Bituminous products for road construction and maintenance

Manual 2

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Manual 3*  Test methods for bitumen rubber
Manual 4*  Specifications for rubber in binders
Manual 5  Guidelines for the manufacture and construction of hot mix asphalt
Manual 6*  Interim specifications for bitumen rubber
Manual 7  SuperSurf: Economic warrants for surfacing unpaved roads
Manual 8  Guideline for the safe and responsible handling of bituminous products (CD)
Manual 9****  Bituminous surfacings for temporary deviations
Manual 10  Bituminous surfacings for low volume roads and temporary deviations (CD)
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Manual 20  Sealing of active cracks in road pavements
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Manual 22  Hot mix paving in adverse weather
Manual 23  Code of Practice: Loading bitumen at refineries (CD)
Manual 24  User guide for the design of hot mix asphalt
Manual 26  Interim guidelines for primes and stone precoating fluids (under review)
Manual 27  Guideline for thin layer hot mix asphalt wearing courses on residential streets
Manual 28  Best practice for the design and construction of slurry seals (CD)
Manual 29  Guide to the safe use of solvents in a bituminous products laboratory (CD)
Manual 30  A guide to the selection of bituminous binders for road construction (CD)
Manual 31  Guidelines for calibrating a binder distributor to ensure satisfactory performance (CD)
Manual 32  Best practice guideline and specification for warm mix asphalt (CD)

* These manuals have been withdrawn and their contents have been incorporated in a manual entitled: The use of modified binders in road construction published as Technical Guideline 1 by the Asphalt Academy.
** This manual has been withdrawn and its software programme incorporated in TRH12: Flexible pavement rehabilitation investigation and design.
*** These manuals have been withdrawn and their contents have been incorporated in a manual entitled: Bitumen stabilised materials published as Technical Guideline 2 by the Asphalt Academy.
**** This manual has been withdrawn and its contents have been consolidated with the second edition of Manual 10.

Technical guidelines

TG1  The use of modified binders in road construction
TG2  Bitumen stabilised materials
TG3  Asphalt reinforcement for road construction
Sabita DVD Series

DVD100  Testing of bituminous products
- Penetration bitumen tests
- Bitumen emulsion tests
- Hot mix asphalt tests
- Bitumen rubber tests

DVD200  Repair of blacktop roads
- Training guide for the construction and repair of bituminous surfacings by hand

DVD300  Hot mix asphalt
- Manufacture, paving and compaction of HMA

DVD410  The safe handling of bitumen

DVD420  Treatment of bitumen burns

DVD430  Working safely with bitumen

DVD440  Firefighting in the bituminous products industry
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Preface

A thorough understanding of the behaviour and performance of bituminous binders is an essential prerequisite for anyone involved in the manufacture, use, design and application of bituminous binders. Therefore the main objective of this manual is to familiarise the less experienced practitioner with the important engineering properties of these binders, and to illustrate the significance of the relevant properties in practice.

Consequently this publication serves as an introduction to bituminous binders used in road construction and maintenance in southern Africa. Their manufacture, properties, types and grades, handling and application are described, and applicable specifications and test methods are included.

It is recommended that this manual be read in conjunction with Sabita Manual 30: A guide to the selection of bituminous binders for road construction which gives valuable guidance to the optimal application of various bituminous binder types in road applications. Guidance is also given on the safe handling of these products to mitigate the risk of injury or loss.

Sabita supports the view that the use of coal tar products as a binder is no longer acceptable as it introduces undue health and environmental hazards. Therefore in the interests of worker safety and environmental conservation there is no reference to coal tar in this document. It should also be noted that, in accordance with global nomenclature, the term "bituminous" refers exclusively to binders and mixtures of binders and aggregate containing bitumen. This fifth edition incorporates:

- Up-to-date information regarding current specifications, use and application as well as packaging;
- Further expansion of the content on the rheology of bitumen, including reference to the dynamic shear rheometer as a means of determining fundamental rheological properties;
- Guidelines on the safe and responsible use of bituminous binders as provided for in the current of the Sabita Manual 8: Guidelines for the safe and responsible handling of bituminous products;
- Alignment with recent technical publications on associated topics.
This manual should be used in conjunction with the following publications:

- Manual 5: Guidelines for the manufacture and construction of hot-mix asphalt;
- Manual 8: Guidelines for the safe and responsible handling of bituminous products;
- Manual 10: Bituminous surfacings for low volume roads and temporary deviations;
- Manual 13: LAMBS - the design and use of large aggregate mixes for bases;
- Manual 23: Code of Practice - Loading bitumen at refineries;
- Manual 25: Code of Practice: Transportation, off-loading and storage of bitumen and bituminous products;
- Manual 26: Interim guidelines for primes and stone precoating fluids;
- Manual 27: Guideline for thin layer hot mix asphalt wearing courses of residential streets;
- Manual 28: Best practice for the design and construction of slurry seals;
- Manual 29: Guide to the safe use of solvents in a bituminous products laboratory;
- Manual 30: A guide to the selection of bituminous binders for road construction;

- DVD100 Testing of bituminous products (2 DVDs);
- DVD300 The manufacture, paving and compaction of HMA;
- DVD410 The safe handling of bitumen;
- DVD430 Working safely with bitumen;
- DVD440 Firefighting in the bituminous products industry.

- Asphalt Academy publications:
  - Technical Guideline: The use of modified bituminous binders in road construction - TG1;
  - Technical Guideline: Bitumen stabilised materials - TG2
1 Manufacture and properties of bituminous binders

Origins and use of bitumen

Bitumen is a dark brown to black viscous liquid or solid, consisting essentially of hydrocarbons and their derivatives. It is soluble in trichloroethylene, is substantially non-volatile, and softens gradually when heated. Although solid or semi-solid at normal temperatures, bitumen may be readily liquefied by applying heat, by dissolving it in petroleum solvents, or by emulsifying it in water. Bitumen is obtained by refining petroleum crude oil, although it is also found as a naturally occurring deposit. As a binder, bitumen is especially valuable to the engineer because it is a strong, readily adhesive, highly waterproof and durable material. It also provides some flexibility to mixtures of mineral aggregates with which it is usually combined. It is highly resistant to the action of most acids, alkalis and salts. Bitumen is also used in many applications not related to traditional construction and transport industries. However, approximately 90% of the bitumen refined from petroleum is used as a paving material - as shown in Figure 1.

Figure 1: Use and application of bitumen
The properties of bitumen, both chemical and physical, are dependent on the crude oil source from which it is derived. Refineries generally use consistent sources of crude which result in consistent bitumen properties. However, there remains a need to evaluate bitumen through laboratory testing to assess its performance characteristics.

**The distillation process**

In South Africa most bitumen used in road construction is processed at oil refineries in Cape Town, Durban and Sasolburg, where imported crude oils are refined to produce petrol, diesel fuel and other petroleum based products. The location of the four refineries in South Africa are shown in Figure 2.

![Figure 2: Location of crude oil refineries in South Africa](image)

Figure 3 illustrates the flow of crude oil through a typical refinery. The diagram emphasises that portion of the process relating to the production of bitumen.
The crude oil is heated and delivered to an atmospheric distillation column, where the lighter fractions are vaporised and drawn off, leaving a residue of heavy oil. This residue is processed, by further distillation under vacuum, into “vacuum bottoms”. Treatment under vacuum enables oil fractions to be drawn off in vapour form at relatively low temperatures. These "vacuum bottoms" are used to produce straight-run bitumen. Sometimes it is further treated by air blowing to produce harder bitumen such as 40/50 penetration grade. The vacuum bottoms not used in bitumen manufacture are further processed to produce marine or furnace fuel oil.

Figure 4 shows the typical distillation yield of crude oil products. Bitumen represents about 2.5% of the total barrel.
The composition of bitumen

Bitumen is a complex combination of hydrocarbons with small quantities of sulphur, oxygen, nitrogen and trace quantities of metals such as vanadium, nickel, iron, magnesium and calcium. Crude oils normally contain small quantities of polycyclic aromatic hydrocarbons (PAHs), a portion of which end up in bitumen. Although some of these PAHs are suspected of causing cancer in humans, the concentrations are extremely low and no causal link to cancer in humans has been established. Most bitumens manufactured from a range of crude oils contain:

- Carbon: 82 - 88%
- Hydrogen: 8 - 11%
- Sulphur: 0 - 6%
- Oxygen: 0 - 1.5%
- Nitrogen: 0 - 1%

The precise composition varies according to the source of crude oil used in the manufacture, the manufacturing processes adopted by a particular refinery, and during in-service ageing. The chemistry of bitumen is complex, and for descriptive purposes has been divided into components derived through chemical separation techniques. It is convenient to separate bitumen into two broad chemical groups, called asphaltenes and maltenes. Maltenes are further subdivided into saturates, aromatics and resins. (See Figure 5)
Asphaltenes

Asphaltenes are fairly high molecular weight, n-heptane insoluble solids that are black and glassy. They make up 5 - 25% of the bitumen, and contain carbon, hydrogen, some nitrogen, sulphur and oxygen. The asphaltenes content has a significant influence on the rheological properties of the bitumen. Increasing the asphaltenes content produces a harder, more viscous binder.

Maltenes

Maltenes are the n-heptane soluble phase of the bitumen, and can be further separated into resins, aromatics and saturates, based on molecular mass.

Resins

Resins are largely composed of hydrogen and carbon, with small amounts of oxygen, sulphur and nitrogen, making up 30 - 50% of the total bitumen. These dark brown solids or semi-solids act as a dispersing (peptising) agent for the asphaltenes. Being polar in nature, they are strongly adhesive. The properties of resins characterise to a degree the type of bitumen, i.e. "solution" (SOL) or "gelatinous" (GEL) (see Bitumen structure.)

Aromatics

Aromatics are dark brown, low molecular weight, viscous fluids making up 40 - 65% of the total bitumen, and the ability to dissolve other, high molecular weight hydrocarbons. The aromatic content of the bitumen determines to a significant extent its compatibility with polymers used for modification.

Saturates

Saturates are straw coloured or white, viscous oils with a molecular weight similar to that of aromatics. They contain both waxy and non-waxy saturates and make up 5 - 20% of the bitumen.

Bitumen structure

The physical arrangement of bitumen particles is generally regarded as a colloidal system consisting of the high molecular mass asphaltenes micelles with an adsorbed sheath of high molecular mass aromatic resins,
dispersed or dissolved in the lower molecular weight oily medium of maltenes. The molecules in the bitumen further fall into two functional categories - polar and non-polar molecules:

- Polar molecules form the network of the bitumen and provide the elastic properties;
- Non-polar molecules provide the body of the bitumen and its viscous properties.

These two categories of molecules co-exist, forming a homogeneous mixture. Their weak interaction results in the Newtonian behaviour of bitumen at high temperatures, where the viscosity change is directly proportional to the temperature change.

The non-polar molecules (saturates and aromatics) form a carrier for the polar molecules (asphaltenes and resins).

In the presence of sufficient quantities of resins and aromatics of adequate solvating capacity, the asphaltenes are fully dispersed, or peptised, and the resulting micelles have good mobility within the bitumen. In such cases the bitumen is known as a "solution" type (SOL) bitumen as shown in Figure 6.

*Figure 6: SOL type bitumen*
If the aromatic or resin fraction is not present in sufficient quantities to peptise the micelles, or has insufficient solvating capacity, the micelles can associate together. This leads to structures of linked micelles, and these types of bitumen are known as "gelatinous" (GEL) types and are depicted in Figure 7.

Examples of GEL type bitumens are oxidised grades used for roofing purposes. In practice, most bitumens are of intermediate character, in which the relatively weak chemical bonds that hold the molecules together can be destroyed by heat or shear stress, giving bitumen its viscoelastic characteristics.

Note

While it is known that the chemical composition of a bitumen will determine its physical properties and performance characteristics, the complex and variable molecular structure makes it extremely difficult to measure and define chemical composition for required performance. It is also known that bitumen from different crude sources (which implies different chemical composition) can have very similar physical properties.

It therefore makes no sense to describe or specify bitumen in terms of its chemical component concentrations nor define the concentrations of individual components (e.g. required proportion of asphaltenes).

Instead - general practice recommends the use of performance related physical properties for specifying and selecting bituminous binders.
The rheology of bitumen

Rheology is the science of the flow and deformation of fluids and constitutes a fundamental engineering property of bitumen. The rheological properties of bitumen are influenced by both its temperature and chemical composition and the structure - or physical arrangement - of the molecules.

Temperature

Bitumen is a thermoplastic hydrocarbon material which softens when heated and turns into a glassy state when cooled. The following states generally describe the consistency of bitumen at various temperatures:

- At low road temperatures - a brittle solid;
- At room temperature - a sticky semi-solid;
- At high service temperatures - a viscoelastic\(^1\) substance;
- At elevated temperatures - a viscous liquid.

\(^1\) The term viscoelastic is used to indicate that the material displays both viscous and elastic properties.

Composition

The rheological properties depend strongly on asphaltene content. At a given temperature an increase in the concentration of asphaltenes will cause an increase in viscosity. Other effects of the chemical composition of bitumen on its rheological properties are:

- Increasing the aromatics content at a constant saturates content: resins ratio has little effect on the rheology;
- Increasing the saturates content while maintaining a constant ratio of resins: aromatics softens the bitumen;
- The addition of resins hardens the bitumen and increases its viscosity.

Air-blowing of bitumen from a given vacuum residue results in a significant increase in the asphaltene content, as well as a significant decrease in aromatics, while saturate and resin content are substantially unchanged. Major changes in viscosity and the relative proportions of chemical components take place during the construction of hot mix asphalt layers.

Figure 8 illustrates these changes in terms of the Ageing Index (viscosity ratio of recovered bitumen to original bitumen) and the broad chemical components. While the Ageing Index continues to increase in the long term, the overall changes in the chemical composition after construction are minor.
The constitution of the bitumen has a significant effect on the viscosity and temperature susceptibility of the material. Furthermore, too little or too much of a particular molecule group can lead to brittleness and poor behaviour at low temperatures. It is important to note that there is no formula for the ideal proportions of saturates, resins, aromatics and asphaltenes; rather it is the interaction between these fractions that will characterise the rheology of bitumen.

**Behaviour of bitumen**

**Viscoelastic properties**

Bitumen displays both elastic and viscous behaviour, depending largely on temperature and load duration. This viscoelastic character of bitumen results in its varied response behaviour under varied loading times and temperatures changes.
Elastic behaviour

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;
- Prolonged low temperature can cause a build-up of internal stress resulting in cracking.

Viscous behaviour

Viscosity measurement:

Dynamic viscosity, or coefficient of viscosity, or simply viscosity, measures the resistance to flow of a fluid and is expressed as the ratio:

\[
\frac{\text{Applied shear stress}}{\text{Rate of shear}}
\]

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

Kinematic viscosity is expressed as the ratio:

\[
\frac{\text{Dynamic viscosity}}{\text{Density of the fluid}}
\]

The SI unit of kinematic viscosity is mm²/s or centiStoke (cSt).

Given that the densities of SA penetration grade bitumen falls within the range of 0.970 - 1.040 kg/l, a dynamic viscosity of 1 Pa.s equates to a kinematic viscosity of 962 - 1 031 cSt.

At elevated temperature and long duration loads:

- Bitumen acts as a viscous fluid - i.e. it undergoes plastic deformation that is not recovered;
- Flow takes place as adjacent molecules flow past each other;
- The force resisting this flow is related to the relative velocity of sliding;
- Fluids like water and Penetration grade bitumen above 60 - 100°C show a linear relationship:

\[
\frac{\text{Resistive force}}{\text{Relative velocity of sliding}}
\]
Viscosity is therefore constant irrespective of the magnitude of applied shear. Such materials are known as Newtonian fluids.

To illustrate how viscoelastic materials respond to applied loads it is common practice to represent material behaviour by a system of springs to simulate the elastic components, and dashpots to simulate the viscous behaviour as follows:

- **Spring:**
  - Elastic deformation;
  - Not time dependent;
  - No permanent deformation.

- **Dashpot:**
  - Viscous deformation;
  - Time dependent;
  - Some permanent deformation.

- **Spring-dashpot in parallel:**
  - Delayed elastic deformation;
  - Time dependent;
  - No permanent deformation.

Burger's model is often used to characterise the response of bitumen to imposed stresses. The model is shown in Figure 9, and the components are described in Table 1.

- **Burger's model:**
  - A spring and dashpot in series (Maxwell model);
  - Spring and dashpot in parallel (Kelvin-Voigt model).
Table 1: Components of Burger's model

<table>
<thead>
<tr>
<th>Model component</th>
<th>Type of deformation due to constant load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring</td>
<td>Elastic deformation - not time dependent, no permanent deformation.</td>
</tr>
<tr>
<td>Dashpot</td>
<td>Viscous deformation, time dependent, permanent deformation.</td>
</tr>
<tr>
<td>Spring - dashpot in parallel</td>
<td>Delayed elastic deformation - time dependent, no permanent deformation.</td>
</tr>
</tbody>
</table>

Low temperature and short duration loading

At low temperatures and/or high frequency (short duration) loads, bitumen tends to act as an elastic solid, returning to its original position after removal of the load. This almost purely elastic behaviour can be represented by a
simplified Burger's model as a spring in series with the Kelvin-Voigt model or even a spring only.

Excessively low temperatures in conjunction with rapid loading may cause brittle failure and cracking. Prolonged low temperatures can also cause a build-up of internal stresses in the bitumen, resulting in cracking as it interacts with the rest of the pavement structure.

**High temperature and long duration loading**

At elevated temperatures and/or low frequency (prolonged duration) loads, bitumen acts as a viscous fluid. It will undergo plastic deformation i.e. the deformation is not reversible. Flow takes place as adjacent 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".

Under conditions of elevated temperature, pavements bound with bitumen will tend to rut under repeated applications of wheel loads, and the rutting will occur at a rate dependent on the temperature and rate of loading. 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.

**Intermediate temperature behaviour**

At intermediate temperatures bitumen displays both elastic and viscous behaviour as represented in the Burger's model. The various components of deformation are represented in Table 1.

Figure 10 illustrates the stress/strain relationships of an asphalt mixture when subjected to a simple creep test. After an instantaneous elastic response, a gradual increase in strain with time takes place until the load is removed. The change in strain with time is caused by the viscous behaviour of the material. On removal of the load, the elastic strain is recovered instantaneously and some additional recovery occurs with time - known as delayed elasticity. Ultimately a permanent residual strain remains, i.e. rutting, which is irrecoverable and is directly caused by viscous behaviour.
The viscoelastic behaviour of bitumen presents the following advantages in its use as a road surfacing product:

- The most common state of bitumen is viscoelastic, enabling it to exhibit the advantageous properties of both elastic and plastic materials;
- As a binder it provides excellent adhesive properties with mineral aggregates;
- Bitumen acts as a lubricant when heated, thereby facilitating spraying, coating of aggregates during hot mix manufacture, as well as compaction during laying;
- Bitumen cools to become a glue, forming part of the solid matrix.

With a binder well-matched to the loading and temperature conditions, the most common response is elastic or viscoelastic, with only a limited plastic behaviour.

*Figure 10: Response of asphalt in a simple creep test*
**Dynamic shear rheometer**

Although not in general use in SA, the measurements afforded by the use of the Dynamic Shear Rheometer (DSR) is the cornerstone of performance grade specifications in the USA. It is mentioned here because it illustrates important components of viscoelastic behaviour and is likely to be introduced in SA in due course for specification and asphalt design purposes.

The use of the DSR is described in AASHTO T 315: *Determining the Rheological Properties of Bitumen using a Dynamic Shear Rheometer (DSR)*. The test is capable of quantifying both elastic and viscous properties of bituminous binders in the in-service pavement temperatures (46-82°C). A DSR is illustrated in Figure 11.

![Figure 11: Dynamic Shear Rheometer](image-url)

The DSR measures a specimen’s complex shear modulus ($G^*$) and phase angle ($\delta$), as indicated in Figure 12.
The complex shear modulus ($G^*$) represents the sample’s total resistance to deformation when repeatedly sheared. The phase angle ($\delta$) is the lag between the applied shear stress and the resulting shear strain. Phase angle ($\delta$) limiting values are:

- For purely elastic material: $\delta = 0$ degrees;
- For purely viscous material: $\delta = 90$ degrees.

The phase angle for bitumen is typically about 88 - 89°, while some modified binders can have phase angles as low as 60°.

**Viscoelastic behaviour**

Although the magnitude of $G^*_1$ and $G^*_2$ (of Bitumen$_1$ and Bitumen$_2$, respectively) depicted in Figure 13 are of similar magnitude, they represent binders that are significantly different in viscoelastic 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; $\delta$ is also required.

Ensuring rut resistance

The bituminous binder should be stiff (i.e. it should not deform too much under loading) and it should be elastic (i.e. it should be able to return to its original shape after load relaxation). The higher the $G^*$ value, the stiffer the binder is to resist deformation, the lower the $\delta$ value, the greater the elastic portion of $G^*$.

**A minimum value of $G^*/\sin \delta$ is therefore specified.**

Ensuring fatigue resistance

The bituminous binder should be elastic (i.e. able to dissipate energy by rebounding and not fracturing) and should not be too stiff, as excessively stiff substances will crack rather than deform. The viscous component of complex shear modulus, $G^*\sin \delta$ should therefore be small.

**A maximum value of $G^*\sin \delta$ is therefore specified.**
Durability

For a bituminous surfacing to achieve its design life it is important that no excessive hardening of bitumen takes place during bulk storage, processing (e.g. manufacture of asphalt and paving) and on the road i.e. when in service.

In thin layers, where exposure to the environment is severe, hardening can have a detrimental effect on the performance of the layer through an increase in brittleness, leading to fracture (cracking), fretting and stone loss.

It should be noted that in some cases, e.g. in asphalt bases, some hardening can be beneficial as it may increase the stiffness of the layer and hence improve its load spreading capability. This hardening is generally termed "curing", and has the capacity to extend pavement life.

Hardening

The dominant mechanisms of bitumen hardening are:

- Oxidation;
- Loss of volatiles (volatilisation);
- Physical (steric);
- Exudation.

Oxidation

Hardening due to oxidation is considered to be the main cause of ageing of bitumen. As with most other organic substances, bitumen is slowly oxidised when in contact with oxygen in the atmosphere, which leads to an increase in viscosity, as well as hardening and a loss of flexibility. The degree of oxidation is highly dependent on:

- Temperature;
- The thickness of binder films; and
- Time.

Inadequate compaction of asphalt layers or excessively thin binder films adopted in the design will advance the rate of oxidative hardening during in-service life, especially in warmer climates. Excessive oxidative hardening can be prevented by ensuring:
Adequately thick binder films;
Proper compaction of e.g. asphalt layers.

Loss of volatiles

The evaporation of volatiles depends mainly on the exposure to sunlight and prevailing temperatures. Penetration grade bitumen, being relatively involatile, is not prone to significant loss of volatiles.

Physical (steric) hardening

Physical hardening occurs at ambient temperatures and is caused by the re-orientation of bitumen molecules and the formation of waxy crystals. This type of hardening is reversible upon reheating.

Exudative hardening

Exudative hardening is caused by the absorption of oily components of the bitumen, i.e. maltenes into porous aggregates. Although this phenomenon is widely acknowledged, little research has been carried out to quantify its extent or to identify aggregates that are particularly prone to this type of absorption.

Hardening during use

During use bitumen is exposed to a range of conditions under which hardening can occur, the most important ones being:

- Hot bulk storage;
- Asphalt manufacture;
- Handling of asphalt (i.e. hot storage, transport and laying);
- In-service.

Hot bulk storage

During bulk storage the bitumen is kept at elevated temperatures for a period varying from days to weeks. Very little hardening actually occurs during this phase, as the surface area exposed to oxygen is generally small relative to the volume of the bitumen.

Asphalt manufacture

During this phase a thin film of bitumen is exposed to the high temperatures of superheated aggregates in the presence of oxygen for a relatively short
period of time. Typically bitumen film thickness during mixing with aggregates is between 5 and 15 μm. Given the elevated temperatures, conditions are ideal for oxidation and loss of volatiles. This process of hardening is well known and should be taken into account when selecting the grade of bitumen to be used. As a rough guide, the penetration of bitumen used for hot mix asphalt falls by about 30% during the mixing process. The hardening during warm mix asphalt manufacture and application will be less than with conventional hot mix asphalt.

Handling of asphalt:

Asphalt is stored either in hot silos or in delivery vehicles during transport prior to being applied to the road surface. In both instances some hardening occurs, principally through oxidation by contact of the binder films with entrained air. Little or no further oxidation occurs during laying and compaction.

In-service hardening

Hardening of the binder will continue on the road until a limiting value is reached. The main factor influencing the extent of in-service hardening is the exposure of binder films to the atmosphere as determined by, e.g., the air void content of asphalt mixes. Studies have shown that, while very little hardening of bitumen in asphalt occurs at void contents of less than 5%, a significant degree of hardening was observed at air void contents in excess of 9%.

Bitumen content of asphalt mixes as represented by bitumen film thickness is also a prominent factor influencing in-service hardening. It is generally suggested that a minimum film thickness of 6 - 8 μm is required for satisfactory performance of asphalt mixes. For porous mixes where higher exposure to air exists, a minimum film thickness of 12 μm is recommended.

Figure 14 illustrates the ageing of bitumen during mixing and subsequently during asphalt hot storage, transport and in service.
Small samples of bitumen or asphalt mixes are heated or reheated in laboratories to perform necessary tests, to test either compliance of the products with the relevant specifications, or to assess their performance characteristics.

Care should be taken in the laboratory heating processes to ensure that bituminous binders are not subject to hardening through oxidation in excess of what would normally occur in actual practice. Such hardening would yield results that are not realistic and lead to errors in judgement.

Figure 14: Ageing of bitumen during mixing, hot storage and application
2 Types and grades of bituminous binders

Penetration grade bitumen

Penetration grade bitumen can be manufactured by straight-run distillation or by blending two base components (one hard such as 35/50 pen and the other soft such as 150/200 pen). Penetration grade bitumen is used either as a primary binder or base bitumen for the manufacture of:

- Cutback bitumen;
- Modified binders;
- Bitumen emulsions.

Cutback bitumen

Cutback bitumen is a blend of penetration grade bitumen and petroleum solvents. The choice of solvent determines the rate at which the bitumen will "set up" or cure when exposed to air. A rapid-curing (RC) solvent will evaporate more quickly than a medium-curing (MC) solvent. The viscosity of the cutback bitumen is determined by the proportion of solvent added - the higher the proportion of solvent, the lower is the viscosity of the cutback. The solvent used in cutback bitumen is sometimes also referred to as the "cutter" or "flux".

When the solvent has evaporated, the binder reverts to the original penetration grade. The advantage of cutback bitumen is that it can be applied at lower temperatures than penetration grades because of its lower
viscosity. A disadvantage is that cutback bitumen consumes non-renewable energy resources which are ultimately lost through evaporation.

**Polymer modified bitumen**

The rheological properties of conventional binders may be modified by the introduction of:

- Elastomers;
- Plastomers;
- Crumb rubber;
- Hydrocarbons.

Modification is costly and is normally justified when bituminous surfacings are subjected to severe conditions such as:

- Steep gradients;
- Very high road surface temperature;
- High traffic loading; or
- Heavily trafficked intersections.

Modification may also be advantageous for surfacings on highly flexible and cracked pavements, where an improvement in the rheological properties of the bitumen is required. Use in such applications should be guided by expert opinion.

The primary aim of the modification of bitumen for use in structural layers is to increase the resistance of these layers to permanent deformation at high road temperatures without compromising the properties of these layers over the rest of the prevailing temperature range.

The use of polymer modified bitumen to obtain improved performance is rising as a result of increases in tyre pressures, axle loads and higher traffic volumes. Improved performance can be achieved in two ways, both of which are aimed at reducing the permanent strain:

- An increase in the elastic component with an associated reduction in the viscous component; and
- Stiffening of the bitumen to reduce the total viscoelastic response of the layer.

In addition to the primary aims above, the range of properties improved include:
• Durability;
• Aggregate retention;
• Resistance to permanent deformation;
• Resistance to fatigue cracking;
• Cohesion (internal strength);
• Elasticity;
• Viscosity less susceptible to temperature changes.

**Modification agents**

Modification is achieved by the introduction of polymers (including crumb rubber), aliphatic synthetic wax or naturally occurring hydrocarbons. Polymers can be broadly categorised as "elastomers" (sometimes referred to as thermoplastic elastomers) for improving the strength and elastic properties of a binder, and "plastomers" (sometimes referred to as thermoplastic polymers) for increasing the viscosity of the bitumen.

**Elastomers**
In South Africa three types of elastomers are in general use:

- Styrene-butadiene-rubber (SBR) latex;
- Styrene-butadiene-styrene (SBS);
- Rubber crumb.

(Although not classified as a polymer, the behaviour of bitumen modified with crumb rubber is similar to one modified with an elastomer).

**Figure 16: Effect of elastomers on the rheological profile of bitumen**

Thermoplastic elastomers derive their strength and elasticity from a physical cross-linkage of the molecules into a three-dimensional lattice. The effect of the addition of thermoplastic elastomers on the rheological profile of a binder is illustrated in Figure 16.

At high road temperatures, say 55 - 60°C, the elastomer modified binder has a significantly higher viscosity than, say, a 40/50 pen grade bitumen and is therefore much stiffer. In conjunction with the elastic nature of the polymer network, such modified binders will exhibit a significantly higher resistance to permanent deformation. Also, at lower service temperatures, the elastomer modified binder is more flexible than the unmodified bitumen
and hence would be less prone to brittleness. Increased flexibility and, hence, resistance to fatigue distress has also been shown to result from elastomer modification.

As illustrated in Figure 17, the fatigue life of bitumen can be increased by a factor of at least three. The material would therefore offer improved performance in areas where high tensile strains are likely to occur in asphalt layers.

**Figure 17: Effect of elastomers on fatigue life**

Styrene-Butadiene-Rubber (SBR)

SBR is available in the form of anionic or cationic latex, which makes blending with bitumen emulsion easier. It is also used to modify hot bitumen, but the water phase in the latex must first be removed by boiling or foaming during the controlled addition of latex to the hot bitumen. SBR modified bitumen has been used extensively in Southern Africa as a cold applied bitumen emulsion in chip seals and micro surfacing, as well as a hot applied binder in chip seals and hot mix asphalt. The modified binder
exhibits elastic properties which make it ideal for surfacing lightly cracked pavements.

**Styrene-Butadiene-Styrene (SBS)**

SBS polymers are available in powder, crumb or pellet form for modifying hot bitumen. Linear as well as radial copolymers can be used depending on the end properties sought. High shear mixers are recommended for blending high polymer content binders, particularly for industrial applications.

Depending on the concentration of this polymer, it increases or improves:

- Softening point;
- Cohesive strength;
- Elasticity;
- Low temperature flexibility; and
- Resistance to permanent deformation.

SBS modified bitumen is used in both chip seals and asphalt applications to enhance the bitumen’s all-round performance characteristics.

**Rubber crumb**

Approximately 20% of rubber crumb is blended with bitumen at a mixing temperature of 170 - 210°C for a period of approximately one hour. During this time the aromatic oils in the bitumen are absorbed by the rubber particles, causing them to swell. After mixing and reaction the blend, known as “bitumen-rubber”, must be applied within six hours as the product has a restricted shelf life. It is much more viscous than unmodified bitumen, and is not a homogeneous binder, requiring special equipment for pumping and spraying.

Bitumen rubber is widely used in South Africa in chip seals, continuously graded asphalt and in semi-open-graded asphalt wearing courses.

On cracked and flexible pavements, bitumen rubber has resisted crack reflection remarkably well and, in spite of high application rates, its resistance to flushing has been clearly demonstrated. This resistance is due to, amongst others, its improved temperature susceptibility. The carbon
black contained in the rubber also acts as an anti-oxidant, thereby increasing the durability of the binder.

**Plastomers**

One type of plastomer in general use in South Africa is ethylene vinyl acetate (EVA). EVA polymers are available in pellet form and are easily dispersed in hot bitumen. EVA modified binders are thermally stable at normal handling temperatures. The two properties of the EVA copolymer that have the most pronounced effect on the binder’s end properties are its molecular weight and vinyl acetate content. EVA modified bitumen is used mainly as a plastomer in hot mix asphalt to improve resistance to permanent deformation e.g. rutting.

**Hydrocarbon substances**

These types of modifiers can be divided into two categories - aliphatic synthetic waxes and naturally occurring hydrocarbons.

*Aliphatic synthetic wax*

Long-chain hydrocarbons produced by the Fischer-Tropsch (FT) synthesis process are used to extend the plasticity range of bitumen. Bitumen modified with FT wax displays unique properties in that it has

![Figure 18: Temperature - viscosity relationship](image)
a lower viscosity than unmodified bitumen above 100°C, but on cooling, the viscosity is higher. This enables hot mix asphalt with bitumen modified with FT wax to be mixed and placed at lower temperatures than those mixes using conventional bitumen (see Figure 18).

The significant increase in R&B softening point places this modifier in the plastomer category.

**Natural hydrocarbons**

Naturally occurring hydrocarbons used for bitumen modification occur as natural deposits in north and south America and are known as Gilsonite and Durasphalt respectively. These materials have high asphaltene contents, generally in excess of 70%, and are used to stiffen bitumen by raising the softening point and lowering the penetration value. Asphalt mixes containing binders modified with these hydrocarbons display high stiffness compared with those containing binders modified with polymers. The high stiffness values achieved will enhance both the resistance to permanent deformation and the load-spreading capability of such layers.

Table 2 summarises the various types and varieties of modification agents discussed above.

**Table 2: Types and varieties of modifiers**

<table>
<thead>
<tr>
<th>Modifier type</th>
<th>Varieties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polymers</td>
<td></td>
</tr>
<tr>
<td>Elastomers</td>
<td>Styrene-butadiene-styrene (SBS)</td>
</tr>
<tr>
<td></td>
<td>Styrene-butadiene-rubber (SBR) latex</td>
</tr>
<tr>
<td></td>
<td>Rubber crumb*</td>
</tr>
<tr>
<td>Plastomers</td>
<td>Ethylene-vinyl-acetate (EVA)</td>
</tr>
<tr>
<td>Hydrocarbon substances</td>
<td></td>
</tr>
<tr>
<td>Aliphatic synthetic wax</td>
<td>Fischer-Tropsch (F-T) wax</td>
</tr>
<tr>
<td>Naturally occurring hydrocarbons</td>
<td>Gilsonite</td>
</tr>
<tr>
<td></td>
<td>Durasphalt</td>
</tr>
</tbody>
</table>

* Although not a homogeneous polymer, rubber is classified as an elastomer

**Classification of modified binders**

In accordance with TG1: *The use of modified bituminous binders in road construction*, modified binders are classified according to:

- The type of application;
- The type of modifier;
The type of binder system;
- The level of modification.

This classification system is intended to allow for a polymer-blind specification whereby the test properties of a specific class must be achieved in order to meet the specification requirements.

**The type of application**

- S - seal;
- A - asphalt; and
- C - crack sealant.

**The type of modifier**

- E - homogeneous elastomer;
- P - homogeneous plastomer;
- R - non-homogeneous elastomer;
- H - Hydrocarbon

**Type of binder system**

If the product is an emulsion, the letter C would follow directly after the letter indicating the type of application.

**Level of modification**

A numerical value is used to indicate increasing softening point values.

This classification system allows for a polymer-blind, non-prescriptive specification whereby the properties for a specific class must be achieved in order to meet the specification requirements.

Typical modified binders in terms of the above classifications are given in Table 3.

**Table 3: Classification of modified bitumen**

<table>
<thead>
<tr>
<th>Modifying agents</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elastomers</td>
<td></td>
</tr>
<tr>
<td>Styrene-butadiene-styrene (SBS)</td>
<td>S-E2, A-E2</td>
</tr>
<tr>
<td>Styrene-butadiene-rubber (SBR) latex</td>
<td>S-E1, A-E1, C-E1</td>
</tr>
<tr>
<td>Bitumen rubber</td>
<td>S-R1, A-R1, C-R1</td>
</tr>
<tr>
<td>Plastomers</td>
<td></td>
</tr>
<tr>
<td>EVA</td>
<td>A-P1</td>
</tr>
<tr>
<td>Hydrocarbons</td>
<td></td>
</tr>
<tr>
<td>Naturally occurring hydrocarbons</td>
<td>A-H1</td>
</tr>
<tr>
<td>Aliphatic synthetic wax</td>
<td>A-H2</td>
</tr>
</tbody>
</table>
Bitumen additives

A number of bitumen additives are employed, particularly in asphalt. These additives are not intended to modify or improve the rheological properties of bitumen; rather the intention is to improve certain performance characteristics to extend the service life of the asphalt.

Table 4 lists additives in common use and their general purpose. Although no specifications for the materials are readily available, examples of generic types are listed to guide the user.

Table 4: Common binder additives used in asphalt

<table>
<thead>
<tr>
<th>Type</th>
<th>General purpose</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extender</td>
<td>Substitutes a portion of bitumen to decrease the amount of bitumen and/or polymer required. Improves the storage stability of SBS modified binders.</td>
<td>Sulphur</td>
</tr>
<tr>
<td>Fibre</td>
<td>Improving the tensile strength and cohesion in hot mix asphalt. Allows higher binder content with reduced risk of drain-down in open-graded asphalt and SMA. Improves durability through increased binder film thickness.</td>
<td>Rock wool, Polypropylene, Polyester, Fibreglass, Mineral, Cellulose</td>
</tr>
<tr>
<td>Antioxidant</td>
<td>Increases the durability of HMA by retarding oxidation.</td>
<td>Carbon black</td>
</tr>
<tr>
<td>Anti-stripping agents</td>
<td>Reduce stripping of binder from aggregate.</td>
<td>Amines, Lime</td>
</tr>
<tr>
<td>Fuel resistance</td>
<td>Improves the resistance of the HMA to fuel spillages.</td>
<td>FT Wax, Selected grades of EVA</td>
</tr>
</tbody>
</table>

A number of additives to facilitate the production, handling, paving and compaction of asphalt at lower temperatures have also been incorporated in recent full-scale trials. These are best described as "viscosity modifying agents" and could be either mineral, e.g. zeolites, or organic, e.g. waxes and surfactants - see Sabita Manual 32: Best practice guideline and specification for warm mix asphalt.

Bitumen emulsions

Bitumen emulsions are two-phase systems consisting of a dispersion of bitumen droplets in water containing an emulsifier. Emulsification of bitumen is a means of reducing the viscosity of a binder so that it behaves as a fluid during handling and application. The emulsifiers are added to assist in the formation of the emulsion, to render it stable, and to modify its properties.
In an emulsion, bitumen is dispersed throughout the water as discrete globules, typically of 0.1 to 50\(\mu\)m in diameter, held in suspension by electrical charges. The net bitumen content of emulsions vary between 60% and 70%.

**Classes of emulsion**

Commonly, bitumen emulsions are available in two classes: cationic; and anionic. The terms cationic and anionic derive from the electrical charges on the bitumen globules.

In an anionic emulsion the bitumen particles are negatively charged (they would adhere to the anode).

In a cationic emulsion the bitumen particles are positively charged (they would adhere to the cathode).

**Mode of breaking**

Cationic emulsions break via a physical-chemical reaction, through the evaporation of the water phase and through mechanical action such as rolling.

Anionic emulsions break predominantly when the bitumen particles agglomerate with the evaporation of the water and through mechanical action such as rolling.

**Invert emulsion**

Another type of emulsion, termed invert, is distinct from normal oil in water emulsions like cationic and anionic types in that the water is dispersed in the binder phase. These types of emulsions are manufactured with cutback bitumen and have water contents of less than 20%.

**Manufacture**

Bitumen emulsions are normally manufactured in a continuous process using a colloidal mill. This equipment consists of a high speed rotor revolving at 1000 - 6000 rpm in a stator. The clearance between the rotor and stator can usually be adjusted between 0.25 and 0.5 mm.

A typical emulsion plant flow diagram is shown in Figure 19.
The water phase is prepared by dissolving the emulsifier chemicals in heated water. These are then saponified with alkalis in the case of anionic emulsions, or acidified with inorganic acids for cationic emulsions. Emulsion manufacturers have distinct anionic and cationic water phase systems.

The temperature of the bitumen phase should be strictly controlled to ensure that its viscosity is within the appropriate range for emulsification, and to prevent boiling of the emulsion on exit from the colloid mill. The base bitumen normally used is 70/100 penetration grade. Cationic spray and premix grade emulsions contain a small percentage of solvent flux, which is varied on a seasonal basis to assist with the "breaking" of the emulsion.

The two phases, bitumen and chemically-treated water, pass through the narrow clearance between the rotor and stator of the colloidal mill, where the bitumen is sheared into microscopic particles.

The stability of the emulsion is determined primarily by the type and quantity of the emulsifying agent used.

On discharge from the mill, the newly formed emulsion is allowed to cool in the storage tanks, which are individually dedicated to particular types and grades of emulsion. Mixing any anionic emulsion with any cationic emulsion...
in any proportion will cause the mixture to "break", i.e. separate into water and bitumen, almost immediately.

**Uses of emulsions**

In some instances emulsions have an advantage over hot binders because they can be used under a wide range of conditions, namely:

- With dusty or damp aggregates for chip sealing;
- With uncoated aggregates for chip seals as the adhesion to a range of aggregates to the cationic emulsion type is normally sufficient;
- Application at lower temperatures in the interests of:
  - enhanced worker safety; lower energy consumption;
  - reduced emissions; and
  - extending work periods during construction;
- For handwork as no heating is required;
- Where lower application rates are required through the dilution with water.

Emulsions are used extensively in slurries, fog sprays, tack coats, stabilisation, chip seals, primes, cold mix asphalt and crack sealants.

**Compatibility with stone aggregate**

Acidic aggregates such as granite and quartzite, which constitute a very large proportion of aggregates used in road construction in southern Africa, are negatively charged, providing good adhesion to the positively charged bitumen in a cationic emulsion. Consequently, in spray seal applications - where there is direct contact between the binder and the aggregate - cationic emulsions are more widely used as they have superior adhesive properties to a range of mineral aggregates.

Conversely good adhesion is achieved between anionic emulsions and positively charged aggregates such as dolomite and limestone. If an anionic emulsion is used with granite or quartzite, effective adhesion is only obtained after the water has evaporated.

However, where the aggregates have been precoated with a bituminous precoating fluid, thus preventing direct contact between the emulsion and the aggregate surface, these restrictions generally do not apply. Also, in the manufacture of slurries where cement or lime is generally used as filler, the positive charges developed by these fillers may well render anionic
emulsions suitable, or even superior, as a binder with all aggregate types, due to improved workability.

**Emulsion grades**

Emulsions are available in the following grades defining the stability when in contact with aggregates:

- Premix grade;
- Quick setting grade;
- Spray grade;
- Stable mix grade.

The binder content of emulsions varies between 60 and 70% by mass.

**Premix grade**

This grade is formulated to be more stable than spray grade emulsion. It is suitable for mixing with medium or coarse graded aggregate with the percentage aggregate passing the 0.075 mm sieve not exceeding 2%.

**Quick setting grade**

A grade specially formulated for use with microsurfacing seal types, where quick setting of the mixture is desired.

**Spray grade**

An emulsion formulated for application by mechanical spray equipment in spray seal construction where no mixing with aggregate is required.

**Stable mix grade**

This grade of emulsion is formulated for mixing with very fine aggregates e.g. sand and crusher dust, and is mainly used for slow-setting slurry seals and tack coats.

In addition to the above four emulsion grades, SBR latex modified emulsions are available for specialised applications such as crack-sealing, reseals on lightly cracked surfaces, geotextile seals and rut filling or rapid-setting microsurfacing overlays. These are three phase cationic emulsion systems, where SBR latex is introduced as a third component in the normal bitumen water two phase system.
Available grades and types of bituminous binders

Figure 20: Available grades and types of bituminous binders
The grades and types of bituminous binders available in South Africa are shown in Table 5 and depicted in Figure 20.

**Table 5: Types and grades of bituminous binders**

<table>
<thead>
<tr>
<th>Type</th>
<th>Grade of Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetration grade bitumen</td>
<td>35/50</td>
</tr>
<tr>
<td></td>
<td>50/70</td>
</tr>
<tr>
<td></td>
<td>70/100</td>
</tr>
<tr>
<td></td>
<td>150/200</td>
</tr>
<tr>
<td>Cutback bitumen</td>
<td>MC10</td>
</tr>
<tr>
<td></td>
<td>MC30</td>
</tr>
<tr>
<td></td>
<td>MC3000</td>
</tr>
<tr>
<td>Modified bitumen</td>
<td>S-E2, A-E2</td>
</tr>
<tr>
<td></td>
<td>S-E1, A-E1, C-E1</td>
</tr>
<tr>
<td></td>
<td>A-P1</td>
</tr>
<tr>
<td>Non-homogeneous polymers</td>
<td>S-R1, A-R1, C-R1</td>
</tr>
<tr>
<td>Bitumen rubber</td>
<td></td>
</tr>
<tr>
<td>Hydrocarbons</td>
<td></td>
</tr>
<tr>
<td>Naturally occurring</td>
<td></td>
</tr>
<tr>
<td>Aliphatic synthetic wax</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A-H1</td>
</tr>
<tr>
<td></td>
<td>A-H2</td>
</tr>
<tr>
<td>Bitumen emulsions</td>
<td>Cationic spray grade - 60%, 65% and 70% binder content</td>
</tr>
<tr>
<td></td>
<td>Cationic premix grade - 60% and 65% binder content</td>
</tr>
<tr>
<td></td>
<td>Cationic and anionic stable mix grade - 60% binder content</td>
</tr>
<tr>
<td></td>
<td>Cationic quick set</td>
</tr>
<tr>
<td></td>
<td>Invert cationic emulsion - 80% binder content (including flux)</td>
</tr>
<tr>
<td>Modified bitumen emulsions</td>
<td>SC-E1, AC-E2</td>
</tr>
<tr>
<td></td>
<td>SC-E1, AC-E1</td>
</tr>
<tr>
<td></td>
<td>CC-E1</td>
</tr>
<tr>
<td>Pre-coat fluids</td>
<td>Proprietary products - bitumen based fluids with cutters and adhesion agents</td>
</tr>
</tbody>
</table>

**Source and packaging**

The four crude oil refineries in South Africa - one in Cape Town, two in Durban and one in Sasolburg - produce bitumen complying with SABS
specifications, although availability of appropriate crude sources and local demand may result in some refineries not producing some of the grades at times. The refineries also produce various grades of cutback bitumen for use in road construction. Penetration and cutback bitumen are sold by mass.

Bituminous binders are usually supplied in bulk road tankers for ease of handling and economic reasons. Delivery can be made to:

- Storage tanks at asphalt plants;
- Emulsion factories; and
- Construction sites; or
- Bulk spray distributors, for direct application to the road surface.

Bulk road tankers are generally fitted with liquid petroleum gas or oil heating systems. The heating system is only used when the road tanker is stationary to maintain or increase the bitumen temperature to the desired pumping, mixing or spray temperature.

Bitumen (particularly emulsions) is also supplied in non-returnable drums of 210\(\ell\) nominal capacity, but to accommodate the change in volume of bitumen when heated or cooled, they are never filled to capacity. Usually the mass of the contents is about 200kg (the unit in which it is sold).

In specific instances, e.g. when bitumen is exported by sea, it is stored in bulk and transported in special ISO type containers, generally referred to as "isotainers". Although the product is transported as a solid, these containers have special heating systems, which enable the bitumen to be liquefied for pumping. Drums and isotainers are more commonly used for bitumen exports by sea.

Bitumen emulsions are manufactured in numerous fixed plants around South Africa. All or most of the grades listed in Table 2 are available in bulk or in 200\(\ell\) drums, depending on local demand. Emulsions are sold by volume.

Bitumen-rubber is usually blended on site in specially designed, high-speed mixing plants, transferred into a distributor and sprayed immediately. When used in the so-called “wet-blend” asphalt mix process, the bitumen-rubber is blended and then fed into the asphalt-mixing plant.
Bitumen rubber is, therefore, only available wherever the required volumes are economic to produce.

A number of polymer modified binders and emulsions are also produced by various manufacturers at plants around the country. The most common modifiers are SBS (styrene-butadiene-styrene), SBR (styrene-butadiene-rubber) and EVA (ethylene-vinyl-acetate).

Supply to a contract is typically by bulk road hauling, although SBR modified emulsions in drums and crack sealants in boxes, pails or special paper bags are often used for small maintenance jobs.

Some blending of modified binders, typically with aliphatic synthetic wax and naturally occurring hydrocarbons also takes place at asphalt manufacturing plants.
3 Specifications and test methods

As stated in Section 1, while it is accepted that the chemical composition of a bitumen will determine its physical properties and performance characteristics, the complex and variable chemical and molecular structure of bitumen makes it extremely difficult to define chemical composition in order to characterise performance. It should also be noted that bitumen derived from different crude sources (and hence of different chemical composition) can have similar physical properties.

For this reason it is makes no sense to describe or specify bitumen in terms of chemical component concentrations, nor to define individual components, e.g. minimum percentage of asphaltenes. It has therefore become general practice, worldwide, to make use of performance-related physical properties as the primary means for specifying and selecting bituminous binders.

Specifications for bituminous binders are intended to ensure that:

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

Standard specifications for bituminous binders for road construction

The specifications published by the South African Bureau of Standards (SABS), as listed in Table 6, are currently applicable in South Africa. Only specification numbers and grades of bituminous binders are given. For more detail, such as the full range of properties monitored and the limits imposed on them, the relative specification should be consulted. Since penetration grade bitumen is used as a base binder for all other bituminous binders, the detailed specification for penetration grade bitumen is given in Table 7.
### Table 6: SABS specifications for bituminous binders

<table>
<thead>
<tr>
<th>Specification number</th>
<th>Title</th>
<th>Grade designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SANS 4001-BT1</td>
<td>Penetration grade bitumen</td>
<td>35/50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50/70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>70/100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>150/200</td>
</tr>
<tr>
<td>SANS 4001-BT2</td>
<td>Cutback bitumen</td>
<td>MC10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MC30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MC3000</td>
</tr>
<tr>
<td>Bitumen emulsions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SANS 4001-BT3</td>
<td>Anionic bitumen road emulsions</td>
<td>Spray type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stable mix type</td>
</tr>
<tr>
<td>SANS 4001-BT4</td>
<td>Cationic bitumen road emulsions</td>
<td>Spray type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Premix type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stable mix type</td>
</tr>
<tr>
<td>SANS 4001-BT5</td>
<td>Invert bitumen emulsion</td>
<td>Prime</td>
</tr>
</tbody>
</table>

### Specifications for penetration grade bitumen

#### Table 7: Requirements SANS 4001-BT1:2012

<table>
<thead>
<tr>
<th>Property</th>
<th>Penetration grade</th>
<th>Test method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penalty at 25°C/100 g/5 s, 1/10 mm.</td>
<td>35 - 50</td>
<td>EN 1426</td>
</tr>
<tr>
<td></td>
<td>50 - 70</td>
<td></td>
</tr>
<tr>
<td></td>
<td>70 - 100</td>
<td></td>
</tr>
<tr>
<td></td>
<td>150 - 200</td>
<td></td>
</tr>
<tr>
<td>Softening point (ring and ball), °C.</td>
<td>49 - 59</td>
<td>ASTM D36*</td>
</tr>
<tr>
<td></td>
<td>46 - 56</td>
<td></td>
</tr>
<tr>
<td></td>
<td>42 - 51</td>
<td></td>
</tr>
<tr>
<td></td>
<td>36 - 43</td>
<td></td>
</tr>
<tr>
<td>Viscosity at 60°C, Pa.s., min.</td>
<td>220</td>
<td>ASTM D4402*</td>
</tr>
<tr>
<td></td>
<td>140</td>
<td></td>
</tr>
<tr>
<td></td>
<td>75</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Viscosity at 135°C, Pa.s.</td>
<td>0,27 - 0,65</td>
<td>ASTM D4402*</td>
</tr>
<tr>
<td></td>
<td>0,22 - 0,45</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0,15 - 0,40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0,12 - 0,30</td>
<td></td>
</tr>
<tr>
<td>Performance when subjected to RTFOT.</td>
<td></td>
<td>ASTM D2872</td>
</tr>
<tr>
<td>a) mass change, % (by mass fraction) max.</td>
<td>0,3</td>
<td>ASTM D2872</td>
</tr>
<tr>
<td>b) viscosity at 60°C, % of original, max.</td>
<td>300</td>
<td>ASTM D4402*</td>
</tr>
<tr>
<td>c) softening point (ring and ball), °C, min.</td>
<td>52</td>
<td>ASTM D36*</td>
</tr>
<tr>
<td></td>
<td>48</td>
<td></td>
</tr>
<tr>
<td></td>
<td>44</td>
<td></td>
</tr>
<tr>
<td></td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>d) increase in softening point, °C, max.</td>
<td>7</td>
<td>ASTM D36*</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>e) retained penetration, % of original, min.</td>
<td>60</td>
<td>EN 1426</td>
</tr>
<tr>
<td></td>
<td>55</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Spot test*, % xylene, max.</td>
<td>30</td>
<td>AASHTO T102</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

* Recommended apparatus is the RV viscometer, using SC 4 spindles with thermosel system;
# Actual values to be reported in five-unit intervals;
* Using shouldered ring.
Sampling of bituminous binders

As bitumen samples are normally subjected to testing for compliance with a specification, the importance of careful and accurate sampling cannot be overstressed.

Samples should be representative of the batch or volume of bituminous binder being assessed. To this end either the whole of the material being sampled should be thoroughly mixed before samples are taken, or portions must be taken and mixed together in such a way that the final bulked sample is representative of the whole.

SANS specifications require that sampling of bitumen and bitumen emulsions be carried out in accordance with the American Society for Testing and Materials (ASTM) Method D140. The procedures for sampling at various operational situations are comprehensively covered in the Sabita Manual 25: Quality management in the handling and transport of bituminous binders. Salient points are:

Immediately the sample has been packed, the containers (not the lid) should be labelled indelibly as described below. Labels should be securely fixed to the containers.

**Sampling at a refinery**

Samples are taken from in-line sampling valves while loading the second third of the load. Numbered sample containers should reflect the following information:

- Grade of bitumen;
- Date and time of sampling;
- Batch number;
- Registration number(s) of tanker and trailer; and
- Tank number.

**Sampling at an off-loading point**

Samples should only be taken while offloading the second third of the load from a sampling valve, positioned either between the discharge pump and receiving tank or, if such a valve does not exist, on the tanker.
Numbered sample containers should reflect the following information:

- Grade of bituminous binder;
- Date and time of sampling;
- Name of refinery or supplier;
- Batch number;
- Transporter;
- Registration number(s) of tanker and trailer;
- Delivery note number;
- Temperature of product;
- Name of person taking the sample.

The apparatus used to take samples depends partly on the physical state of the binder and partly on the type of container. All apparatus used to take samples and all receptacles and containers must be thoroughly cleaned before use.

When sampling from drums, one container should be sampled from each batch and tested against specification. If it is found not to comply, then several containers must be sampled, the number being the cube root of the total number of containers in the batch.

In the case of liquid binders, the drum contents should be thoroughly mixed by rolling the containers, or stirring, and the sample taken with a thief sampler.

Samples of solid binder should be chopped out or, for softer grades, cut out with a stiff putty knife. Samples must be taken at least 75 mm from the sides and ends of the containers.

The following minimum sample sizes are required:

- 4\(\ell\) from bulk storage tanks and bulk road tankers;
- 1\(\ell\) from drums of liquid binder;
- 1kg from drums of solid binder.

When more than one container from a batch has to be sampled, not less than 0,1kg should be taken from each of the calculated number of containers to constitute a composite sample of about 4\(\ell\). The most convenient containers for samples are wide-mouthed cans with lined screw
tops for liquid binders, and triple-seal friction-top cans or heavy gauge plastic bags for solid binders.

When sampling, all appropriate safety precautions contained in Sabita Manual 8: *Guidelines for the safe and responsible handling of bituminous binders* should be observed.

In order to resolve contractual obligations, it is considered good practice to retain bitumen samples for a minimum of two years, although, in the case of emulsions with a shelf life of approximately six months, this retention period cannot be achieved.

**Standard tests**

**Tests performed on bitumen**

Various test methods published by the American Society for Testing and Materials (ASTM), the American Association of State Highway and Transportation Officials (AASHTO) and CEN (the European Committee for Standardisation) are followed in South Africa.

It is of utmost importance that these methods be carried out meticulously to ensure that the results are correct. This enables an accurate assessment of the quality of the product being assessed for compliance with the relevant specification.

Often small deviations from or variations in methods can cause significant differences in results. In most cases criteria for judging the acceptability of test results are given. These limits of variability are defined as repeatability when applied to a single tester, and reproducibility when applied to different testers in different laboratories.

In this way a tolerance on the quality recorded at the time of manufacture allows for slight differences between test equipment at various laboratories and for human error. The precision of each test in terms of its repeatability and reproducibility should be taken into account when assessing compliance with a specification, or when disputes arise.

The following tests are normally carried out on bitumen. Test apparatus is illustrated schematically, but for complete details of the apparatus and the method, the quoted test methods should be consulted. Where appropriate, the relevant repeatability and reproducibility limits in accordance with ASTM are given.
The reader should note that solvents used in testing and cleaning of laboratory equipment may be toxic and injurious to health, and it is therefore recommended that practitioners be acquainted with the content of Sabita Manual 30: *Guide to the safe use of solvents in a bituminous products laboratory*.

Tests for penetration grade bitumen

Penetration test (Test method EN 1426)

This test measures the relative hardness or consistency of bitumen at 25°C, representing an average in-service temperature. The value is used to classify the bitumen into standard penetration ranges in accordance with SANS 4001-BT1. The penetration value of bitumen is defined as the distance in tenths of a millimetre (dmm) that a standard needle will penetrate into the bitumen under a load of 100g applied for five seconds at 25°C. A bitumen, which has a penetration of 70 dmm to 100 dmm, is referred to as 70/100 pen bitumen, which indicates that the greater the penetration, the softer the bitumen. The test is depicted diagrammatically in Figure 21.

![Figure 21: Penetration test](image)
Precision of the test method

Repeatability

If the penetration is less than 50        2 dmm
If the penetration is equal to or greater than 50    4% of the mean value

Reproducibility

If the penetration is less than 50        3 dmm
If the penetration is equal to or greater than 50    6% of the mean value

Softening point test (Test method ASTM D36)

This is another test of consistency, which determines the temperature at which the bitumen is transformed from a solid to liquid phase. For the majority of bitumen this viscosity value is in the region of 1 200 Pa.s. The results of this test also indicate the capacity of a particular bitumen to perform adequately at high in-service temperatures. (For instance bitumen with a softening point that is too low may, in a particular environment of climate and traffic, lead to excessive bleeding in chip seals or rutting in asphalt layers.)

Also referred to as the ring-and-ball softening point test, this test determines the temperature at which a bitumen disc of controlled dimensions softens sufficiently to allow a steel ball, initially placed on the surface, to sink through the disc and continue sinking to a further prescribed distance - i.e. it measures the temperature at which bitumen has a particular consistency.

The test is depicted diagrammatically in Figure 22.

Precision of test method

Repeatability - duplicate softening points by the same operator should not be considered suspect unless they differ by more than 1,1°C.

Reproducibility - the softening points reported by each of two laboratories should not be considered suspect unless the two reports differ by more than 2,0°C.
Dynamic Viscosity Test (ASTM D4402)

Viscosity, i.e. the resistance to flow or shear, is a fundamental characteristic of bitumen as it describes its behaviour at a particular temperature or over a temperature range. The resistance to flow or shear stress is governed by the internal friction, and can be measured and expressed in units of stress required to overcome this friction.

The ratio of applied shear stress and the rate of shear is called the coefficient of viscosity, dynamic viscosity or more often simply viscosity. (see Viscous behaviour, page 20).

The dynamic viscosity, or resistance to shear, of penetration grade bitumen can be determined by measuring the torque required to rotate a spindle immersed in bitumen. The viscometer used for specifying penetration grade bitumen in South Africa is the Brookfield model RV with Thermosel system using SC-4 type spindles, and the test method to be followed must be in accordance with ASTM D4402.

By varying the spindle size, the viscosity can be determined over a large range of bitumen grades - from very viscous to very liquid materials. The SI unit of dynamic viscosity is the Pascal second (Pa.s). In the cm/gm/s (CGS) system, the unit of viscosity is the poise, such that 1 Pa.s = 10 poises.

Figure 22: Softening Point Test
Viscosity can be measured over a wide range of temperatures, including maximum bitumen application and operating temperatures, enabling the susceptibility of viscosity to temperature to be assessed. The viscosity is specified at both 60°C and 135°C, which provides a means of controlling consistency at high in-service and application temperatures, respectively. The test method is depicted in Figure 23.

**Precision of the test method**

**Repeatability** - duplicate values by the same operator shall not be considered suspect unless they differ by more than 3.5%.

**Reproducibility** - the values reported by each of two laboratories, representing the arithmetic average of duplicate determinations, shall not be considered suspect unless the differ by more than 14.5%.

*Figure 23: Brookfield viscometer with Thermosel system*
Rolling thin-film oven test (RTFOT) (ASTM D2872)

This test gauges the resistance of bitumen to ageing and hardening due to the effect of heat and oxidisation in the presence of air as would occur in an asphalt manufacturing plant and during handling and compaction. It does not, however, purport to simulate long term in-service ageing.

In the RTFOT a series of glass containers rotate in a vertical plane so that a fresh surface of bitumen is continuously being exposed to air. This exposure (at 163°C) is continued for 75 minutes and a controlled flow of air is blown over the surface of the bitumen from a single nozzle. At the end of the test, the change in mass, viscosity, softening point and penetration is assessed in terms of the requirements of SANS 307.

Figure 24: Rolling thin film oven test

The Bitumen Test Data Chart (BTDC) developed by Heukelom (see Figure 25) provides a system whereby penetration, softening point and viscosity can be jointly described as a function of temperature.
Figure 25: Bitumen Test Data Chart
During manufacture and construction of asphalt, there are optimal bitumen viscosities for coating of aggregate and compaction. The BTDC enables the selection of appropriate temperatures to achieve the optimum viscosity for any grade of bitumen.

**Spot test (Test method AASHTO T102)**

The n-Heptane/Xylene spot test is a test for compounds which are likely to be more susceptible to oxidation and could affect the durability of the bitumen during service on the road.

The spot test is carried out by dropping a solution of bitumen in prescribed mixtures of n-heptane and xylene onto a filter paper. The test is negative when a uniformly brown stain is formed, otherwise the test is positive.

**Other tests**

Other properties of bitumen, not necessarily specified, are often monitored to provide users with information vital to correct application. Examples are density determination to permit conversion of mass to volume in calculations, and viscosities measured at high temperatures to ensure the establishment of correct application temperatures.

The method for determination of kinematic viscosity is described in the following section on cutback bitumen.

While the test requirements for penetration grade bitumen are based on empirical measurements, they ensure that bitumen produced have consistent rheological properties over a temperature range covering ambient to application conditions, i.e. 25 - 135°C before and after ageing.

Figure 26 provides a graphical illustration of the specification limits at the various temperatures.
Tests on cutback bitumen

Kinematic viscosity test (Test method ASTM D2170)

This test of consistency is used to classify cut back binders. The measurement of kinematic viscosity is made by timing the flow of the cutback bitumen through a glass U-tube capillary viscometer at a given temperature. Each viscometer is calibrated, and the product of efflux time and viscometer calibration factor gives the kinematic viscosity in stokes.

The U-tube reverse flow viscometer for measuring kinematic viscosity is illustrated diagramatically in Figure 27.

Cutback bitumens are classified by their kinematic viscosity at 60°C, expressed in centistokes (cSt). The type of solvent used is associated with this, either medium curing (MC) or rapid curing (RC). The lower limit of the viscosity range is used in the grade designation, while the upper limit is
double this lower figure, e.g. MC30 has a viscosity at 60°C in the range of 30 - 60 cSt. As is the case with penetration grade bitumen, the temperature/viscosity relationships of cutback bitumens can be used to determine the correct spraying, mixing and pumping temperatures.

**Distillation test (Test method IP27)**

This test indicates the rate at which the binder will cure through the evaporation of volatile fractions. The proportion and type of solvent present in a cutback bitumen is determined by heating the material, condensing the vapours and noting the volume of the condensate collected at various specified temperatures up to 360°C. The undistilled portion remaining constitutes the binder content of the cutback. The apparatus for this test is shown schematically in Figure 28.
Typical bitumen contents of various grades of cut back binders are given in Table 8.

**Table 8: Typical bitumen content of cutback bitumen**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Bitumen content by % volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC10</td>
<td>45</td>
</tr>
<tr>
<td>MC30</td>
<td>56</td>
</tr>
<tr>
<td>MC3000</td>
<td>88</td>
</tr>
</tbody>
</table>

The residue from the distillation test is tested for penetration. It is slightly softer than the original base bitumen, as the distillation process, no matter how carefully performed, may not remove all of the very heaviest constituents of the solvent.
Precision of the test method

*Repeatability* - duplicate values by the same operator shall not be considered suspect unless the determined percentages differ by more than 1,0 volume % of the original sample

*Reproducibility* - the values reported by each of two laboratories, shall not be considered suspect unless the reported percentages differ by more than the following:

<table>
<thead>
<tr>
<th>Distillation fractions</th>
<th>volume % of the original sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 175°C</td>
<td>3,5</td>
</tr>
<tr>
<td>Above 175°C</td>
<td>2,0</td>
</tr>
<tr>
<td>Residue</td>
<td>2,0</td>
</tr>
</tbody>
</table>

**Flash Point**

The flash point temperature is a measure of the tendency of the test specimen to form a flammable mixture with air under controlled laboratory conditions. It is only one of a number of properties which must be considered in assessing the overall flammability hazard of a material.

The flash point, being a measure of the temperature to which cutback bitumen can safely be heated under certain conditions, is usually monitored at the point of manufacture and used in shipping and safety regulations to define flammable and combustible materials, and to formulate precautions that are necessary during transport and application of the product.

ASTM D93 describes the standard test methods for flash point by the Pensky-Martens closed cup tester. In this method a brass test cup is filled with a test specimen and fitted with a cover. The sample is heated and stirred at specified rates. An ignition source is directed into the cup at regular intervals with simultaneous interruption of stirring until a flash that spreads throughout the inside of the cup is noticed. The corresponding temperature is its flash point.

**Other tests**

There is a general requirement in the specification that cutback bitumen should be free of visible water, and will not foam when heated to application temperature.
Tests on bitumen emulsions

The tests performed on bitumen emulsions are as specified in SANS 4001-BT3, BT4 and BT5. The following test methods are for the conventional bitumen emulsion (bitumen droplets dispersed in a continuous water phase). Invert bitumen emulsions are less frequently used, and some test methods for this product differ from those for conventional bitumen emulsions. SANS 4001-BT5 should be consulted for tests for invert bitumen emulsions.

Binder content test (Test method ASTM D244)

Bitumen emulsions may contain up to 40% of water by volume, and it is essential that the quantity of residual bituminous binder (which may include cutters) actually applied to the road surface is accurately determined. The bitumen content is determined by means of a distillation procedure using equipment commonly referred to as the Dean and Stark apparatus, illustrated schematically in Figure 29.

An organic liquid immiscible with water (xylol is usually used) is added to the sample and the flask is heated. The organic liquid distils into the receiving flask, carrying with it the water, which then separates into a lower layer. The volume of water is measured and, by difference, the residual binder content determined.

Figure 29: Dean and Stark apparatus
Table 9 gives the binder content ranges for various grades of emulsions.

**Table 9: Binder content of emulsions**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Binder content % by mass</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anionic stable mix</td>
<td></td>
<td>60</td>
<td>62</td>
</tr>
<tr>
<td>Cationic stable mix</td>
<td></td>
<td>60</td>
<td>63</td>
</tr>
<tr>
<td>Cationic spray 60</td>
<td></td>
<td>60</td>
<td>63</td>
</tr>
<tr>
<td>Cationic spray 65</td>
<td></td>
<td>65</td>
<td>68</td>
</tr>
<tr>
<td>Cationic spray 70</td>
<td></td>
<td>70</td>
<td>73</td>
</tr>
<tr>
<td>Cationic premix 60</td>
<td></td>
<td>60</td>
<td>63</td>
</tr>
<tr>
<td>Cationic premix 65</td>
<td></td>
<td>65</td>
<td>68</td>
</tr>
<tr>
<td>Invert emulsion</td>
<td></td>
<td>80</td>
<td>-</td>
</tr>
</tbody>
</table>

**Precision (water content)**

*Repeatability* - duplicate results by the same operator should not be considered suspect unless they differ by more than the following amount:

- Water content, weight %  Difference, weight %
  - 30 to 50  0,8

*Reproducibility* - the results submitted by each of two laboratories should not be considered suspect unless they differ by more than the following amount:

- Water content, weight %  Difference, weight %
  - 30 to 50  2,0

**Particle charge test (Test method in SANS 4001-BT3 & BT4)**

This test distinguishes between cationic and anionic emulsions. Two electrodes are immersed in a sample of emulsion and connected to a low power direct current power source. If, at the end of the specified period, bitumen deposits are observed on the cathode, i.e. the electrode connected to the negative side of the current source, the emulsion is identified as a cationic bitumen emulsion.
There is no precision statement for this test method.

**Viscosity test (Test method ASTM D244)**

The viscosity of an emulsion is monitored by means of this test to ensure that its flow properties are appropriate to the application, e.g. steep gradients and high super elevation. The viscosity of bitumen emulsion is measured by means of the Saybolt Furol viscometer (Figure 30).

This test measures the time of efflux of a specified volume of emulsion at 50°C through the standard orifice.

![Saybolt Furol Viscometer](image)

*Figure 30: Saybolt Furol Viscometer*

**Precision**

*Repeatability* - duplicate results by the same operator should not be considered suspect unless they differ by more than the following amount:
Reproducibility - the results submitted by each of two laboratories should not be considered suspect unless they differ by more than the following amount:

Test temperature (°C)  Viscosity (seconds)  % of the mean
25  20 - 100  5,0
50  75 - 400  9,6

Coagulation value test (Test method in SANS 4001-BT2 & BT4)

This test determines the ability of a stable mix grade emulsion not to break prematurely in the presence of cement or lime.

Sieve test (Test method in SANS 4001-BT3 & BT4)

This test assesses the quality of an emulsion in terms of bitumen particle size. The bitumen particles in a good quality emulsion should be so small that they virtually all pass through the mesh of a 150μm sieve. In the test a quantity of emulsion is poured through a very fine sieve, and after rinsing, the amount of bitumen in the form of large particles, strings or lumps retained on the sieve is determined.

Sedimentation test (Test method in SANS 4001-BT3 & BT4)

This test ensures that the emulsion possesses adequate storage stability, especially when packaged in drums. A sample of emulsion is placed in a jar, which is centrifuged for a specified time at a specified speed. No excessive sedimentation should occur after the centrifuge stops. The degree of sedimentation is determined by rotating the jar end over end in a special apparatus until the sediment is re-dispersed in an added soap solution.

Water suitability

It is recommended that the potential sources of potable water to be used for diluting emulsion be subjected to testing to determine its suitability. A quick on-site test can be performed by diluting the emulsion with the candidate
water and examining the resultant mixture for any separation, i.e. incompatibility.

**Test on modified binders**

Test methods for modified binders are covered comprehensively in the Asphalt Academy publication TG1: *The use of modified bituminous binders in road construction*. Only brief descriptions of the purpose and nature of some of the important tests are described below. Test method numbers given are those listed in the above publication.

**Softening Point (Method MB-17)**

This test is essentially the same as that described for penetration grade bitumen and is a measure of the degree of modification of the binder.

**Dynamic viscosity**

*Bitumen rubber (Method MB-13)*

The results from this test enable the selection of the appropriate pumping, spraying and mixing temperatures for bitumen-rubber. The viscosity is measured with a hand-held rotary cup viscometer, thereby producing instant readings to determine whether the binder is within the specification limits.

*Polymer modified binder (Method MB-18)*

The test method is identical to ASTM D4402 described for penetration grade bitumen and reported at the binder’s application temperature for handling purposes.

**Elastic recovery (Method MB-4)**

This method is used to assess the elastic properties of polymer modified binders at relatively low temperatures. In this test duplicate samples are extended under controlled conditions for a distance of 200 mm. The elongated thread is then cut and the extent of its recovery after one hour is measured and expressed as a percentage of the extended length.
Storage stability (Method MB-6)

This test assesses the compatibility, and hence the stability, of bitumen/polymer systems by measuring the softening point of binder in the upper and lower sections of a sample stored vertically for three days at 165°C.

Modified Rolling Thin Film Oven Test (RTFOT) (Method MB-3)

This test, performed on homogenous polymer modified binders, is similar to the one described for penetration grade bitumen. However, to address the increased viscosity in the oven bottles, this method uses a larger quantity of binder and a metal bottle with an internal roller to assist the flow of binder during the test.

Ball penetration and resilience test (Method MB-10)

This test is used to assess the relative hardness or consistency of bitumen-rubber. The test measures the penetration of a standard ball into non-aged and oven-aged binder, as well as the rebound recovery.

Compression recovery (Method MB-11)

This test measures the contribution made by the rubber crumbs to the capacity of a bitumen-rubber to recover elastically after compression. The elastic recovery of the binder is determined after it has been compressed to half its original height.

Flow test (Method MB-12)

This test measures the resistance to flow (viscous behaviour) of bitumen-rubber at elevated temperatures (60°C).
4 Handling of bituminous binders

Bitumen presents a low order of potential hazard as long as sound and responsible practices are observed during the handling of the product.

These practices are described in detail in Sabita Manual 8: *Guidelines for the safe and responsible handling of bituminous binders.*

As bitumen is invariably handled and applied at elevated temperatures, it brings with it a number of hazards that are briefly covered below.

Users of the product should be aware that there is an obligation on the part of the supplier of bituminous binders to compile and issue Material Safety Data Sheets (MSDS) for each product in accordance with the regulations governing hazardous chemical substances.

The MSDS is the primary source of information and advice on the safe handling of the specific product.

Penetration grade bitumen is shipped or transported under UN Code 3257: ELEVATED TEMPERATURE LIQUID. The code relevant to all other binders is UN 1999: TARS LIQUID.

Note

Although emulsions and cutback bitumen are by no means tar binders, they do contain cutters and fluxes that render them flammable under certain conditions.

Hazards

Hazards associated with the use of bitumen are:

- Elevated temperatures;
- Combustion;
- Vapour emissions;
- Contact with water.

---

3 As it is not the intention to cover the topic in detail in this manual, it is strongly recommended that the reader acquaint himself with the contents of Manual 8 to ensure that the exposure of personnel to hazards while working with bitumen is mitigated.
Elevated temperature

The most significant hazard associated with bitumen is the high temperature (150 - 210°C) at which the product is held during handling and processing. As skin contact with hot bitumen will cause severe burns or even result in loss of life, it is critical that appropriate personal protection equipment (PPE) is worn to avoid any skin contact with hot bitumen.

Combustion

While the flash point (auto-ignition temperature) of penetration grade bitumen is generally in the region of 400°C, cutbacks are usually handled above the flash point of the cutter or solvent. Under conditions of high temperatures and in the presence of oxygen or a sudden increase in the availability of oxygen, an exothermic reaction can occur, leading to the risk of fire or explosion. Manholes or tank hatch covers should therefore be shut or at least lowered to prevent an explosion.

Vapour emissions

When bitumen is heated to temperatures above 150°C, visible vapours or fumes develop and these emissions can double for each 10°C increase in temperature. Fumes are mainly composed of hydrocarbons, containing small quantities of hydrogen sulphide (H₂S). The latter is of particular concern as exposure to this gas can be fatal at concentrations as little as 500 ppm.

It is therefore essential that any space where H₂S may be present be tested and approved as being free from noxious gas before permitting entry to the area. Bitumen fumes also contain small concentrations of poly-aromatic hydrocarbons (PAHs), but these do not present a health risk to personnel when sound work practices are adopted.

Contact with water

When water comes into contact with bitumen, it is converted to steam and its volume increases by a factor of approximately 1400, resulting in spitting, foaming and possibly boil-overs. This may bring the bitumen into contact with hot objects or burners, resulting in fire.
Contact between bitumen and water would therefore be avoided by ensuring that tanks or containers are free of water before discharging bitumen into them.

Additives should also be checked for the presence of water.

**Treatment of burns**

First aid procedures are covered comprehensively in Sabita Manual 8: *Guidelines for the safe and responsible handling of bituminous binders*. In addition, appropriate procedures for the handling of bitumen, the treatment of bitumen burns and firefighting are covered and in the following DVDs:

- DVD 410  The safe handling of bitumen;
- DVD 420  Treatment of bitumen burns;
- DVD 430  Working safely with bitumen;
- DVD 440  Firerfighting in the bituminous products industry.

The purpose of this document is merely to apprise the reader of the critical issues pertaining to the various injuries that arise from contact of the body with hot bituminous binders.

It should also be noted that first aid is not a substitute for prompt medical attention, and serves only to protect life and manage pain and injury until professional medical treatment can be obtained.

**Skin burns**

The affected area should be cooled as quickly as possible with running water to prevent further damage. No attempt should be made to remove the bitumen from the affected area, irrespective of the severity of the burn.

**Circumferential burns**

When a limb is completely encircled by hot bitumen, a tourniquet effect may ensue. In this case the adhering bitumen should be softened and/or split to allow the circulation of blood.

**Eye burns**

The injured person should be referred urgently for specialist medical attention. No attempt should be made to remove the bitumen by unqualified personnel.
5 Selection and application

It is not the intention of this manual to instruct readers in road construction techniques, since these are well documented elsewhere, particularly in Sabita Manual 30: *A guide to the selection of bituminous binders for road construction*. It will, however, be useful to link the ranges of products previously discussed with conventional structural and functional layers of roads where they serve as binding, waterproofing and stabilising agents. The applications refer to both new road construction and maintenance practices.

In chip seals the chippings are bound to the base or existing surfacing by the sprayed binder to form an all-weather surface which is dust free, has the required surface texture and skid resistance, resists the ravelling action of traffic and seals off underlying layers to the ingress of surface water. In hot mix asphalt the binder is mixed in the manufacturing plant with heated aggregates.

Asphalt surfacings perform the same functions and, in addition, if of sufficient thickness, add to the load-bearing capacity of the pavement structure. When applied to uneven surfaces, an asphalt overlay can provide a significant improvement in riding quality.

Stabilisation of base course, subbase and selected subgrade layers by means of bituminous binders improves the load-bearing capacity of these layers. They help to resist the ingress of water and thus prevent damage to these layers due to the softening effects of excessive moisture and, in extreme climates, damage due to freezing and thawing.

Bitumen-bound layers are relatively flexible and will, within limits and subject to the correct selection of grade of binder, accommodate movements in underlying layers without excessive cracking.

**Selection of bituminous binders**

The selection of bituminous binders is dictated by several factors. These include the material that has to be bound together, prevailing environmental conditions of climatic and traffic both in service and during construction, geographic location, topography, traffic loading, costs/budgets, specified construction methods and various other specific requirements imposed by a
client. There is no substitute for extensive experience and knowledge in this regard, and the following comments can only serve as a general guide.

The selection of bituminous binders for specific applications is dictated by several factors. These include:

- The configuration and type of material that has to be treated or bound together;
- Prevailing environmental conditions of climate (both during construction and in service), topography and traffic loading;
- The position and function of the layer; and
- Costs.

**Selection criteria**

An indication of typical applications of the various binders is given below. The reader is referred to the following documentation for more comprehensive guidance on the selection, use and application of bituminous binders:

- Chip seals and slurries - TRH3\(^4\), Sabita Manual 10\(^5\) and Sabita Manual 28\(^6\);
- Modified binders - TG1;
- Asphalt - Sabita Manuals 5, 13 and 27;
- Primes and stone precoating fluids - Sabita Manual 26;
- back coats - Sabita Manual 5 Bitumen stabilised materials - TG 2\(^7\)

**Binders for priming**

A prime coat is a spray application of a suitable bituminous binder to a non-bituminous (granular) layer prior to the application of further bituminous materials or layers.

**Standard products**

The primes most widely used in the construction of roads include:

- MC 10 or MC30 cutback bitumen grades complying with SANS 308;

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\(^4\) Technical recommendations for highways 2007: TRH3 - *Design and construction of surfacing seals*.
\(^5\) Bituminous surfacings for low volume roads and temporary deviations.
\(^6\) Best practice for the design and construction of slurry seals.
\(^7\) TG2: A guideline for the design and construction of bitumen emulsion and foamed bitumen stabilised materials published by the Asphalt Academy.
• Invert bitumen emulsion complying with SANS 1260:2004.

The main factors that influence the selection of the type of prime to be used are the type and the absorptive properties of the base and the prevailing weather conditions.

Proprietary products

Should primes be used that do not comply with SANS specifications, the supplier should provide specifications against which the product can be tested for compliance. Preferably such products should be certified as being fit-for-purpose by Agrément South Africa. For further guidance on the selection of prime coats the reader is referred to Sabita Manual 26: Interim guidelines for primes and stone precoating fluids.

Binders for tack coats

Tack coats are sprayed bituminous binders applied either to a primed granular substrate or a bituminous layer to promote adhesion between the existing surface and an asphalt layer being placed. Usually stable mix (anionic or cationic) bitumen emulsion is diluted 1:1 with water to achieve full coverage of the underlying layer with a thin residual bitumen film.

Binders for slurries

A slurry is in fact a cold-prepared asphalt mixture used as either a maintenance measure or as a surfacing - or part thereof - in new construction. Although both anionic and cationic stable grade 60% emulsions are suitable for conventional slurries, anionic emulsions are mostly used - mainly for reason of costs. The reader should note that, since cement or lime is generally used as filler in slurries, the positive charges developed by these fillers may well render anionic emulsions suitable, or even superior, as a binder due to improved workability.

"Microsurfacings" are slurries that are specially prepared by commercial firms and applied in thicker layers (say > 10 mm) and incorporate purpose-made rapid setting emulsions.

Binders for crack sealants

The following binders are generally used to seal cracks to prevent ingress of water into the road pavement:

• Hot applied elastomer modified C-E1;
• Emulsion elastomer modified CC-E1;
• Hot applied bitumen rubber C-R1.
Binders for chip seals

Chip seals consist of ordered applications of one or more bituminous products and aggregates. A wide range of bituminous binders is used for spray seals, such as:

- 70/100;
- 150/200;
- MC 3000;
- SBR/SBS hot modified bitumen - S-E1;
- Cationic Spray grade emulsion 65 %;
- Cationic Spray grade 70 %;
- SBR modified emulsion 65 % - SC-E1;
- SBS modified emulsion 70 % - SC-E2;
- Bitumen rubber - S-R1;
- Cationic spray grade emulsion - 60 %.

TRH3 lists the factors that will influence the selection of an appropriate bituminous binder for spray seals.

Binders for premixed asphalt

Premixed asphalt is prepared in an asphalt mixing plant where various stone aggregate fractions, filler and bituminous binders are accurately proportioned prior to transporting to site and paving and compaction of the material into layer.

Wearing course

Bituminous binders and modifiers in general use in wearing course asphalt are:

- Conventional binders:
  - 35/50 pen bitumen;
  - 50/70 pen bitumen;
  - 70/100 pen bitumen.
- Modified binders:
  - Styrene-butadiene-rubber (SBR) latex modified;
  - Styrene-butadiene-styrene (SBS) modified;
  - Bitumen-rubber;
  - Ethyl-vinyl-acetate (EVA);
  - Gilsonite, Durasphalt modified;
  - Fischer-Tropsch (F-T) Wax modified.
Bitumen used in asphalt wearing courses may also contain additives such as listed in Table 4 - Common binder additives used in asphalt on page 40.

**Asphalt bases**

Bituminous binders and modifiers in general use in asphalt bases are:

- **Conventional binders:**
  - 35/50 pen grade bitumen;
  - 50/70 pen grade bitumen.

- **Modified binders:**
  - Styrene-butadiene-styrene (SBS);
  - modified Bitumen-rubber modified;
  - Ethyl-vinyl-acetate (EVA) modified;
  - Gilsonite, Durasphalt modified;
  - Fischer-Tropsch (F-T) Wax modified.

**Asphalt seals (functional layers)**

Thin asphalt surfacings, i.e. those of specified thickness less than 30 mm on roads carrying light traffic - typically in residential areas - do not constitute a significant component of the structure of the pavement. For such layers the selection of binders should be guided by the attainment of good workability, low permeability and flexibility.

In view of the relative narrow time windows available for the compaction of such thin asphalt layers, the use of a softer grade of bitumen, e.g. 70/100 penetration should be given due consideration, mindful of climatic conditions. Consideration could also be given to the use of hydrocarbon modifiers such as F-T wax to extend the compaction window, bearing in mind the cost implications.

**Binders for stabilisation**

Bitumen stabilisation normally entails the upgrading of the quality of readily available pavement materials by treatment with relatively low concentrations of bitumen (normally < 3% by mass). Bitumen is introduced either as:

- An emulsion; or
- Foamed bitumen.
**Bitumen emulsion stabilisation**

In South Africa cationic or anionic 60% stable mix grade is used almost exclusively. The base bitumen is usually 70/100 penetration grade. The use of stable mix grade enables proper mixing of the binder with dense graded materials with high fines content and extended workability periods for good dispersion. The selection of an emulsion class for stabilisation is influenced by the type of aggregate to be treated. The reader is referred to Sabita Manual 30 for guidance in this matter.

**Foam bitumen stabilisation**

Foam bitumen is produced by injecting water (and sometimes air) into hot bitumen in an expansion chamber. During this process the water is turned into vapour trapped in tiny bitumen bubbles and the binder volume expands about 15 times. Binders with penetration values between 70 and 100 are generally selected for bitumen foam stabilised materials. It should, however, be noted that the penetration value alone does not assure suitability of a particular grade of bitumen for use in a foamed bitumen mix.

**Binders for curing membranes**

These binder coats are applied to facilitate curing of cementitious layers (i.e. cement or lime stabilised). For curing membranes to be effective, the residual bituminous layer needs to be continuous. Anionic stable-mix bitumen emulsion is most suited to this purpose, given the typically relatively low application rates.

**Precoating fluids**

Pre-coating of surfacing chips with bitumen-based fluids has become common practice as a cost-effective to measure minimise the risk of early chip loss due to poor adhesion. They should not be regarded, though, as a licence for accepting dirty/dusty aggregate or poor workmanship. The addition of a cutter to the binder as a substitute measure does not reflect good practice.
**Typical binder handling and application temperatures**

Table 10 gives an indication of the typical applications of the various binders, as well as the temperatures to which binders should be heated during handling and application. The maximum temperatures must not be exceeded, as prolonged heating will cause degradation of the binder properties. Modified hot binders must be circulated during heating to prevent localised over-heating around the flues. Circulation of emulsions must be kept to a minimum to prevent shearing of the bitumen droplets.

These temperatures have been arrived at by considering typical temperature/viscosity relationships of South African manufactured binders. Relevant viscosities for these operations are:

- **Pumping** 2 Pa.s maximum;
- **Mixing** $0.17 \pm 0.2$ Pa.s;
- **Compaction** $0.28 \pm 0.03$ Pa.s;
- **Spraying** $0.07 \pm 0.03$ Pa.s

Overheating or prolonged storage of bituminous binders at unnecessarily high temperatures adversely affects the characteristics of the material, leading to the loss of volatile fractions and, in severe cases, carbonisation of the material.

Although the applicable SABS specifications list maximum temperatures for storage, these are generally higher than the indicated minimum temperature for pumping. This justifies the storage of bituminous binders at the minimum temperature indicated for pumping.

Bitumen emulsions can be pumped, mixed or sprayed at ambient temperature. For spraying operations, however, the emulsion is heated to moderate temperatures to facilitate efficient operation of the spraying equipment.

It is emphasised that safe working temperatures should never be exceeded, and readers should refer to Sabita Manual 8: *Guidelines for the safe and responsible handling of bituminous binders* for details.

Also listed are typical densities at spray temperatures to facilitate the calculation of correct application volumes.
Table 10. Typical applications and handling temperatures for bitumen binders.

<table>
<thead>
<tr>
<th>Product</th>
<th>Spraying temperature (°C)</th>
<th>Typical density at spray temperature</th>
<th>Maximum time at spray temperature (hours)</th>
<th>Minimum road temperature (°C)</th>
<th>Minimum pumping temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Binders for chip seals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70/100</td>
<td>170 - 180</td>
<td>0.93</td>
<td>24</td>
<td>25</td>
<td>115</td>
</tr>
<tr>
<td>150/200</td>
<td>155 - 165</td>
<td>0.93</td>
<td>24</td>
<td>21</td>
<td>105</td>
</tr>
<tr>
<td>MC3000</td>
<td>125 - 145</td>
<td>0.93</td>
<td>8</td>
<td>15</td>
<td>80</td>
</tr>
<tr>
<td>SBR hot modified</td>
<td>190 - 200</td>
<td>0.92</td>
<td>8</td>
<td>25</td>
<td>150</td>
</tr>
<tr>
<td>SBS hot modified</td>
<td>180 - 190</td>
<td>0.92</td>
<td>24</td>
<td>25</td>
<td>140</td>
</tr>
<tr>
<td>SBR modified emulsion 65%</td>
<td>65</td>
<td>0.98</td>
<td>8</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>SBR modified emulsion 70%</td>
<td>70</td>
<td>0.98</td>
<td>8</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Bitumen rubber</td>
<td>200 - 210</td>
<td>0.93</td>
<td>6</td>
<td>25</td>
<td>150</td>
</tr>
<tr>
<td>Cationic spray 60%</td>
<td>60</td>
<td>0.99</td>
<td>24</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Cationic spray 65%</td>
<td>65</td>
<td>0.98</td>
<td>24</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Cationic spray 70%</td>
<td>70</td>
<td>0.98</td>
<td>24</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td><strong>Binders for priming bases</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC10</td>
<td>10 - 30</td>
<td>0.90</td>
<td>8</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>MC30</td>
<td>45 - 65</td>
<td>0.91</td>
<td>8</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Invert emulsion</td>
<td>60</td>
<td>0.90</td>
<td>8</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td><strong>Binders for stabilisation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anionic or cationic stable mix 60%</td>
<td>60</td>
<td>0.99</td>
<td>24</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>150/200</td>
<td>180</td>
<td>0.91</td>
<td>8</td>
<td></td>
<td>105</td>
</tr>
<tr>
<td>70/100</td>
<td>190</td>
<td>0.92</td>
<td>8</td>
<td></td>
<td>105</td>
</tr>
</tbody>
</table>
Table 10 (continued)

<table>
<thead>
<tr>
<th>Product</th>
<th>Spraying temperature (°C)</th>
<th>Compaction temperature (°C)</th>
<th>Maximum storage temperature &lt; 24 hrs (°C)</th>
<th>Minimum storage temperature &gt; 24 hrs (°C)</th>
<th>Minimum pumping temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binders for asphalt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50/70</td>
<td>150 - 160</td>
<td>135 - 145</td>
<td>160</td>
<td>140</td>
<td>120</td>
</tr>
<tr>
<td>35/50</td>
<td>155 - 165</td>
<td>140 - 150</td>
<td>165</td>
<td>140</td>
<td>125</td>
</tr>
<tr>
<td>SBR modified</td>
<td>165 - 175</td>
<td>150 - 160</td>
<td>180</td>
<td>140</td>
<td>140</td>
</tr>
<tr>
<td>SBS modified</td>
<td>160 - 170</td>
<td>140 - 150</td>
<td>180</td>
<td>140</td>
<td>140</td>
</tr>
<tr>
<td>EVA modified</td>
<td>160 - 170</td>
<td>140 - 150</td>
<td>170</td>
<td>140</td>
<td>140</td>
</tr>
<tr>
<td>FT wax modified</td>
<td>135 - 145</td>
<td>120 - 130</td>
<td>150</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Natural hydrocarbon modified</td>
<td>165 - 175</td>
<td>150 - 160</td>
<td>175</td>
<td>140</td>
<td>130</td>
</tr>
<tr>
<td>Bitumen rubber</td>
<td>190 - 210</td>
<td>150 - 165</td>
<td>165</td>
<td>140</td>
<td>160</td>
</tr>
</tbody>
</table>

Where warm mix asphalt technology is employed in the manufacture of asphalt, the temperatures given above could be reduced to the ranges recommended in Sabita Manual 32: *Best practice guideline for warm mix asphalt*, given in Table 11.

**Table 11 - Typical manufacturing and paving temperatures**

<table>
<thead>
<tr>
<th>Binder Type</th>
<th>Manufacturing (°C)</th>
<th>Upon arrival at paver (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30/50 pen</td>
<td>130 - 140</td>
<td>120 - 130</td>
</tr>
<tr>
<td>50/70 pen</td>
<td>120 - 130</td>
<td>110 - 120</td>
</tr>
<tr>
<td>A-P1</td>
<td>140 - 150</td>
<td>130 - 140</td>
</tr>
<tr>
<td>A-E2</td>
<td>140 - 150</td>
<td>130 - 140</td>
</tr>
</tbody>
</table>
## 6 Glossary

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt</td>
<td>A mixture of inert mineral matter, such as aggregate, mineral filler and bituminous binder in predetermined proportions.</td>
</tr>
<tr>
<td>Binder, bituminous</td>
<td>Any bitumen-based material used in road construction to bind together or to seal aggregate or soil particles. The term explicitly excludes coal tar products.</td>
</tr>
<tr>
<td>Binder, modified</td>
<td>Bitumen modified by the addition of substances to enhance performance. Examples of modifiers are polymers and natural or synthetic rubbers</td>
</tr>
<tr>
<td>Bitumen</td>
<td>a non-crystalline solid or viscous mixture of complex hydrocarbons that possess characteristic agglomerating properties. Bitumen, which is obtained from crude petroleum by refining processes, softens gradually when heated and is substantially soluble in trichloroethylene.</td>
</tr>
<tr>
<td>Bitumen, cutback</td>
<td>a liquid bitumen product obtained by blending penetration grade bitumen with a volatile solvent to produce rapid curing (RC) or medium curing (MC) cutbacks, depending on the volatility of the solvent used. After evaporation of the solvent, the properties of the original penetration grade bitumen become operative.</td>
</tr>
<tr>
<td>Bitumen emulsion</td>
<td>An emulsion of bitumen and water with the addition of an emulsifier or emulsifying agent to ensure stability. Conventional bitumen emulsion most commonly used in road works has the bitumen dispersed in the water. An invert bitumen emulsion has the water dispersed in the bitumen. In the former, the bitumen is the dispersed phase and the water is the continuous phase. In the latter, the water is the dispersed phase and the bitumen is the continuous phase. The bitumen is sometimes fluxed to lower its viscosity by the addition of a suitable solvent.</td>
</tr>
<tr>
<td>Bitumen emulsion, anionic</td>
<td>An emulsion where the emulsifier is an alkaline organic salt. The bitumen globules carry a negative electrostatic charge.</td>
</tr>
<tr>
<td>Bitumen emulsion, cationic</td>
<td>An emulsion where the emulsifier is an acidic organic salt. The bitumen globules carry a positive electrostatic charge.</td>
</tr>
<tr>
<td>Bitumen, penetration grade</td>
<td>That fraction of the crude petroleum remaining after refining processes, which is solid or near solid at normal air temperature and which has been blended or further processed to products of varying hardness or viscosity.</td>
</tr>
<tr>
<td>Bitumen rubber</td>
<td>A blend of bitumen and approximately 20% by weight of crumb rubber, containing where necessary extender oil and/or diluent.</td>
</tr>
<tr>
<td>Bituminous surfacing</td>
<td>A layer consisting of a bituminous binder and aggregate with which traffic makes direct contact. (See &quot;wearing course&quot;)</td>
</tr>
<tr>
<td>Bitumen-stabilised material</td>
<td>A base layer consisting of granular material mixed together with a bituminous binder.</td>
</tr>
<tr>
<td>Chip Seal</td>
<td>One or more spray applications of bituminous materials to a pavement surface with a cover of mineral aggregate.</td>
</tr>
<tr>
<td>Filler</td>
<td>Mineral matter composed of particles smaller than 0,075 mm and consisting of cement, lime or rock flour.</td>
</tr>
<tr>
<td>Fog Spray</td>
<td>A light application of diluted bitumen emulsion to the final layer of stone of a reseal or chip seal or to an existing bituminous surfacing as a maintenance treatment.</td>
</tr>
<tr>
<td>Hydrocarbon</td>
<td>A chemical compound consisting mainly of hydrogen and carbon.</td>
</tr>
<tr>
<td>Polymer</td>
<td>A chemical compound consisting of molecules formed by a large number of repeated units of one or more compounds of low molecular weight.</td>
</tr>
<tr>
<td>Product</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Polymer-modified bitumen</td>
<td>Bitumen with improved physical properties obtained by the addition of a polymer.</td>
</tr>
<tr>
<td>Reseal</td>
<td>A chip seal or treatment applied to an existing bituminous surface.</td>
</tr>
<tr>
<td>Seal</td>
<td>A term frequently used instead of &quot;reseal&quot; or &quot;surface treatment&quot; or &quot;chip seal&quot;. Also used in the context of &quot;double seal&quot; and &quot;sand seal&quot; where sand is used instead of stone.</td>
</tr>
<tr>
<td>Surface treatment</td>
<td>A general term incorporating chip seals, micro surfacing, fog sprays or tack coats.</td>
</tr>
<tr>
<td>Wearing course</td>
<td>The upper layer of a road pavement on which the traffic runs. (See &quot;bituminous surfacing&quot;).</td>
</tr>
</tbody>
</table>