TECHNICAL GUIDELINE:

THE INTRODUCTION OF A PERFORMANCE GRADE SPECIFICATION FOR BITUMINOUS BINDERS

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Technical Guideline: The introduction of a Performance Grade Specification for Bituminous Binders

Forward

The process of transition from the current penetration grade bitumen specification framework to one which strives to define bitumen properties more closely related to the performance of bituminous layers, has commenced and is due for trial implementation during 2016/177. To facilitate the process of implementation of this new, performance related specification, the Lead Group of the Working Group on Performance Grade Bituminous Binder Specifications – a subset of the RPF Task Group on Bituminous Materials – deemed it appropriate to publish a document to introduce the principles underpinning the development of such a specification. In response to this proposal, Sabita undertook to develop and publish this document.

For the time being the national standard for bitumen SANS 4001-BT1, and the recommendations contained in TG1, *Technical Guideline: The use of modified bituminous binder in road construction* will hold sway, until such time as there is sufficient confidence that the proposed framework and compliance limits are well established and relevant to South African binders and conditions. It is envisaged that the period of transition to a performance grade specification will be of the order of two years.

During 2016 SABS has been approached for the formulation of a technical specification – SANS 4001-BT10 for Performance grade bitumen to initiate the formal process of introducing a new specification. This technical specification will be introduced nationally on a trial basis during the period of implementation referred to above.

It is the aim that the publication of this guideline document and the trial implementation of the principles contained therein will advance constructive interaction with members of the engineering practice, ultimately to give impetus to the implementation of a performance related specification in South Africa.

1. INTRODUCTION

The purpose of this document is to introduce the fundamental principles of developing a performance grade (PG) specification for use in South Africa and to explain how they present a rational framework for such a specification. Ultimately the aim of the specification is to present a clear set of compliance criteria to ensure the optimal selection of bituminous binders for specific applications.

This guideline will cover the following topics:

- Reasons for transitioning to a PG specification
- The basis of the specification
- Rheological concepts and their measurement to characterise bituminous binders
- The simulation of ageing of binders as it affects durability
- The framework of the specification, including test procedures, provisional compliance limits and mandatory reporting of test results as an interim measure

This document is aimed at engineers, technicians and technologists, who, in performing their professional functions, are involved in the introduction of this specification, its application, its evolution and, ultimately, its adoption as a national standard.

2. REASONS FOR THE TRANSITION TO A PERFORMANCE GRADE SPECIFICATION

Recent developments in South Africa, such as the implementation of the SANRAL-sponsored SA Pavement Design Method and the Sabita-sponsored revision of a national asphalt mix design method – introduced to practice during 2016 as TRH 8 – necessitated the adoption of a specification framework for bituminous binders based on engineering properties to ensure optimal performance of flexible pavements, especially in the higher traffic categories.

In the USA the implementation of such a specification type in 1995, termed a performance grade (PG) system, was deemed to have yielded notable benefits such as:

- Test conditions suited to specific environmental conditions of climate and traffic;
- The introduction of the measurement of rheological properties of bitumen, which gave a better understanding of the behaviour of bituminous binders in a range of operating conditions;
- The importance of assessing long term ageing characteristics;
- Market shifts to accommodate regional requirements in terms of binder grades; and
- A rational understanding of the need or otherwise to modify straight bitumen.

The current South African national standard specification (SANS 4001-BT1) which can best be described as an “industrial grading system” has distinct limitations in meeting the challenges associated with the technological developments mentioned above, such as:

- In essence, it merely defines the “consistency” of the binder over a range of temperatures (from 25°C to 135°C) in terms of surrogate properties such as penetration, softening point and dynamic viscosity;
- Compliance limits refer to neat and *short term aged* binder which emulates heating of the binder for (hot) spray applications and mixing and paving of asphalt; there is no assessment of the *in-service longer term ageing* characteristics to assess the durability of the binder.
- The specification framework does not cover critical factors related to:
  - Traffic levels and speeds
  - Climate (especially temperature ranges)

- Critical performance characteristics such as excess viscous flow during periods of elevated temperature or crawling traffic or cracking of the binder due to ageing and temperature fluctuations

As a direct result of these limitations, the basis of selection of binder grades or types for specific applications is often arbitrary or conventional.

3. THE BASIS OF THE SPECIFICATION

Asphalt layers and spray seals in service are required to resist the following forms of distress:

- Distortion – permanent deformation; and
- Fracture due to:
  - Fatigue or loss of durability
  - Temperature fluctuations

In addition they should be durable i.e. maintain their properties to counter distress for a long period.

As a result, the concept of damage resistance characteristics (DRC) developed in 2010 in the USA was introduced to provide a specification framework to gauge the binder's resistance to damage resulting from:

- Permanent deformation (viscous flow) – at elevated temperatures and slow rates of loading;
- Cracking – at intermediate temperatures; and
- Temperature fracture – at low temperatures.

The specification framework should facilitate rational selection of binders on the basis of:

- traffic volumes and speed
- climate (max and min temperatures)
- binder durability

In the interests of resource economy, the aim was to limit specialist laboratory equipment to:

- Dynamic shear rheometer (DSR)
- Bending beam rheometer (BBR)
- Rolling thin film oven (RTFO)
- Pressure Ageing Vessel (PAV)

Further to the above performance related properties, additional requirements need to be set in the interests of safety, storage stability and viscosity limits to facilitate handling and application at elevated temperature.

BEHAVIOUR OF BITUMEN

Bitumen displays both *elastic* and *viscous* behaviour, depending largely on temperature and loading duration or frequency. This *visco-elastic* character of bitumen results in a variable response behaviour under varied loading times and temperatures changes.

ELASTIC BEHAVIOUR

This behavioural characteristic of bitumen can be divided into three categories:

- At low temperature and short duration loads bitumen tends to act as an elastic solid, returning to its original position after removal of the load;
- Excessively low temperature in conjunction with rapid loading may cause brittle failure and cracking; and
- Prolonged low temperature can cause a build-up of internal stress resulting in thermal fracture

VISCOUS BEHAVIOUR

At elevated temperatures and/or low frequency loads associated with slow moving traffic, bitumen acts as a viscous fluid. It will undergo plastic deformation i.e. the deformation is not fully recovered. Pavement layers bound with bituminous materials will tend to deform (i.e. rut or flow) under repeated applications of wheel loads depending on the temperature and rate of loading. It is important to note, though, that this plastic behaviour of the bitumen at high temperatures can be offset by the interlocking action of the aggregate, which serves to resist permanent deformation.

Flow in the binder takes place as adjacent bitumen molecules slide past each other, the resulting friction or resistive force being related to the relative velocity of sliding. The relationship of this resistive force and the relative velocity (of sliding) is termed "viscosity".

Dynamic viscosity represented by the symbol η, is thus a measure of the resistance to flow of a fluid and is expressed as:

$$\eta = \frac{Resistive\ force}{Relative\ velocity\ of\ sliding}$$

The SI unit of dynamic viscosity is *Pascal second* (Pa.s)

VISCO-ELASTIC BEHAVIOUR

The load and associated deformation of an asphalt mixture subjected to a constant stress is illustrated schematically in Figure 1. After an instantaneous elastic response to the application of the stress, a gradual increase in deformation (or strain) takes place until the load is removed. This ongoing deformation is caused by the viscous behaviour of the material. Upon removal of the stress, the elastic strain is recovered instantaneously and some additional recovery occurs with time – known as delayed elasticity. Ultimately a permanent residual deformation remains, which is non-recoverable and is directly caused by viscous behaviour of the binder.

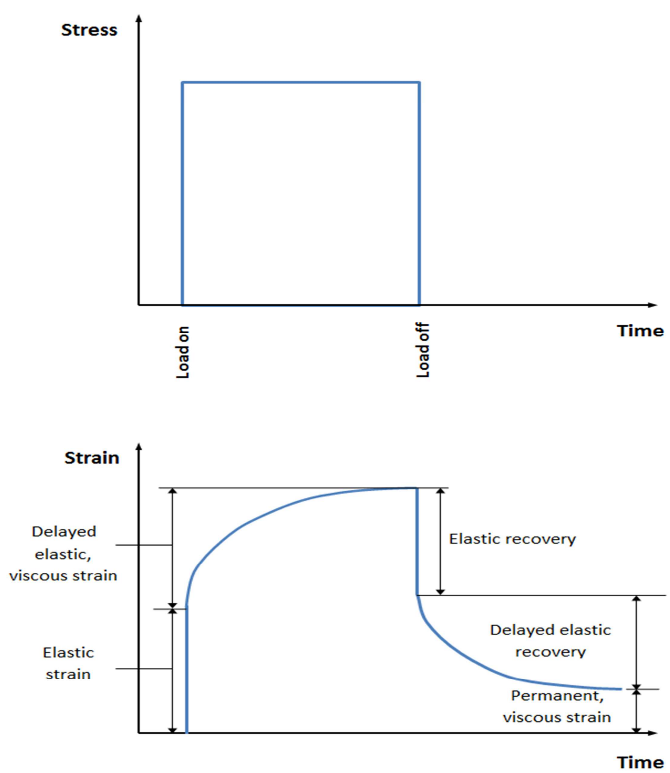

Figure 1 *Response of asphalt in a simple creep test*

Rheometry

Rheology is the study of the flow and deformation of matter, including soft solids under conditions in which they flow rather than deform and recover fully.

The fundamental engineering properties of bituminous binders, as influenced by temperature, chemical composition and the structure – or physical arrangement – of the binder molecules, are well described by rheological principles.

Rheometry refers to the laboratory measurement techniques to determine the rheological properties of materials. For bituminous binders, this entails the measurement of both elastic and viscous behaviour under varied conditions, primarily the type and frequency of loading and temperature of the specimen being tested. Two types of instruments in general use globally will be covered in this document:

- Dynamic shear rheometer
- Bending beam rheometer

Dynamic shear rheometer

Measurements through the use of the Dynamic Shear Rheometer (DSR), shown in Figure 2, are the cornerstone of performance grade specifications. It illustrates important components of viscoelastic behaviour and is currently being introduced in SA for specification purposes.

Figure 2 *Dynamic Shear Rheometer*

Two categories of measurement are afforded by the DSR:

- Fundamental rheological properties
- Creep behaviour of a bituminous binder

Fundamental rheological properties

The proposed DSR testing regimen is capable of quantifying both elastic and viscous properties of bituminous binders within the in-service pavement temperature range (e.g. 10 – 65°C). The operation of a DSR is illustrated in Figure 3.

The basic DSR test uses a thin asphalt bituminous binder sample sandwiched between two circular plates. The lower plate is fixed while the upper plate oscillates across the sample at a selected frequency to simulate the shearing action corresponding to a selected traffic speed.

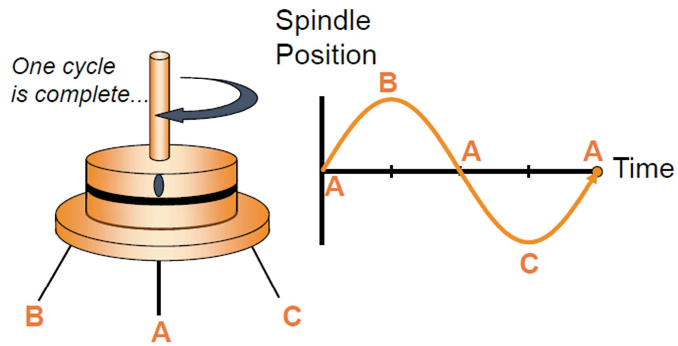

Figure 3 *Operation of the DSR*

Both viscous and elastic behaviour is assessed by measuring the ***complex shearing modulus, G****
(G-star) and the ***phase angle, δ*** (delta). G* is a measure of the total resistance of a material to deformation when exposed to shear load pulses. The phase angle, δ, indicates the relative proportions of recoverable and non-recoverable deformation.

When testing within the linear visco-elastic range of the bituminous binder:

$$G^* = \frac{Maximum\ applied\ shear\ stress}{Maximum\ resulting\ shear\ strain}$$

$$\delta,\ is\ the\ phase\ angle$$

The phase angle δ represents the time lag between the maximum applied shear stress and the maximum resulting shear strain.

The DSR measurement of a specimen's complex shear modulus (G*) and phase angle (δ), is indicated in Figure 4.

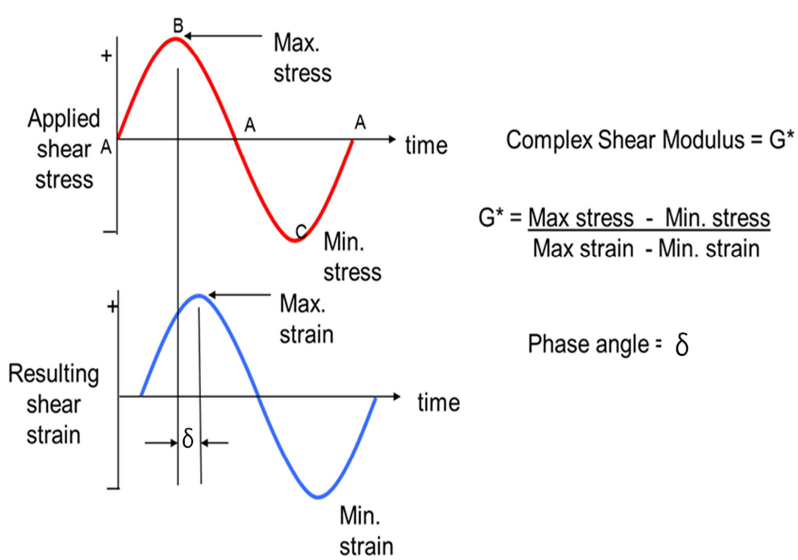

Figure 4 *DSR Measurements of visco-elastic behaviour*

Limiting values of δ are:

- For purely elastic material: δ = 0 degrees
- For purely viscous material: δ = 90 degrees

The phase angle for neat (unmodified) bitumen is typically about 88 – 89°, indicating that the material behaves almost completely in a viscous manner, while some modified binders can have phase angles as low as 60°, i.e. they behave in a more elastic manner.

Although the magnitude of G^*_1 and G^*_2 (of $Bitumen_1$ and $Bitumen_2$, respectively) depicted in Figure 5 are of similar magnitude, they represent binders that are significantly different in visco-elastic behaviour. For instance, $Bitumen_2$ has a larger elastic component and will recover better from applied loading. Thus G* alone cannot describe the behaviour asphalt; δ is also required.

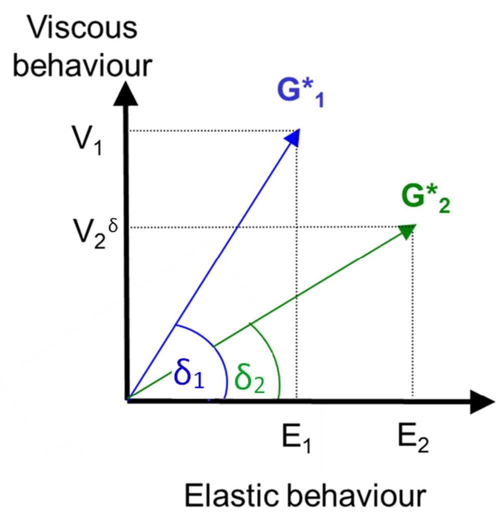

Figure 5 *Visco-elastic behaviour*

CREEP BEHAVIOUR

This test is performed in a DSR at an elevated temperature to assess the extent to which a bituminous binder will recover after the relaxation of an applied torque load. It is especially significant when considering the permanent deformation (rutting potential) of asphalt layers and the flushing / bleeding of spray seals.

The Multiple Stress Creep Recovery (MSCR) test measures the recovery and non-recoverable creep of bituminous binders. This test procedure consists of a one-second constant stress interval followed by a nine-second unloaded recovery period. The loading and recovery interval is repeated 30 times as follows:

- The first 10 cycles are performed at 0.1 kPa stress level to condition the sample;
- 10 more cycles at 0.1 kPa stress level and
- 10 cycles at 3.2 kPa stress level.

The whole test takes only six minutes until it is completed.

The response of the binder during one cycle of this test is illustrated Figure 6. Figure 7 shows the effect of repeated cycles.

From this test the *Non-recoverable Creep Compliance* (J_{NR}) for a particular cycle is determined as follows:

$$J_{NR} = \frac{non-recoverable\ shear\ strain}{applied\ shear\ stress}$$

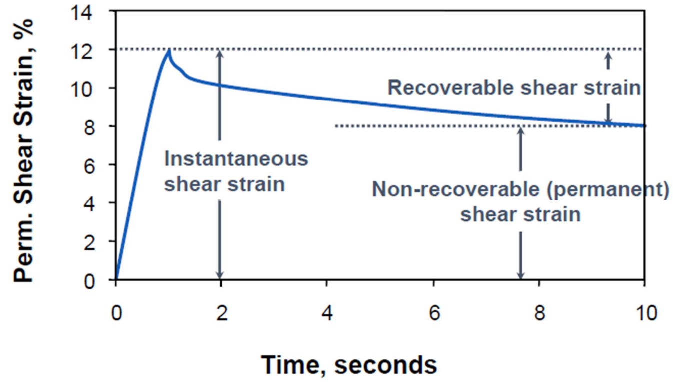

Figure 6 *Binder creep and recovery per cycle*

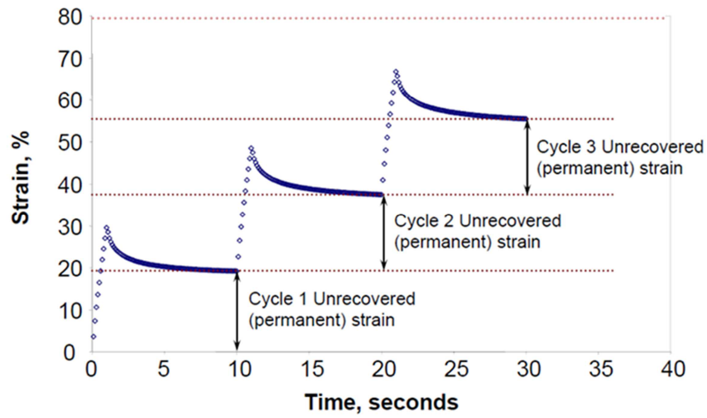

Figure 7 *Binder creep and recovery during repeated cycles*

Low temperature behaviour

To measure the binder's ability to resist low temperature cracking use is made of the measured low temperature stiffness and stress relaxation properties of binders.

Bending Beam Rheometer

The Bending Beam Rheometer (BBR) is used to measure how much a binder undergoes permanent deformation (or creep) under a sustained load at a given temperature. The test temperatures selected relate to the pavement's lower range of service temperature, when the bituminous binder acts more like an elastic solid. The test is usually carried out on binders that have been aged to simulate the hardening that takes place during asphalt manufacture and paving as well as in-service ageing.

In this test a blunt-nosed shaft applies a load to the midpoint of a simply-supported bituminous binder beam to simulate the stresses that gradually build up in a pavement layer when temperature drops – see Figure 8.

The method uses beam theory to calculate the stiffness of the bituminous binder under a constant (creep) load. By measuring the central deflection of the beam throughout the duration of the test, the stiffness (S) and creep rate (m) is calculated. S is a measure of the resistance of the binder to creep loading and m is the change in binder stiffness with time during loading – also called the stress-relaxation factor.

Using elastic beam theory and the elastic-viscoelastic correspondence principle the creep stiffness related to time is calculated as follows:

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

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

The BBR software performs this calculation. A schematic of the test and the recorded outputs of deflection and deduced stiffness are shown in Figure 8 below.

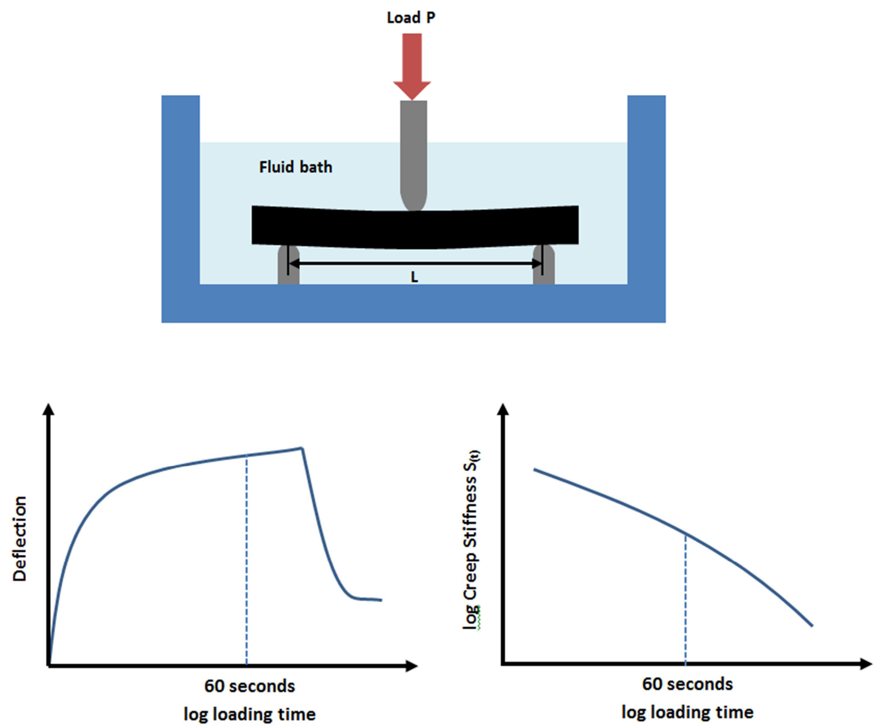

Figure 8 *Bending Beam Rheometer test*

The criteria for resistance to thermal cracking are based on the behaviour of the binder at a selected low temperature. They entail maximum creep stiffness (S) after 60 seconds to control tensile stresses and an m-value, being the rate of change of S with time, i.e. the slope of the creep stiffness curve with time, also after 60 seconds.

Another value, derived from BBR testing, that has been found to quantify the loss of relaxation properties and, hence, its susceptibility to durability cracking as the binder ages is ΔT(c), the difference in temperature at which the binder stiffness S = 300 and m, the slope of the creep curve = 0.3, i.e.:

$$\Delta T(c) = T_{s,300} - T_{m,0.3}$$

(See Figure 9)

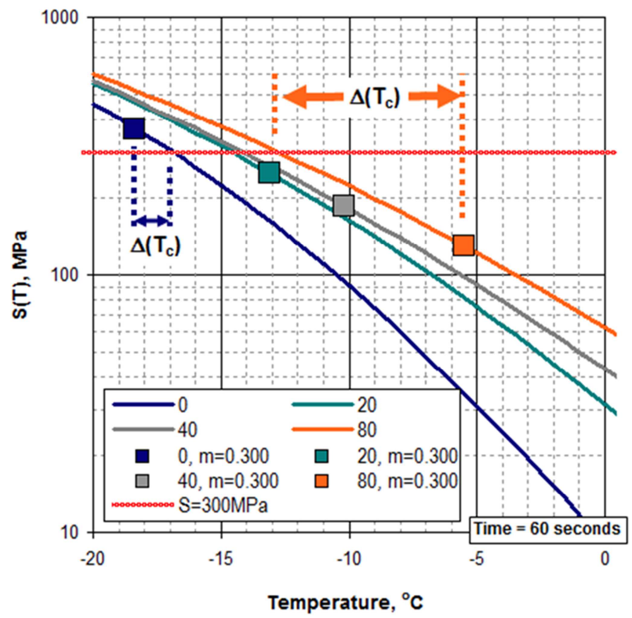

Figure 9 Determination of Δ T(c)

Age Hardening

Bituminous binders age primarily due to two distinct mechanisms – *volatilisation* of the light oils present in the bitumen and *oxidation* by reacting with the oxygen in the environment. Ageing is generally placed in two categories – short term ageing and long term ageing. Figure 10 illustrates the ageing of bitumen in an asphalt layer during mixing and, subsequently, during hot storage, transport and in-service. The ageing during handling up to the point of application comprises *short term ageing*; that which occurs in-service is termed *long term ageing*.

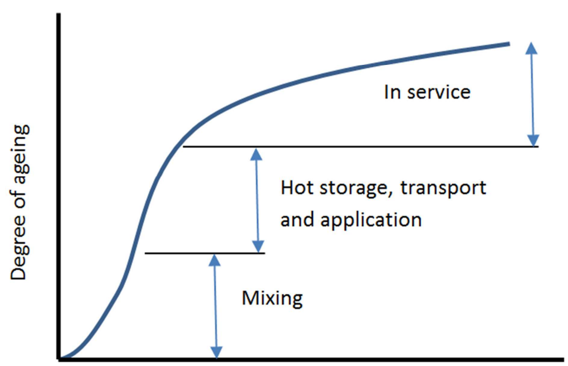

Figure 10 *Ageing of bitumen during mixing, handling and in-service*

Distress of asphalt layers or spray seal coats attributable to ageing typically includes fatigue or durability cracks, thermal induced (shrinkage) cracks, and ravelling. In practice the actual time for short-term and long-term aging depends on site-specific conditions like heating temperatures, hauling distances and period of pavement usage. Ageing caused by the oxidation of bitumen molecules and loss of volatile components are irreversible which subsequently has an impact on the rheological properties of the binders.

For asphalt and spray seal layers to achieve their design lives it is important that no excessive hardening of bitumen takes place during bulk storage, processing (e.g. manufacture and paving of asphalt or spraying operations) and on the road i.e. when in service.

It is therefore important that the rheological and performance related properties of the binder also be assessed after both short and long term ageing simulation. While it is impractical to simulate actual ageing, tests have been devised to give an indication of the susceptibility of a specific binder to ageing.

TEST SPECIMEN CONDITIONING

Test will either be conducted on unaged binder or binder having been subjected to laboratory ageing techniques to simulate short and long term ageing. The ageing procedures adopted are standard ones, described below.

Short term ageing

As is currently the case, the PG specification uses the rolling thin film oven test (RTFOT) as per ASTM D2872 to simulate this form of ageing. Thin binder films are exposed to the effect of heat and oxidation in the presence of air as would typically occur in an asphalt manufacturing plant and during subsequent actions to construct the layer.

Another useful output of the RTFO procedure is the volatiles mass loss during the process. It should be noted that some binders may gain mass during this test procedure due to the formation of oxidative products.

While binders used in spray seals are not necessarily exposed to the same conditions, some short term ageing is likely to take place during handling, on-processing and modification processes.

Long term ageing

The effects of long term ageing – not covered by the current specification – is simulated in a Pressure Ageing Vessel (PAV) as per ASTM D6521: *Standard Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)*, which exposes the binder to high pressure (2,07 MPA) and temperature (e.g. 100°C) for 20 hours. See Figure 11. Since the binder (especially in asphalt) exposed to long term ageing has also undergone prior heating in the mixing and construction processes, the PAV uses binder that has already been aged in the rolling thin film oven.

Figure 11 ***Pressure ageing vessel***

While, ultimately, all binders end up in a similar state of ageing, it is important that the *rate* of ageing during handling and in the medium term be gauged. Consequently an *Ageing Ratio* requirement has been introduced. Two ratios are envisaged, being $G^*_{RTFOT}/G^*_{Original}$ and $G^*_{PAV}/G^*_{Original}$ at the intermediate temperature.

4. Performance grade specification

The key feature of this new specification is limiting the potential of the binder to contribute to permanent deformation, fatigue cracking and low temperature cracking. The term "performance grade" refers to the concept that binders will be graded in terms of their use and application to perform in specific environments defined by climate (particularly temperature ranges) and the intensity and rate of traffic loading.

The specification does not explicitly differentiate between neat and modified binders. Rather, it imposes requirements to meet traffic and climatic conditions – the need for modification and the type of modification rests with the binder suppliers.

The list of requirements is formulated to ensure that the binder will resist damage imposed by the operating conditions. Although these requirements are derived from fundamental, performance related engineering properties of bituminous binders, the compliance limits are based on empirical evidence of their validity in terms of actual field performance.

Performance criteria

Measurement of the rheological properties of bituminous binders in a DSR and BBR enables the formulation of criteria that would ensure adequate performance of the binder to limit:

- excessive permanent or plastic deformation at elevated temperatures;
- fatigue failure (durability cracking) at intermediate temperatures; and
- thermal fracture due to large fluctuations in layer temperatures.

In considering the development of appropriate criteria to assure adequate binder performance quality, it should be borne in mind that the characteristics of the binder alone will not ensure optimal performance of an asphalt layer or a spray seal. Design methods covering these types of application should safeguard adequate performance of the layer through optimal configuration of its components.

What can be achieved in the formulation of this specification is to ensure that the quality of the binder – the glue that holds aggregate particles together – is of a suitable quality ***to augment the role and function of the other components of the layer*** to perform adequately in a set of traffic and environmental conditions.

Safety and handling

Although not directly linked to performance characteristics, three requirements related to safety, ease of handling and the stability during storage are covered in the specifications:

- Safety – flash point
- Handling – flow characteristics (viscosity) of the binder at elevated temperatures to give reasonable assurance that it can be pumped, sprayed, mixed with aggregate and the resulting asphalt compacted.
- Storage stability – for modified binders this requirement serves as an indicator of the compatibility of the base bitumen and the modifier used and whether special procedures of agitation during site storage is required.

Specification framework

The specification framework provides for the following categories of operating conditions and performance requirements and safety and handling aspects. A more detailed description of the performance requirements within the context of the operating categories is given in terms of:

- Operating categories;
  - Climate
  - Traffic
- Resistance to viscous flow;
- Resistance to fatigue / durability cracking;
- Low temperature cracking;
- Mandatory reporting of G*and δ frequency sweeps at intermediate temperature on original binder, RTFO and PAV aged binder;
- Storage stability;
- Safety;
- Pumping and handling; and
- Ageing simulation

Operating categories

Climate

The effect of climate is taken into account by a grading designation component related to:

- the average seven-day maximum pavement design temperature, and
- minimum pavement design temperature.

The maximum pavement design temperatures adopted for South Africa are 58°C, 64°C and 70°C.

While the minimum temperature in SA rarely falls below -10°C, the minimum temperatures adopted *for grading purposes* are considerably lower, to align the specification to the US standard and to determine the temperatures at which other tests are carried out, e.g. intermediate temperatures for fatigue (durability) and the low temperature cracking. The three low temperatures associated with 58°C, 64°C and 70°C are -22°C, -16°C and -10°C, respectively i.e. an 80°C difference in all cases.

Traffic

Traffic will be classified in terms of *Standard*, *Heavy*, *Very Heavy* and *Extreme* categories with the associated symbols of S, H, V and E, respectively. The classification is based on both *traffic volume* and *traffic speed* as shown in **Error! Reference source not found.**:

Table 1 Bitumen categories in term of traffic volumes and operating speed

Design traffic (million E80)[a]	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	E	E	V

[a] The anticipated traffic in the design lane over a 20 year period, regardless of the actual design life of the road.

The binder classification system, in terms of both traffic and climate (temperature) according to which compliance requirements will be determined is as shown in Table 2.

Table 2 Binder classification system

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			

In prescribing the temperatures at which tests are to be performed, the following benchmarks have been established:

– ***High temperature, T_{max}***: the applicable maximum pavement design temperature, e.g. 58°C, 64°C, 70°C

– ***Intermediate temperature, T_{int}***: a temperature midway between T_{max} and the minimum grading temperature T_{min} plus 4°C, i.e. $[(T_{max} + T_{min})/2 + 4]°C$

– ***Low temperature: T_{min}***: 10°C above the minimum grading temperature, T_{min}, i.e. $[T_{min} + 10°]C$

Viscous flow

The binder's susceptibility to viscous flow, which may contribute to permanent deformation or flushing of bituminous layers, especially at elevated temperatures, is assessed with DSR testing of the RTFO aged binder at the ***maximum temperature*** of the binder classification, T_{max} to determine the non-recoverable compliance, J_{NR}, of the binder in accordance with ASTM D7405: *Standard Test Method for Multiple Stress Creep and Recovery (MSCR) of Asphalt Binder Using a Dynamic Shear Rheometer*.

Fatigue / durability cracking

Durability cracking can be considered as a function of both fatigue and thermal effects, especially at low temperature. As it appears to be reasonable to predict asphalt cracking with linear visco-elastic parameters focus has been brought to bear on the use of the Glover-Rowe parameter (GR): $GR = G^* \left({(\cos\delta)^2}/{sin\delta} \right)$

to gauge the resistance of the binder to this type of distress. It was shown in the USA that this parameter correlates well with ductility at 15°C, which in turn has been linked to damage onset and significant cracking as follows:

– Damage onset (5 cm ductility): GR = 180 kPa

– Significant cracking (3 cm ductility): GR = 450 kPa

As mentioned above, the parameter ΔT(c) is also being investigated as an alternative indicator of binder susceptibility to cracking as a result of loss of durability. Until finality is reached on the validity of these criteria and compliance limits of the G-R parameter or the limits of ΔT(c), frequency sweep tests will be performed on binders to determine G* and δ at an intermediate temperature. During the period of implementation of the PG specification, these frequency sweeps will be performed on unaged, RTFO-aged and PAV- aged binders and reporting of these results would be a mandatory requirement – on SANRAL projects initially.

The use of the DSR for this purpose is described in ASTM 7175: *Standard Test Method for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer.* These tests will be carried out at the relevant ***intermediate temperature***.

As mentioned above, another parameter that will be examined for identifying the susceptibility of a binder to this type of distress is ΔT(c). This parameter will be determined in accordance with ASTM D7643: *Standard Practice for Determining the Continuous Grading Temperatures and Continuous Grades for PG Graded Asphalt Binders.*

LOW TEMPERATURE CRACKING

The resistance of the binder to (low) temperature fracture will be assessed by an upper limit of creep stiffness (to limit its brittleness) and its stress relaxation characteristics using the BBR as described in ASTM D6648: *Standard Method of Test for Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer (BBR)*. The test is conducted on binder specimens at the ***low temperature***.

STORAGE STABILITY

Storage stability will be assessed by the difference in G* at T_{max} carried out on unaged binder in the top and bottom of the container with a maximum value being assigned.

SAFETY

The flash point indicates the temperature to which the binder can be heated without danger of instantaneous flash in the presence of an open flame. The test is carried out on unaged binder in accordance with ASTM D92: *Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester.*

PUMPING AND HANDLING

To ensure that binders, especially modified ones, can be pumped and handled at elevated temperatures a viscosity test is performed on the unaged binder at 165°C using a rotational viscometer as described in ASTM D4402: *Standard method for viscosity determinations of unfilled asphalt using the Brookfield Thermosel apparatus*.

Alternative methods, e.g. using a rheometer are also being investigated.

5. PROVISIONAL SPECIFICATION

The proposed PG specification for trial introduction in South Africa is shown in Table 3.[1] The columns indicate the 12 binder grades for the two maximum pavement design temperatures and associated minimum grading temperatures for each of the four traffic intensity categories.

In addition to the requirements listed, the finalisation of the specification and its implementation will require the determination of the specification parameter(s) and associated compliance limits for resistance to fatigue / durability cracking. To this end the reporting of the frequency sweeps at the intermediate temperatures on original, RTFOT aged binder and PAV aged binder will be mandatory. Once sufficient data has come to hand through this procedure, compliance limits will be proposed for implementation.

It was noted during the development stage of this specification framework that straight run bitumen produced at SA refineries would in all probability comply with the requirements of the "S" grades. Compliance with higher grades, i.e. higher traffic categories would most likely require modification by the secondary binder industry.

[1] For details and appropriate test standards refer to SANS 4001-BT10

Table 3 Proposed PG specification and report values

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											
G* and δ at T_{int}	Compulsory report only during implementation phase											
G*/sinδ, at T_{max}, (kPa)	≥ 1.0											
Viscosity @ 165˚C (Pa.s) @ ≥30 s^{-1}	≤ 0.9											
Storage stability (% diff, G^*_T and G^*_B) at T_{max}	≤ 10											
Flash Point (˚C)	≥ 230											
	After RTFO ageing											
G* and δ at T_{int}	Compulsory report only during implementation phase											
Mass Change (m/m %)	≤ 0.3	≤ 1.0			≤ 0.3	≤ 1.0			≤ 0.3	≤ 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											
G* and δ at T_{int}	Compulsory report only during implementation phase											
Creep stiffness, S (60s) at T_{min} + 10°C , MPa,	≤ 300											
m (60s) at T_{min} + 10°C, minimum	≥ 0.300											
$\Delta T_c = T_{s,300} - T_{m,0.3}$ (°C)	≥ – 5											
Ageing Ratio, $G^*_{PAV}/G^*_{Original}$	≤ 6.0											