will ultimately replace SANS 4001-BT1
- Purpose of module to give ***background to requirements and compliance limits SATS 3208***

Type of specification

- Chemical composition of bitumen determine its physical properties and performance characteristics
- Complex and variable chemical and molecular structure of bitumen makes it extremely ***difficult to define chemical composition*** to characterise performance.
- General practice, worldwide, use ***performance-related physical properties*** as means for specifying and selecting bituminous binders.

Purpose of **P**erformance **G**rade (PG) Spec

- For a specific set of conditions – define quality to minimise potential of binder to contribute to:
  - ***permanent deformation***
  - ***fatigue cracking***
  - ***(non-load associated) low temperature cracking***

Features of PG spec

- Provides for binders to be graded to perform in specific environments defined by:
  - climate (particularly ***temperature ranges***)
  - intensity and rate of ***traffic loading***
- Does ***NOT*** differentiate between conventional and modified binders or modifier type
- Need for modification / additives (and type) determined by binder manufacturing industry

Features of PG spec / cont.

- Requirements are derived from ***fundamental rheological properties*** of bituminous binders
- Compliance limits are based on ***empirical evidence of their validity*** in terms of actual field performance.

Basis of PG spec

- Influenced by the USA spec
- Spec framework based on the performance of ***asphalt mixes***
- No evidence that spec inappropriate for chip seals
- Having 2 specs totally impracticable for SA
- PG spec launched – proviso that steps be taken to cater for chip seals when necessary

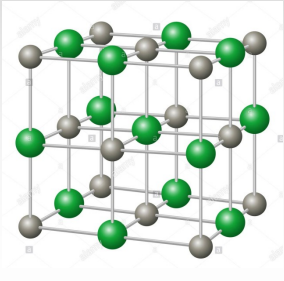
Performance Criteria

- Measure rheological properties using DSR and BBR
- Criteria for adequate performance:
  - excessive permanent deformation (viscous flow) at elevated temperatures
  - fatigue failure (durability cracking) at intermediate temperatures
  - thermal fracture due to large fluctuations in layer temperatures

- Characteristics of the binder ***alone*** will not ensure optimal performance layer
- Design methods – safeguard adequate layer performance through optimal configuration of ***all its components***.
- PG spec ensures quality of the binder is suitable ***to augment the role and function of the other components of the layer***

PG spec framework

- The specification framework provides for:
  - range of operating conditions
  - performance requirements
  - safety and handling aspects.



Specification categories

- Operating bands
  - Climate
  - Traffic
- Resistance to ***viscous flow***;
- Resistance to ***fracture***
  - fatigue / durability cracking;
  - Low temperature cracking;
- Storage stability;
- Safety
- Pumping and handling

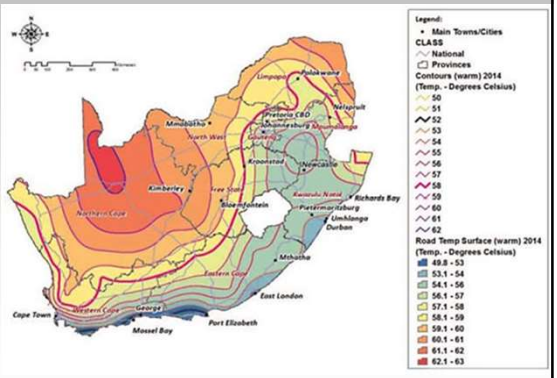
- Performance
- Handling

Operating bands

- **Climate**
  - ***Max. temperature*** – average 7-day max pavement temperature (20 mm below asphalt surface)
  - ***Minimum temperature***
- **Traffic**

Maximum design temperature

- Max design temperatures adopted for SA:
  - 58°C
  - 64°C
  - 70°
- Isotherm bands 7-day mean max temp zones for 58°C and 64°C
- Provision for areas with max temp of 70°C within the 64°C region



Minimum temperature

- Min temp in SA rarely below -10°C
- Minimum temp adopted *for* ***grading purposes***
  - aligned to US standard
  - determines temperatures at which other tests are carried out
    - intermediate temperatures for fatigue (durability)
    - low temperatures for thermal cracking

Minimum temperature / cont.

- The min temps associated with
  - 58°C
  - 64°C
  - 70°C
- Are:
  - -22°C
  - -16°C
  - -10°C, respectively

(80°C difference in all cases)

Operating bands

- **Climate**
  - ***Max. temperature*** – average 7-day max pavement temperature (20 mm below asphalt surface)
  - ***Minimum temperature***
- **Traffic**

Traffic

- Classified as
  - ***Standard – S***
  - ***Heavy – H***
  - ***Very Heavy – V***
  - ***Extreme – E***
- Based on ***BOTH volume & speed***
- At **low speeds** heavy traffic exerts stress durations that will test the binder's ***resistance to viscous flow***

Traffic categories

Design traffic (million E80s)	Traffic Speed (km/h)		
	< 20	20 - 80	>80
< 0.3	S	S	S
0.3 - 3	H	S	S
>3 - 10	V	H	S
>10 - 30	E	V	H
>30 - 100	E	E	V
> 100	E	E	E

Specification framework

Binder classification (in terms of previous descriptors

Classification	58S -22	58H -22	58V -22	58E -22	64S -16	64H -16	64V -16	64E -16	70S -10	70H -10	70V -10	70E -10
Maximum pavement design temperature, T_{max} (˚C)	58				64				70			
Minimum grading temperature, T_{min} (˚C)	-22				-16				-10			

Relevant (test) temperatures

- ***Maximum temperature, T_{max}*** : 58, 64, 70°C
- ***Minimum grading temperature, T_{min}*** : $[T_{max} - 80]°C$
- ***Intermediate temperature, T_{IT}*** : midway between T_{max} and T_{min} plus 4°C, i.e. $\left[\frac{T_{max}+T_{min}}{2} + 4\right]°C$
- ***Low temperature: T_{LT}*** : 10°C above T_{min}, i.e. $[T_{min}+10]°C$

Conditioning (Ageing)

- Ageing classified in two phases

1. ***Short-term (STA) –*** simulates ageing
   – during handling, manufacture, storage, transport and placement - (high temperature process)
2. ***Long-term* (LTA) –** simulates ageing
   – over the in-service life of the layer,
   – deemed as ageing over 5 - 10 years
   – medium temperature process ranging between - 5°C and 70°C

Effects of ageing

- Ageing - significant impact on the behaviour of binder and, hence, the layer
- Increase in bitumen stiffness
  - ***negative*** influence on fatigue life of a layer
  - positive effect – increased stiffness (bearing capacity)

Significance of ageing tests

- ***Cannot simulate the actual*** conditions accurately
- STA / LTA ***indication*** of susceptibility of the binder to ageing
- Tool - assessing / rating, binder suitability
- In PG spec
  - Rolling Thin-film Oven (RTFO) - simulate STA
  - Pressure Ageing Vessel (PAV) - simulate LTA.

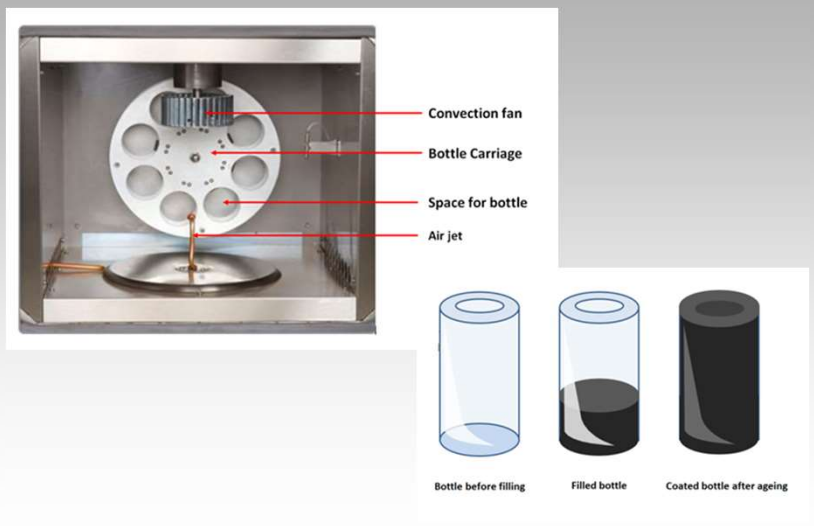
RTFO ageing

- Described in ASTM D2872
- Simulates ageing and hardening due to effect of heat & oxidisation in air
- As would occur in an asphalt manufacturing plant and during storage, handling and compaction.

ASTM D2877

- Glass containers containing specimen rotate in a vertical plane
- At 163°C for 75 minutes
- Fresh surface of bitumen continuously exposed to air
- Flow of air blown over surface of bitumen from single nozzle
- Current local practice for modified binders: tested according to method MB-3 (in TG1), in which e.g. the glass bottles are replaced with brass ones (this may change)

RTFO apparatus



Test outputs

- Tests on binder after RTFO gauge chemical changes as reflected by:
  - a mass change
  - changes in rheological parameters.
- The ***resistance of the binder to viscous flow*** is conducted at this stage i.e. after RTFO conditioning.
  - not allowing the potentially beneficial effects of LTA to come into play.

PAV Ageing

- Carried out on RTFO-aged specimens
- Immediately prepared for PAV testing before cooling
- As described in ASTM D 6521
  - 50 ± 0.5 g of RTFO-aged binder
  - In stainless steel pans of 140 ± 1 mm dia.
  - binder thickness of approximately 3.2 mm
  - At a pressure of 2.10 ± 0.10 mPa
  - At a temperature of 100 ± 10°C..

PAV pan holder

- Pans with binder placed in the pre-heated pan holder
- Unused slots filled with empty pans

Pressure vessel

Completion of ageing

- When test complete, internal pressure is slowly released within 15 minutes
- Pan holder is removed
- Pans - oven (168°C for 15 ± 1 min)
- If binder in multiple pans, decanted into single container and stirred to blend
- If tests on aged specimens not performed immediately, samples are covered and stored appropriately for future testing.

Purpose of **P**erformance **G**rade (PG) Spec

- For a specific set of conditions – define quality to minimise potential of binder to contribute to:
  - permanent deformation (viscous creep)
  - fracture
    - (non-load associated) low temperature cracking
    - fatigue cracking

Performance tests

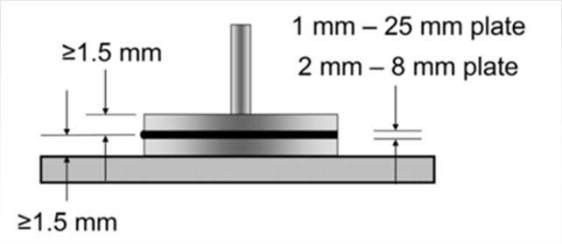
- **SATS 3208**: binders in either asphalt layers or chip seals
- Assessed by testing their resistance to:
  - excessive viscous flow at elevated temps
  - fatigue failure (durability cracking) at intermediate temperatures
  - thermal fracture due to large fluctuations in layer temperatures

Resistance to viscous creep

- Assessed by:
  - Multi-Stress Creep Recovery (MSCR) test according to ASTM D7405 with DSR
  - ***non-recoverable creep compliance J_{nr}*** as defined in ASTM D7175
  - Elastic recovery can also be assessed
- Carried out on RTFO-aged binder
- Test specimen should reach thermal equilibrium at the test temperature T_{max}.

Specimen configuration

- SATS 3208 provides for two sizes of plate diameter:
  - 25 mm parallel plate, 1 mm gap
  - 8 mm parallel plate, 2 mm gap.



Specimen preparation

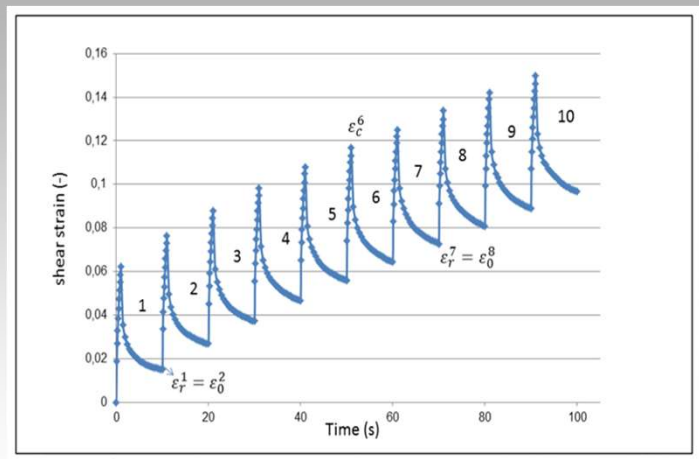
- In placing the binder between the two plates, care is taken to ensure that:
  - Specimen is carefully trimmed to match diameter of plates
  - The gap between plates is carefully controlled

Test procedure

Using the DSR

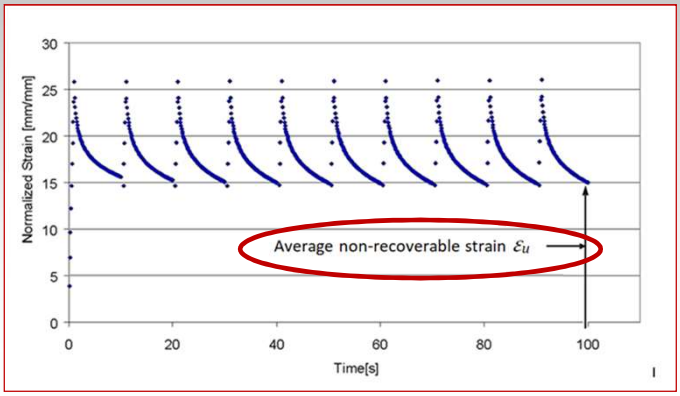
- 1-second creep load is applied
- released and the sample allowed to recover for 9 seconds
- test is started with the application of a low stress (0.1 kPa) for 10 creep/recovery cycles (setting in)
- stress is increased to 3.2 kPa and repeated for an additional 10 cycles

Creep recovery plot



Normalisation

- Plot is normalised as shown to determine average unrecovered strain ε_u



Non-recoverable compliance J_{nr}

- Calculated as:

  $J_{nr} = {}^{\varepsilon_u}/_{\tau}$

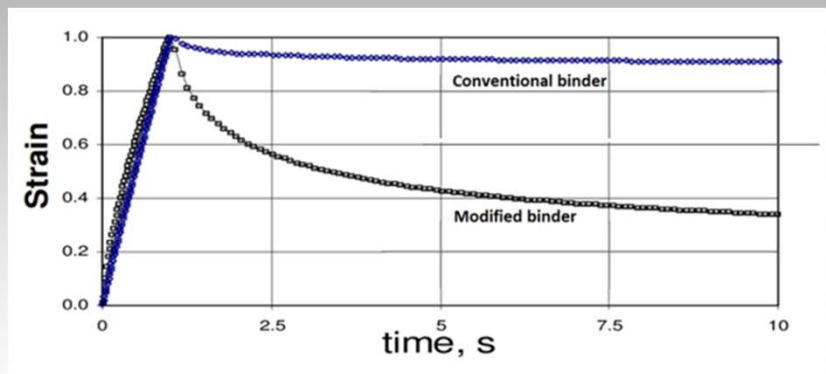
where

  - ε_u - average unrecovered strain at end of the 9-s recovery portion, over 10 cycles.
  - τ - shear stress applied during the 1-s creep portion

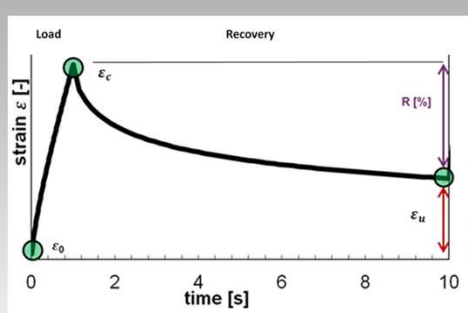
Elastic recovery

- Test - valuable insight into elastic behaviour
- % age identifies presence of elastomeric polymer
- Recovery of elastomeric modified binders - higher than conventional binders
- Test used to select binders for special applications e.g.:
  - crack sealing
  - surfacing on slightly fractured, highly flexible pavements.

Comparative elastic recovery



Percent recovery



Percent Recovery = $\frac{\varepsilon_c - \varepsilon_u}{\varepsilon_c} \times 100$

where

ε_c = is the maximum strain in the creep stage

ε_u = final unrecovered strain

Purpose of **P**erformance **G**rade (PG) Spec

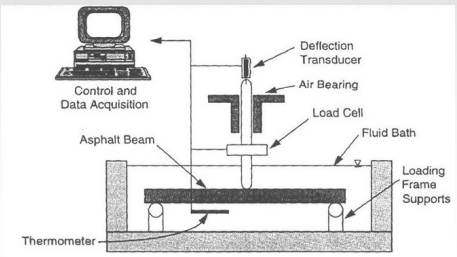
- For a specific set of conditions – define quality to minimise potential of binder to contribute to:
  - permanent deformation (viscous creep)
  - fracture
    - fatigue cracking
    - (non-load associated) low temperature cracking

Fracture

- Common sources of fracture due to binder properties:
  - Thermal contraction and expansion due to temperature fluctuations
  - Fatigue arising from stress or strain reversals due to:
    - repeated traffic loading
    - daily pavement temperature fluctuations
  - Loss of pliability due to ageing

Test procedure

- ***Bending Beam Rheometer*** (BBR) is used in SATS 3208 to establish:
  - criteria for resistance to thermal cracking
  - susceptibility to fatigue cracking (loss of durability)



Thermal cracking

- As temperatures drop, pavements contract, build up internal stresses
- Two situations cause fracture:
  - high stiffness of the binder gives rise to high stresses to initiate fracture
  - if thermal contraction occurs fast enough fracture may occur if induced stresses could not relax sufficiently.
- These types of cracks usually run transverse to the direction of travel.

BBR

- Test in accordance with ASTM D6648: *Determining the flexural creep stiffness of asphalt binder using the bending beam rheometer*
- Test is carried out:
  - on RTFO plus PAV aged binder
  - at T_L i.e. **Tmin + 10°C** (to be discussed later)

BBR test

- Two moulded bitumen specimens:
  - 6.35 mm thick
  - 12.7 mm wide
  - 127 mm long
- Supported at two points 102 mm apart
- In controlled temperature fluid bath
- 981 ± 5 mN force applied at the midpoint
- Deflection measured at 8, 15, 30, 60, 120 and 240 seconds.

Test outputs

- Beam stiffness, “creep stiffness” calculated at the above intervals:

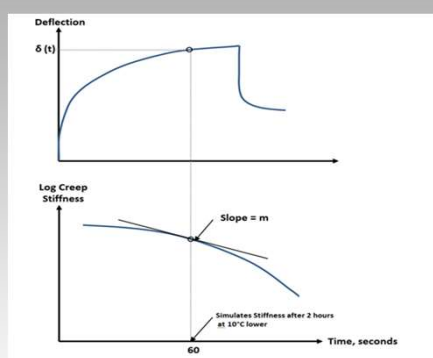
$$S_t = \frac{PL^3}{4bh^3\delta_t}$$

Where

S_t is the creep stiffness at time t
P is the applied constant load
L is the distance between beam supports
b is the beam width
h is the beam depth
δ_t is the deflection at time t

A stiffness curve is then fitted to these points,

Compliance parameters

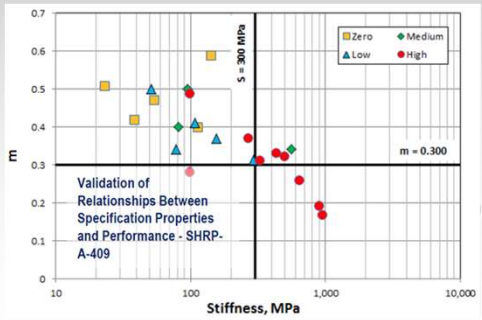


1. Creep stiffness at 60 seconds, S(60)
2. Slope of the creep stiffness vs. time plot at 60 seconds, m(60)

are specified as low temperature cracking criteria.

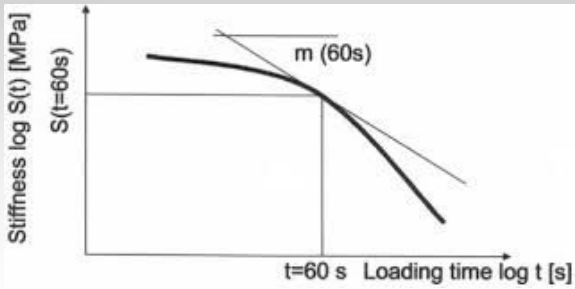
Compliance criteria

- Research indicated that if S and m criteria apply simultaneously, i.e.:
  - S60 ≤ 300 MPa
  - m ≥ 0.300, this type of distress is infrequent,



Compliance criteria

- $S_{(60)} \leq 300\ MPa$
- $m_{(60)}$ ≥0.30



Fatigue / durability

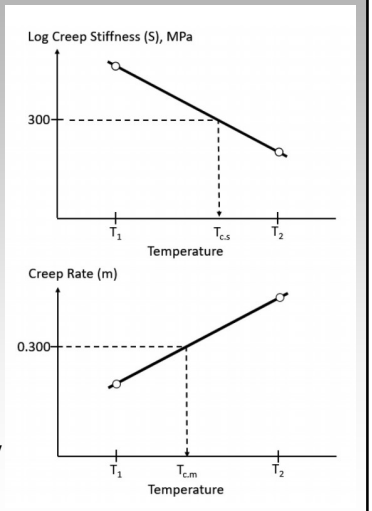
- ASTM D7643: *Determining the Continuous Grading Temperature and Continuous Grades for PG Graded Asphalt Binders* is specified in SATS 3208
- Determine ΔTc – temperature difference:
  - at which the binder stiffness, S = 300
  - slope of the creep curve, m = 0.3
- Quantifies:
  - loss of relaxation properties
  - susceptibility to progressive ravelling & cracking

Determination of ΔTc

T_C.S: critical temperature
where *S*(60) = 300 MPa
T_C.*m*: critical temperature
where *m*(60) = 0,3 MPa/s

S(60) and *m*(60) determined at more than one temperature
S(60) = 300 and *m*(60) = 0,3 are both covered ***within*** ranges of test temperatures

These regions for *S* and *m* may differ
T_C.S and T_C.*m* may only be established by interpolation; ***extrapolation is not allowed***.



Calculation of ΔT_c

- $\Delta T_c = T_c.S - T_c.m$
- $T_c.S = T_1 + \left(\frac{((T_1 - T_2)(\log 300 - logS_1))}{logS_1 - logS_2}\right) - 10$
- $T_c.m = T_1 + \left(\frac{(T_1 - T_2)(0.300 - m_1)}{m_1 - m_2}\right) - 10$

Example

- BBR tests at two temperatures:
  - **-18°C:** S = 243 MPa; m-value = 0.309
  - **-24°C:** S = 400 MPa; m-value = 0.256
- low continuous grade temperatures:
  - $T_c.S = -18 + \left(\frac{(-18+\quad)(2.4771-2.3856)}{2.3856-2.6021}\right) - 10 = -30.5°C$
  - $(T_c.m) = -18 + \left(\frac{(-18+24)(0.300-0.309)}{0.309-0.256}\right) - 10 = -29.0°C$
- $\Delta T_c = -30.5 - (-29.0) = -1.5°C$
- Binder complies: $\boldsymbol{\Delta T_c \geq -5°C}$

BBR

- Test in accordance with ASTM D6648: *Determining the flexural creep stiffness of asphalt binder using the bending beam rheometer*
- The test to assess the binder's susceptibility to thermal cracking test is carried out:
  - on RTFO and PAV aged binder
  - at T_i, i.e. **Tmin + 10°C** (to be discussed later)

- ***Why the -10°C?***
- originally critical values determined **at T_{min}**
- **for 2 hours** loading time
- test duration deemed to be impracticable
- time-temperature superposition used to obtain similar values at **T_{min} +10°C and 60 seconds** loading time.

Specification categories

- Operating bands
  - Climate
  - Traffic
- Resistance to ***viscous flow***;
- Resistance to ***fracture***
  - fatigue / durability cracking
  - Low temperature cracking
- Storage stability
- Safety
- Pumping and handling

- Performance related
- Ease of handling

Storage stability

- ***Resistance to Ageing***
- SATS 3208 stipulates compliance limits for an ***Ageing Ratio***
  - indication of the sensitivity of the binder to ageing during handling and construction – short term ageing (STA)
  - and in-service – long term ageing (LTA)

Ageing ratio's

- Tested to ASTM D7175 at T_l ,10 radians/s
- Two compliance limits:
  - STA ageing:
    $G^*RTFO / G^*Original \leq 3.0$
  - LTA ageing:
    $G^*PAV / G^*Original \leq 6.0$

Specification categories

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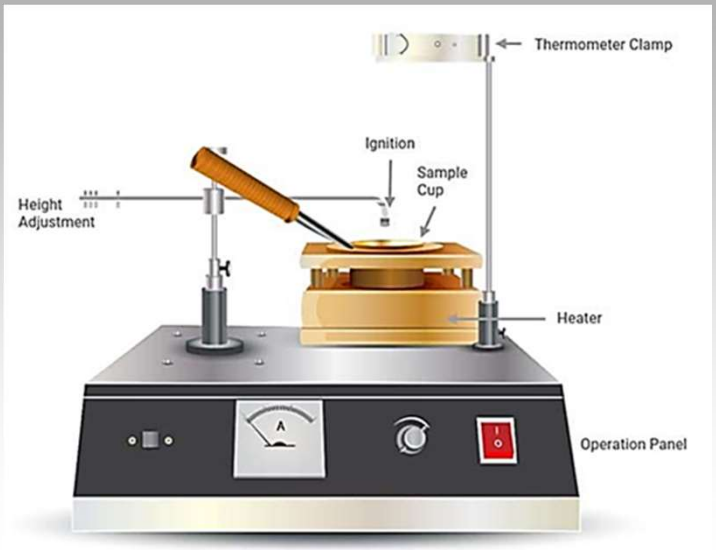
Safety

- Bitumen release volatiles at high temperatures
- Mixed with air
  - can catch fire
  - causing a flash
- Tendency is measured according to
  - ASTM D92: *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester*
  - Flash point – lowest **temperature** at which flash occurs when small flame brought in contact with bitumen vapours when gradually heated
  - A measure of temperature to which bitumen can be safely heated

Cleveland cup Apparatus



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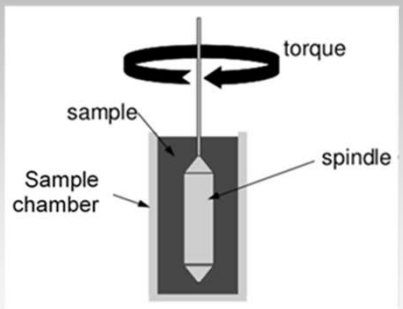
- Pumping and handling

- Performance related
- Ease of handling

Pumpability

- SATS 3208 pumpability ensured:
  - Upper limit dynamic viscosity at 165°C
  - According to ASTM D4402: *Standard Test Method for Viscosity Determination of Asphalt at Elevated Temperatures Using a Rotational Viscometer*
    - torque required to rotate a spindle immersed in bitumen in a temperature-controlled chamber
    - within the range of 38 to 260°C
    - viscometer – Brookfield Thermosel, SC-4 spindles.

Brookfield RV



Storage stability

- G* top & bottom of a cylindrical specimen
- Carried out according to ASTM D7175.
- Procedure:
  - glass tube: length 300 mm, int. dia. 12.5 mm
  - filled with the binder
  - placed vertically in oven @ 180 ± 2°C for three days
  - cooled to 0°C, tube cut into 3 equal sections

Storage stab / cont. ..

- top and bottom portions – DSR testing at T_{MAX} and 10 rad/sec.
- The storage stability difference in G* (highest value minus lowest value) divided by the highest G* value:

$$(G^*_{HIGH} - G^*_{LOW})/G^*_{HIGH}$$

Performance grade specification

- Current SABS ***technical*** specification SATS 3208
- Precursor to ***standard*** specification
- SANS 4001-BT1 still in force
- SATS 3208 – 12 binder grades
  - 3 max pavement design temperature
  - 4 traffic intensity categories.

Test property	Performance grade											
	58S -22	58H -22	58V -22	58E -22	64S -16	64H -16	64V -16	64E -16	70S -10	70H -10	70V - 10	70E -10
Maximum pavement design temperature, T_{max} (˚C)	58				64				70			
Minimum grading temperature, T_{min} (˚C)	-22				-16				-10			
	Original binder											
Viscosity @ 165˚C, ≥30 s^{-1}, (Pa.s)	≤ 0.9											
Storage stability at 180°C (% diff, G^*_{HIGH} and G^*_{LOW}) at T_{max}	≤ 15											
Flash Point (˚C)	≥ 230											
	After RTFO ageing											
Mass Change (m/m), (%)	≤ 1.0											
J_{NR} @ T_{max}, (kPa^{-1})	≤ 4.5	≤ 2.0	≤ 1.0	≤ 0.5	≤ 4.5	≤ 2.0	≤ 1.0	≤ 0.5	≤ 4.5	≤ 2.0	≤ 1.0	≤ 0.5
Ageing Ratio, $G^*_{RTFOT}/G^*_{Original}$	≤ 3.0											
	After RTFO and PAV ageing											
Creep stiffness, S (60s) at T_{min} + 10°C, (MPa)	≤ 300											
m (60s) at T_{min} + 10°C, minimum, (MPa/s)	≥ 0.300											
$\Delta T_c = T_c S - T_c m$, (°C)	≥ – 5											
Ageing Ratio, $G^*_{PAV}/G^*_{Original}$	≤ 6.0											

Tests on processed bitumen

- PG spec applies to base / modified bitumen
- Cutbacks and emulsions tested to ensure ease of handling and correct consistency
- Tests on cutback bitumen
- Tests on bitumen emulsions

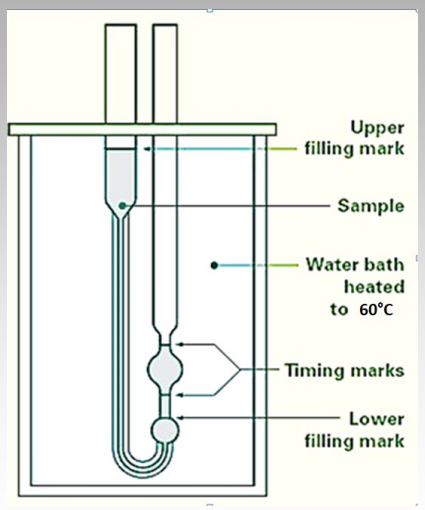
Tests on cutback bitumen

- Tests covered in SANS 4001-BT2
- Tests unique to cutback bitumen:
  - Kinematic viscosity test
  - Distillation test

Kinematic viscosity

- According to ASTM D2170
- Used to ***classify*** cutback binders
- Time of flow through a glass U-tube capillary calibrated viscometer at a given temperature
- $Kinematic\ viscosity = Efflux\ time\ \times calibration\ factor\ (Stokes)$

U-tube reverse flow viscometer



Classification of cutbacks

- In terms of:
  - Kinematic viscosity at 60°C (cSt)
  - type of solvent used – medium curing (MC) or rapid curing (RC)
- Lower limit of viscosity range - grade designation
- Upper limit = lower x 2
  - e.g. MC30 has a viscosity at 60°C in the range of 30 - 60 cSt.
- Temperature/viscosity relationships used to determine correct spraying, mixing and pumping temperatures

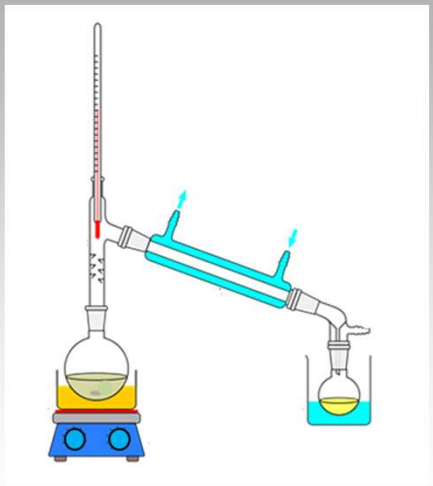
Distillation test

- Proportion/type of solvent determined by:
  - heating the binder
  - condensing the vapours
  - noting the volume of the condensate collected at various specified temperatures up to 360°C
  - undistilled portion constitutes the bitumen content
  - This residue tested for compliance with spec
  - Residue may be slightly softer than base bitumen as distillation does not remove all (heaviest components of) solvent

Bitumen content

Grade	Bitumen content by % volume
MC-10	40
MC-30	50
MC-3000	80

Distillation apparatus



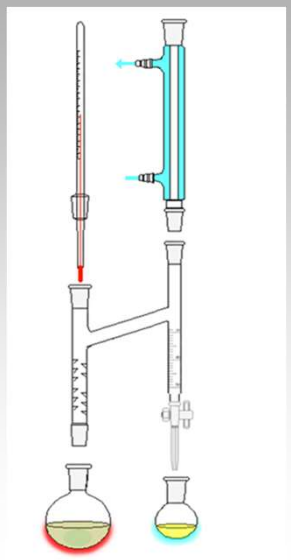
Tests on bitumen emulsions

- Tests for composition and consistency of the emulsified binder are required
- Specified in:
  - SANS 4001-BT3 for anionic emulsions
  - SANS 4001- BT4 cationic emulsions
  - SANS 4001- BT5 inverted emulsions
- Tests for O/W emulsions (4001-BT3 & 4) discussed here

Binder content

- Test standard: ASTM D402
- Emulsions may contain up to 40% of water
- Essential that quantity of residual bitumen (which may include cutters) actually applied to the road surface is accurately determined
- Distillation procedure using Dean & Starke apparatus

Dean & Starke apparatus



1. Organic liquid immiscible with water (xylol) added to sample and flask heated
2. Organic liquid distils into the receiving flask, carrying with it the water
3. Water then separates into a lower layer
4. The volume of water is measured and, by difference, the residual binder content determined

Particle charge

- ASTM D244
- Differentiates cationic & anionic types
- Two electrodes immersed in a sample of emulsion and connected to DC source
- After specified period if bitumen deposits on the cathode, (connected to the -ve pole emulsion is identified as a cationic bitumen emulsion

Viscosity at 50°C

- Test standard: ASTM D244
- Monitored to ensure flow properties are appropriate to the application, e.g. steep gradients and high super elevation
- Measured by means of the Saybolt Furol viscometer
- Measures the time of efflux of a specified volume of emulsion at 50°C through the standard orifice

Residue on sieving

- Test standard: IP 91
- The emulsion should:
  - pass through a 710 µm size
  - then through a 150 µm size
- Mass of dry residue on both sieves.
- Upper limits for residue (g/100 ml) given for the two sieves for:
  - spray grade
  - premix type
  - stable mix type

Coagulation value

- SANS 401-BT3
- Ability of a stable mix grade emulsion not to break prematurely in the presence of cement or lime
- Two methods for determining this value
  - mixed with standard dolerite chippings
  - mixed with cement
- Coagulation value is determined

Sedimentation test

- Test standard: SANS 4001-BT3
- 10 g of emulsion centrifuged for 5 min
- Soap solution added, jar placed in a mixer
  - Rotated at a rate of 1 rev per second
  - After every 5 rotations the apparatus is stopped for 10 s to allow the washings to drain down
- Presence of sediment at bottom of jar noted
- Repeated until the sediment removed
- Number rotations required for complete removal of the sediment is recorded.

Notes on sampling and testing

Test specimens

- Specimens are prepared from samples of materials in a prescribed manner
- The sampling procedures are described in:
  - ASTM D140: Standard Practice for Sampling Asphalt* Materials
  - TG1 method MB-1: Sampling of modified binders
  - TMH-5: Sampling methods for road construction materials

* For “asphalt” read “bitumen”

Notes on sampling/cont…

- All apparatus and containers should be thoroughly clean
- All appropriate safety precautions should be taken – Sabita manual 8
- Sampling at various operational situations are comprehensively covered in Sabita Manual 25

Notes on sampling / cont.

- Sample specimens normally tested for *compliance with a specification*
- Compliance or non-compliance has significant *contractual* implications
- Since the entire product (or batch) can not be sampled nor tested it should be ensured that *samples* taken for testing are *representative of the batch* being assessed.
- Immediately after sample has been packed:
  - Container (not lid) should be labelled (indelibly)
  - Labels should be securely fixed to containers

Uncertainty / precision of test results

- Expressed quantitatively as a dispersion of results likely to contain 99% of measurements
- Variation in test results not suspect unless they differ by more than these values
- Tolerance limits allow for slight differences between equipment and human error

Criteria

- Criteria for acceptability of test results are defined in terms of:
  - Repeatability
  - Reproducibility
- All ASTM and AASHTO methods have published values of these

Repeatability

Variation in measurements by:

- Single operator or instrument
- On same items
- Under same conditions of
  - Procedure
  - Instrument / apparatus
  - Location
  - Repetitions over a short period of time

Reproducibility

Variation in measurements by:

- Two or more operators
- In different locations
- On the same items
- Using same measurement techniques

Module 3 - Summary

- Specifications and tests intended to:
  - ensure that binders manufactured to accepted, uniform standards that will ensure satisfactory performance
  - safeguard that binders are not adversely affected during correct handling
- Tests should be carried out meticulously - strictly in accordance with the test standard
  - ***Small deviations from the method – significant differences in results***