Bituminous binders for road construction and maintenance

Manual 2
Fourth Edition
August 2007

Published by Sabita
Postnet Suite 56
Private bag X21
Howard Place 7450

ISBN 978-1-874968-30-6
Manuals published by Sabita

Manual 1  Construction of bitumen rubber seals
Manual 2  Bituminous binders for road construction and maintenance
Manual 3*  Test methods for bitumen rubber
Manual 4*  Specifications for rubber in binders
Manual 5  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  Safe and responsible handling of bituminous products
Manual 9  Bituminous surfacings for temporary deviations
Manual 10  Appropriate standards for bituminous surfacings
Manual 11  Labour enhanced construction for bituminous surfacings
Manual 12  Methods and procedures - Labour enhanced construction for bituminous surfacings
Manual 13  LAMBS - The design and use of large aggregate mixes for bases
Manual 14  GEMS - The design and use of granular emulsion mixes
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Manual 21  ETB: The design and use of emulsion treated bases
Manual 22  Hot mix paving in adverse weather
Manual 23  Bitumen Hauliers’ Code: Guidelines for loading bitumen at refineries
Manual 24  User guide for the design of hot mix asphalt
Manual 25  Quality management in the handling and transport of bituminous binders
Manual 26  Interim guidelines for primes and stone precoating fluids

* These manuals have been withdrawn and their contents have been incorporated in a manual entitled: The use of modified binders in road construction published as Technical Guideline 1 by the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

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Acknowledgements

The first edition (1987) was edited by Danie Ackermann, with acknowledgement to:

DG Green Shell SA  RH Kingdon Much Asphalt
PA Myburgh Sabita  AJ Nel Protea Asphalt
CW Nootenboom Caltex Oil SA  RH Renshaw Tosas
ADJ Swanepoel Vialit

The second edition (1995) was edited by:

TR Distin Engen  RH Kingdon Colas SA
CP van der Merwe UWP  RM Vos Sabita
MP Zacharias Shell SA

The third edition (2001) was edited by:

TR Distin Colas SA  JG Louw Colas SA
PA Myburgh Sabita  CD Olwagen Shell SA
T Pillay Sasol Carbo-Tar  G Reitsma Blacktop Holdings
GP Rutland Murray & Roberts  DE Sadler Tosas

This fourth edition (2007) has been edited by:

TR Distin Sabita  JG Louw Colas SA
PA Myburgh MP Zacharias Shell Oil Products Africa

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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 lesser experienced practitioner with the important engineering properties of these binders, and to illustrate the significance of the relevant properties in practice.

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.

Guidance is also given on the safe handling of these products to mitigate the risk of injury or loss.

It is now globally accepted that the use of coal tar products as a binder for road construction introduces undue health and environmental hazards, and that their use is no longer considered acceptable. Sabita supports this view in the interests of worker safety and environmental conservation; hence 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 fourth edition incorporates:

- Up-to-date information, with current specifications, use and application including modified binders, as well as packaging;
- Expanded information on the constitution and rheology of bitumen;
- Guidelines on the safe and responsible use of bituminous binders as provided for in the current edition (December 2006) of the Sabita Manual 8: Guidelines for the safe and responsible handling of bituminous products.
This manual should be used in conjunction with the following Sabita publications and videos:

**Manual 8:** Guidelines for the safe and responsible handling of bituminous products;

**Manual 23:** Bitumen Hauliers' Code - guidelines for loading bitumen at refineries;

**Manual 25:** Quality management in the handling and transport of bituminous binders;

**Manual 26:** Interim guidelines for primes and stone precoating fluids;

**DVD100** Testing of bituminous products
- Penetration bitumen tests
- Bitumen emulsion tests
- Bitumen rubber tests

**DVD420** Treatment of bitumen burns

Sabita acknowledges with thanks the permission granted by Shell Petroleum International to reproduce a number of figures and tables published in that company's 5th edition of The Shell Bitumen Handbook.
Illustrations

Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>Simplified flow diagram showing refining of bitumen</td>
<td>11</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Crude oil distillation products</td>
<td>11</td>
</tr>
<tr>
<td>Figure 3</td>
<td>Broad chemical composition of bitumen</td>
<td>13</td>
</tr>
<tr>
<td>Figure 4</td>
<td>Solution (SOL) type bitumen</td>
<td>15</td>
</tr>
<tr>
<td>Figure 5</td>
<td>Gelatinous (GEL) type bitumen</td>
<td>15</td>
</tr>
<tr>
<td>Figure 6</td>
<td>Changes in bitumen composition during ageing</td>
<td>17</td>
</tr>
<tr>
<td>Figure 7</td>
<td>Burger's Model</td>
<td>18</td>
</tr>
<tr>
<td>Figure 8</td>
<td>Response of asphalt in a simple creep test</td>
<td>21</td>
</tr>
<tr>
<td>Figure 9</td>
<td>Ageing of bitumen during mixing, hot storage and application</td>
<td>25</td>
</tr>
<tr>
<td>Figure 10</td>
<td>Effect of elastomers on the rheological profile of bitumen</td>
<td>27</td>
</tr>
<tr>
<td>Figure 11</td>
<td>Effect of elastomers on fatigue life</td>
<td>28</td>
</tr>
<tr>
<td>Figure 12</td>
<td>Typical emulsion plant flow diagram</td>
<td>33</td>
</tr>
<tr>
<td>Figure 13</td>
<td>Penetration Test</td>
<td>45</td>
</tr>
<tr>
<td>Figure 14</td>
<td>Softening Point Test</td>
<td>47</td>
</tr>
<tr>
<td>Figure 15</td>
<td>Brookfield viscometer with Thermosel system</td>
<td>48</td>
</tr>
<tr>
<td>Figure 16</td>
<td>Rolling Thin Film Oven Test (RTFOT)</td>
<td>49</td>
</tr>
<tr>
<td>Figure 17</td>
<td>Bitumen Test Data Chart</td>
<td>50</td>
</tr>
<tr>
<td>Figure 18</td>
<td>Consistency limits at various temperatures</td>
<td>51</td>
</tr>
<tr>
<td>Figure 19</td>
<td>U-tube reverse flow viscometer</td>
<td>52</td>
</tr>
<tr>
<td>Figure 20</td>
<td>Cutback bitumen distillation apparatus</td>
<td>53</td>
</tr>
<tr>
<td>Figure 21</td>
<td>Dean and Stark apparatus</td>
<td>55</td>
</tr>
<tr>
<td>Figure 22</td>
<td>Cup viscometer</td>
<td>57</td>
</tr>
<tr>
<td>Figure 23</td>
<td>Classification of bituminous binders</td>
<td>76</td>
</tr>
</tbody>
</table>

Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1</td>
<td>Components of Burger's model</td>
<td>20</td>
</tr>
<tr>
<td>Table 2</td>
<td>Types and grades of bituminous binders</td>
<td>36</td>
</tr>
<tr>
<td>Table 3</td>
<td>SABS specifications for bituminous binders</td>
<td>40</td>
</tr>
<tr>
<td>Table 4</td>
<td>SANS 307, December 2005 (Amendment No. 7)</td>
<td>41</td>
</tr>
<tr>
<td>Table 5</td>
<td>Typical bitumen content of cutback bitumen</td>
<td>54</td>
</tr>
<tr>
<td>Table 6</td>
<td>Binder content of emulsions</td>
<td>56</td>
</tr>
<tr>
<td>Table 7</td>
<td>Typical application and handling temperatures for bitumen binders</td>
<td>68-70</td>
</tr>
</tbody>
</table>
## CONTENTS

**PREFACE**  

**CHAPTER 1: Manufacture and properties of Bituminous Binders**  
- Origins and use of bitumen  
- The distillation process  
- The composition of bitumen  
- Bitumen structure  
- The rheology of bitumen  
- Behaviour of bitumen  
  - *Viscoelastic properties*  
  - *Durability*  
  - *Hardening*  

**CHAPTER 2: Types and grades of Bituminous Binders**  
- Penetration grade bitumen  
- Cutback bitumen  
- Modified bitumen  
  - *Types of modifiers used in bitumen*  
  - *Classification of modified binders*  
- Bitumen emulsions  
- Available grades and types of bituminous binders  
- Source and packaging  

**CHAPTER 3: Specifications and Test Methods**  
- Standard specifications for bituminous binders for road construction  
- Specifications for penetration grade bitumen  
- Sampling of bituminous binders  
- Standard tests  

**CHAPTER 4: Handling of Bituminous Binders**  

**CHAPTER 5: Selection and Application**  

**CHAPTER 6: Bibliography**  

**CHAPTER 7: Glossary**  

**APPENDIX 1: Viscosity measurement**  

**APPENDIX 2: Classification of bituminous binders**

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>PREFACE</td>
<td>5</td>
</tr>
<tr>
<td>CHAPTER 1</td>
<td>10</td>
</tr>
<tr>
<td>CHAPTER 2</td>
<td>26</td>
</tr>
<tr>
<td>CHAPTER 3</td>
<td>39</td>
</tr>
<tr>
<td>CHAPTER 4</td>
<td>61</td>
</tr>
<tr>
<td>CHAPTER 5</td>
<td>64</td>
</tr>
<tr>
<td>CHAPTER 6</td>
<td>71</td>
</tr>
<tr>
<td>CHAPTER 7</td>
<td>72-74</td>
</tr>
<tr>
<td>APPENDIX 1</td>
<td>75</td>
</tr>
<tr>
<td>APPENDIX 2</td>
<td>76</td>
</tr>
</tbody>
</table>
Chapter 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. 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.

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 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.

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 all 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.

Figure 1 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.

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**Figure 1: Simplified flow diagram, showing refining of bitumen.**

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**Figure 2: Crude oil distillation products**
Figure 2 shows the typical distillation yield from 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 (PAH’s), a portion of which ends up in bitumen. Some of these PAH’s are suspected of causing cancer in humans. However, the concentrations of these carcinogens 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 3).

These fractions are commonly referred to as SARA (saturates, aromatics, resins and asphaltenes).
Asphaltenes

Asphaltenes are fairly high molecular weight, polar n-heptane insoluble solids that are black and glassy, and they make up 5 - 25% of the bitumen. They contain carbon, hydrogen, some nitrogen, sulphur and oxygen.

The asphaltene content has a significant influence on the rheological properties of the bitumen. Increasing the asphaltene content produces a harder, more viscous binder.

Maltenes

Maltenes are the n-heptane soluble phase of the bitumen, and can be further separated into components broadly based on molecular mass and polarity.

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 ratio of resins to asphaltenes characterises to a degree the type of bitumen: "Solution" (SOL) or "Gelatinous" (GEL). (see Bitumen structure, page 14).
Aromatics are dark brown, low molecular weight, viscous fluids making up 40 - 65% of the total bitumen. They have a high dissolving ability for other, high molecular weight hydrocarbons. The aromatic content of the bitumen determines to a significant extent its compatibility with polymers used for modification.

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 asphaltene micelles with an absorbed sheath of high molecular mass aromatic resins, dispersed or dissolved in the lower molecular mass 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 its elastic properties;
- Non-polar molecules form the body of the bitumen and provide its viscous properties.

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

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.

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, illustrated in Figure 4.
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. These bitumens are known as "gelatinous" (GEL) types and are depicted in Figure 5.
Examples of GEL type bitumens are oxidised grades used for roofing purposes. In practice, most bitumens are of intermediate character.

Relatively weak chemical bonds hold the molecules together and these can be destroyed by heat or shear stress, which gives bitumen its viscoelastic characteristics.

**The rheology of bitumen**

Rheology is the science of the flow and deformation of fluids. The rheological properties of bitumen at a given temperature are determined by both the chemical composition and the structure - or physical arrangement - of the molecules.

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: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 6 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.
Figure 6: Changes in bitumen composition during ageing
The constitution of the bitumen has a huge effect on the viscosity and temperature susceptibility of the material. Furthermore, too little or too much of particular molecule groups can lead to brittleness and poor behaviour at low temperatures.

It is important to note that there is no ideal formula for SARA proportional fractions, and that it is the interaction between these fractions that will characterise the rheology of the bitumen.

**Behaviour of bitumen**

**Viscoelastic properties**

The viscoelastic character of bitumen results in its varied response behaviour under varied loading times and temperature changes. 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.

Burger's Model is often used to characterise the response of bitumen to imposed stresses. The model is shown in Figure 7 and consists of:

- A spring and dashpot in series (Maxwell model);
- Spring and dashpot in parallel (Kelvin-Voigt model).

![Figure 7: Burger's Model](image)
**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" (See Appendix 1).

Materials such as penetration grade bitumen above 60° - 100°C and water display a linear relationship between the resisting force and the relative velocity. The viscosity of the material is therefore constant, irrespective of the magnitude of the applied shear. Such materials are known as "Newtonian fluids".

Under conditions of elevated temperature, pavements bound with bitumen will tend to rut, under repeated applications of wheel loads, 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.
Table 1: Components of Burger’s Model

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

Figure 8 illustrates the stress/strain relationships of asphalt 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.
Figure 8: Response of asphalt in a simple creep test
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.

**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 hot mix 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 hardening, e.g. in asphalt bases, can be beneficial. 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:** As with most other organic substances, bitumen is slowly oxidised when in contact with oxygen in the atmosphere. This 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 will advance the rate of oxidative hardening during in-service life, especially in warmer climates. Hardening due to oxidation is considered to be the main cause of ageing.

**Loss of volatiles:** The evaporation of volatiles depends mainly on the exposure to sunlight and prevailing temperatures. Penetration grade bitumens, being relatively involatile, are 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 into porous aggregates of oily components of the bitumen, i.e. maltenes.

**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;
- Hot mix 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 a high temperature 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.

**Hot mix 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 in a pug mill 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.

**Handling of asphalt:** Hot mix 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. A 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 9 illustrates the ageing of bitumen during mixing and subsequently during asphalt hot storage, transport and in service.
Note on heating in laboratories:

Small samples of bitumen or asphalt mixes are heated or reheated in laboratories to perform necessary tests to assess either compliance with the relevant specifications or 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.
Chapter 2: Types and grades of Bituminous Binders

Penetration grade bitumen

Penetration grade bitumen can be manufactured by straight-run distillation or by blending two or more base components (one hard, such as 40/50 pen, and the other soft, such as 150/200 pen). Penetration grade bitumen is used either as a primary binder or as a base bitumen for the manufacture of cutback bitumen, modified binders or bitumen emulsions.

Cutback bitumen

Cutback bitumens are blends of penetration grade bitumen and slow, medium or rapid curing 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, which in turn will cure more rapidly than a slow-curing (SC) solvent. The viscosity of the cutback bitumen is determined by the proportion of solvent added - the higher the proportion of solvent, the lower the viscosity of the cutback. The solvent used in cutback bitumens 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 bitumens is that they can be applied at lower temperatures than penetration grades because of their lower viscosities.

Modified bitumen

When bituminous surfacings are subjected to severe conditions such as steep gradients, very high road surface temperatures, high traffic loading or heavily trafficked intersections, or are used on highly flexible and cracked pavements, an improvement in the rheological properties of the bitumen is required. 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 modified bitumens 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.

Modification is achieved by the introduction of polymers, crumb rubber, aliphatic synthetic wax or naturally occurring hydrocarbons.

Polymers can be broadly classified into "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. However a wide range of binder properties can be improved, the most important being:

- durability;
- aggregate retention due to higher binder viscosity and adhesive strength;
- resistance to permanent deformation;
- resistance to fatigue cracking;
- cohesion;
- elasticity;
- viscosity less susceptible to changes in temperature.

Figure 10: Effect of elastomers on the rheological profile of bitumen
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 elastomers on the rheological profile of a binder is illustrated in Figure 10.

At high road temperatures, say 55 - 60°C, the 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 modified binder is more flexible than the unmodified bitumen and hence would be less prone to cracking. Increased flexibility and, hence, resistance to fatigue distress has also been shown to result from elastomer modification.

As illustrated in Figure 11, the fatigue life of bitumen can be increased by a factor of at least three. The material would therefore offer improved

![Figure 11: Effect of elastomers on fatigue life](image-url)
performance in areas where high tensile strains are likely to occur in asphalt layers.

Types of modifiers used in bitumen

In South Africa three types of elastomers are generally in use:

- **Styrene-butadiene-rubber (SBR) latex;**
- **Styrene-butadiene-styrene (SBS);**
- **Rubber crumb (although not classified as a polymer, the behaviour of bitumen-rubber blends resembles that of elastomers).**

One type of plastomer in general use is Ethylene-vinyl-acetate (EVA);

Other modifiers used are:

- **Aliphatic synthetic wax.**
- **Naturally occurring hydrocarbons**

**Styrene-Butadiene-Rubber (SBR) latex:** SBR is available in the form of an 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 South 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 hot mix asphalt applications to enhance the bitumen’s all-round performance characteristics.

**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 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 rut resistance.

**Rubber crumb**: About 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 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, amongst others, to its improved temperature susceptibility of viscosity. The carbon black contained in the rubber also acts as an anti-oxidant, thereby increasing the durability of the binder.

**Aliphatic synthetic wax**: Long-chain hydrocarbons produced by the Fischer-Tropsch (F-T) synthesis process are used to extend the plasticity range of bitumen. Bitumen modified with F-T wax displays unique properties in that it has 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 F-T wax to be mixed and placed at lower temperatures than those mixes using conventional bitumen.

The significant increase in Ring and Ball softening point of binders modified with F-T wax renders asphalt incorporating such binders to have enhanced resistance to permanent deformation.

**Naturally occurring hydrocarbons**: Naturally occurring hydrocarbons used for bitumen modification occur in 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
resilient modulus values compared with those containing binders modified with polymers. The high resilient moduli achieved will enhance both the resistance to permanent deformation and the load spreading capability of the layers.

Hydrocarbon modification is not recommended for use in pavements with high transient deflections.

Classification of modified binders

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

1. The type of application
   - S - seal;
   - A - asphalt and
   - C - crack sealant.

2. Type of modifier
   - E - elastomer;
   - P - plastomer;
   - R - rubber crumb
   - H - hydrocarbon

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

4. Level of modification
   A numerical value is used to indicate increasing softening point values.

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

Refer to Table 2 on page 36 for the various grades of modified binders.
Bitumen emulsions

Description

Emulsification of bitumen is a means (along with heating and the addition of solvents) of reducing the viscosity of a binder and its tendency to behave as a fluid during application.

Bitumen emulsions are two-phase systems consisting of a dispersion of bitumen droplets in water which contains an emulsifier. 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 µm in diameter, held in suspension by electrical charges. (See Figure 12).

Commonly bitumen emulsions are available in two classes:

- cationic
- 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). Cationic emulsions are more widely used as they have superior adhesive properties to a range of mineral aggregates.

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.

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 bitumens 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 µm.

A typical emulsion plant flow diagram is shown in Figure 12.

![Figure 12: A typical emulsion plant flow diagram](image)

The water phase is prepared whereby the emulsifier chemicals are dissolved in heated water and are saponified with alkalis in the case of anionic emulsions, or acidified with inorganic acids for cationic emulsions. Emulsion manufacturers have separated 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 80/100 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.

**Properties of emulsions**

The most important properties of an emulsion are:

- stability;
- viscosity;
- breaking.

**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 of the cationic emulsion type to a range of aggregates is normally sufficient;
- Application at lower temperatures in the interests of:
  - enhanced worker safety;
  - lower energy consumption;
  - reduced emissions; and
  - extended 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.

**Emulsion-aggregate adhesion**

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 cationic emulsion.

Good adhesion is achieved between anionic emulsion 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.

The emulsion will break when the bitumen particles agglomerate. Unlike anionic, cationic emulsion break occurs via a physical-chemical reaction. The use of anionic spray and premix grades has largely been replaced by the cationic equivalents worldwide, while anionic stablemix grades are still widely used.

**Classification of emulsions**

Road emulsions are classified according to their particle charge, stability when in contact with aggregates, and binder content. Four main grades - spray, premix, stablemix and quick setting - are produced, and these are defined in the Glossary under *Bitumen Emulsion Grades*. The binder content of emulsions varies between 60 and 70% by mass.

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 a SBR latex is introduced as a third component in the normal bitumen-water two phase system.
Available grades and types of bituminous binders

A generic classification of road binders is given in Appendix 2, and the grades and types of bituminous binders available in South Africa are shown in Table 2.

<table>
<thead>
<tr>
<th>Type</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetration grade bitumen</td>
<td>40/50</td>
</tr>
<tr>
<td></td>
<td>60/70</td>
</tr>
<tr>
<td></td>
<td>80/100</td>
</tr>
<tr>
<td></td>
<td>150/200</td>
</tr>
<tr>
<td>Cutback bitumen</td>
<td>MC-30, MC-3000</td>
</tr>
<tr>
<td>Modified binders</td>
<td></td>
</tr>
<tr>
<td>SBS</td>
<td>S-E2, A-E2, C-E1</td>
</tr>
<tr>
<td>SBR</td>
<td>S-E1, A-E1</td>
</tr>
<tr>
<td>EVA</td>
<td>A-P1</td>
</tr>
<tr>
<td>Natural hydrocarbons</td>
<td>A-H1</td>
</tr>
<tr>
<td>F-T wax</td>
<td>A-H2</td>
</tr>
<tr>
<td>Non-homogeneous Bitumen</td>
<td>S-R1, A-R1, C-R1</td>
</tr>
<tr>
<td>Rubber</td>
<td></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 grade mix - 60% binder content</td>
</tr>
<tr>
<td></td>
<td>Invert cationic emulsion - 80% binder content (including flux)</td>
</tr>
<tr>
<td>Modified bitumen emulsion</td>
<td>SC-E1, SC-E2, CC-E1</td>
</tr>
<tr>
<td>Stone pre-coating fluids</td>
<td>Bitumen 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 - collectively produce the full SABS range of penetration grade and cutback bitumens for road-making, 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 bitumens 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 economical reasons. Delivery can be made to storage tanks at asphalt plants, emulsion factories and construction sites, or into bulk spray distributors, for direct application to the road surface.

Bulk road tankers are generally fitted with liquid petroleum gas (LPG) burners firing into flues, which pass through the tanker, or sometimes oil heating systems, which are electrically heated. The heating system is used when the road tanker is stationary to maintain or increase the bitumen temperature to the desired pumping, mixing or spray temperature.

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

Bitumen can also be 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 liter 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" hot 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). These are used where superior performance is required.

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 hot mix asphalt manufacturing plants.
Chapter 3: Specifications and Test Methods

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 bitumens derived from different crude sources (and hence of different chemical composition) can have similar physical properties.

For this reason it makes no sense to describe or specify bitumens 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;
- that they will not be adversely affected during normal handling, transport and storage, even when heated; and
- that 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 3, 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. The detailed new specification for penetration grade bitumen is given in Table 4.
Table 3: SABS specifications for bituminous binders

<table>
<thead>
<tr>
<th>Specification number</th>
<th>Title</th>
<th>Grade designations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Bitumen</strong></td>
<td></td>
</tr>
<tr>
<td>SANS 307</td>
<td>Penetration grade</td>
<td>40/50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>60/70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80/100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>150/200</td>
</tr>
<tr>
<td>SANS 308</td>
<td>Cutback bitumens</td>
<td>MC-30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MC-3000</td>
</tr>
<tr>
<td></td>
<td><strong>Bitumen emulsion</strong></td>
<td></td>
</tr>
<tr>
<td>SANS 309</td>
<td>Anionic bitumen road emulsions</td>
<td>Spray type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stablemix type</td>
</tr>
<tr>
<td>SANS 548</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>Stablemix type</td>
</tr>
<tr>
<td>SANS 1260</td>
<td>Invert bitumen emulsion</td>
<td>Prime</td>
</tr>
</tbody>
</table>
### Specifications for penetration grade bitumen

**Table 4: SANS 307, December 2005 (Amendment No 7)**

<table>
<thead>
<tr>
<th>Property</th>
<th>Penetration grade</th>
<th>Test method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40/50</td>
<td>60/70</td>
</tr>
<tr>
<td>Penetration at 25°C (100g/5s) 1/10mm</td>
<td>40 - 50</td>
<td>60 - 70</td>
</tr>
<tr>
<td>Softening point (ring and ball), °C</td>
<td>49 - 59</td>
<td>46 - 56</td>
</tr>
<tr>
<td>Viscosity at 60°C, Pa.s</td>
<td>220 - 400</td>
<td>140 - 250</td>
</tr>
<tr>
<td>Viscosity at 135°C, Pa.s</td>
<td>0.27 - 0.65</td>
<td>0.22 - 0.45</td>
</tr>
<tr>
<td>Performance when subjected to the rolling thin film oven test:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) mass change, % (m/m) max.</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>(b) viscosity at 60°C, % of original max.</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>(c) softening point (ring and ball), °C min.</td>
<td>52</td>
<td>48</td>
</tr>
<tr>
<td>(d) increase in softening point, °C max.</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>(e) retained penetration, % of original, min</td>
<td>60</td>
<td>55</td>
</tr>
<tr>
<td>Spot test* % xylene, max.</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

+ Recommended apparatus is the RV viscometer, using SC4 spindles with the 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. Therefore 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 75mm from the sides and ends of the containers.

The following minimum sample sizes are required:

- 4 l from bulk storage tanks and bulk road tankers;
- 1 l from drums of liquid binder;
- 1 kg from drums of solid binder.

When more than one container from a batch has to be sampled, not less than 0.1 kg should be taken from each of the calculated number of containers to constitute a composite sample of about 4 l.

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 laid down by the American Society for Testing and Materials (ASTM) and the American Association of State Highway and Transportation Officials (AASHTO) are followed in South Africa. Some of the methods published by the Institute of Petroleum (IP) are equivalent.

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 judged for compliance.

Often small deviations from or variations in methods can cause significant differences in results. For this reason it is of utmost importance that methods applicable or actually carried out are clearly stated in specifications and reports.

In most cases criteria for judging the acceptability of test results are given. These limits of variability are defined as *repeatability* and *reproducibility*:

- **Repeatability** is the variation in measurements taken by a single person or instrument on the same items under the same conditions of procedure, instrument, location and repetitions over a short period of time;
- **Reproducibility** is the variation in average measurements when two or more persons in different locations measure the same items using the same measuring techniques.

Repeatability and reproducibility are expressed quantitatively as a dispersion of results that is likely to contain 99% of the measurements. Variation in test results, given the basis of comparison, should not be considered suspect unless they differ by more than the values of repeatability or reproducibility given.
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.

**Tests for penetration grade bitumen**

**Penetration test (Test method ASTM D5)**

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 307.

The penetration value of a 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 gave a

![Figure 13: Penetration Test](image)
penetration of 80 dmm to 100 dmm, is referred to as 80/100 pen bitumen. It will be noted that the higher the penetration, the softer the bitumen.

Temperature control during the test to within $\pm 0.1^\circ C$ is critical.

The apparatus for carrying out the penetration test is illustrated in Figure 13.

**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 of the two results

*Reproducibility*

- If the penetration is less than 50
  - 4 dmm
- If the penetration is equal to or greater than 50
  - 8% of the mean of the two results

**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 bitumens this viscosity value is in the region of 1200 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 a bitumen with a softening point 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 to a further prescribed distance.

**Precision of the test method:**

*Repeatability* - $1.1^\circ C$.

*Reproducibility* - $2.0^\circ C$.

The apparatus for carrying out the softening point test is illustrated in Figure 14.
Viscosity test (ASTM D4402)

Viscosity, i.e. the resistance to flow or shear, is a fundamental characteristic of bitumen as it describes the behaviour of the material 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 Appendix 1 (page 75) - Viscosity measurement.)

The dynamic viscosity, or resistance to shear, of penetration grade bitumen can be determined by measuring the torque required to rotate a spindle which is 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.

![Brookfield viscometer with Thermosel system](image)

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. 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.

**Precision of the test method:**

- **Repeatability** - 3.5%.
- **Reproducibility** - <4.5%.
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 a hot mix asphalt manufacturing plant. It does not, however, purport to simulate long term in-service ageing.

In the RTFOT a series of glass containers rotates 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.

The apparatus for this test is illustrated in Figure 16.

![Figure 16: The Rolling Thin Film Oven Test (RTFOT)](image)
The Bitumen Test Data Chart (BTDC)

Developed by Heukelom, the BTDC (see Figure 17) provides a system whereby penetration, softening point and viscosity can be jointly described as a function of temperature.

During manufacture and construction of hot mix 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.

![Bitumen Test Data Chart](image)

**Figure 17: Bitumen Test Data Chart**

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 as well as dynamic to kinematic viscosity, and viscosities measured at high temperatures to ensure the establishment of correct application temperatures. A 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 bitumens produced have consistent rheological properties over a temperature range covering ambient to application conditions, i.e. 25 - 135°C before and after ageing.

Figure 18 provides a graphical illustration of the specification limits at the various temperatures.

Figure 18: Consistency limits at various temperatures
Tests on cutback bitumen

Kinematic viscosity test (Test method ASTM D2170)

This test of consistency is used to classify cutback 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.

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.

Figure 19: U-tube reverse flow viscometer for measuring kinematic viscosity
**Precision of the test method**

<table>
<thead>
<tr>
<th>% of the mean</th>
<th>Viscosity (cSt)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Repeatability</strong></td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>(below 3 000)</td>
</tr>
<tr>
<td>2.0</td>
<td>(3 000 - 6 000)</td>
</tr>
<tr>
<td><strong>Reproducibility</strong></td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td>(below 3 000)</td>
</tr>
<tr>
<td>9.0</td>
<td>(3 000 - 6 000)</td>
</tr>
</tbody>
</table>

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 in Figure 20.

*Figure 20: Cutback bitumen distillation apparatus*
Typical bitumen contents of various grades of cutback binders are given in Table 5.

**Table 5: Typical bitumen content of cutback bitumen**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Bitumen content by % volume</th>
</tr>
</thead>
<tbody>
<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 the heaviest constituents of the solvent.

**Precision of the test method:**

*Repeatability* - 1.0 volume % of the original sample.

*Reproducibility* -

<table>
<thead>
<tr>
<th>Distillation fractions</th>
<th>volume % of 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>

**Other tests**

There is a general requirement in the specification that cutback bitumens should be free of visible water, and will not foam when heated to application temperature. Flash point, a measure of the temperature to which a cutback bitumen can safely be heated under certain conditions, is usually monitored at the point of manufacture since certain precautions are necessary during transportation and application of the product.

**Tests on bitumen emulsions**

The tests performed on bitumen emulsions are as specified in SANS 309, 548 and 1260.
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 1260 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 bitumen (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 21.

![Dean and Stark apparatus](image)

*Figure 21: Dean and Stark apparatus*
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.

Table 6 gives the binder content ranges for various grades of emulsions.

**Table 6: Binder content of emulsions**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Binder content % by mass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
</tr>
<tr>
<td>Anionic stablemix</td>
<td>60</td>
</tr>
<tr>
<td>Cationic stablemix</td>
<td>60</td>
</tr>
<tr>
<td>Cationic spray 60</td>
<td>60</td>
</tr>
<tr>
<td>Cationic spray 65</td>
<td>65</td>
</tr>
<tr>
<td>Cationic spray 70</td>
<td>70</td>
</tr>
<tr>
<td>Cationic premix 60</td>
<td>60</td>
</tr>
<tr>
<td>Cationic premix 65</td>
<td>65</td>
</tr>
<tr>
<td>Invert emulsion</td>
<td>80</td>
</tr>
</tbody>
</table>

**Precision of the test (water content):**

- **Repeatability**
  - Water content, weight %: 30 to 50
  - Difference, weight %: 0.8

- **Reproducibility**
  - Water content, weight %: 30 to 50
  - Difference, weight %: 2.0

**Particle charge test (Test method in SANS 309 and 548)**

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 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. At present, 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 22). This test measures the time of efflux of a specified volume of emulsion at 50°C through the standard orifice.

![Cup viscometer](image)

**Figure 22: Cup viscometer**

**Precision of the test:**

<table>
<thead>
<tr>
<th>Repeatability</th>
<th>Test temperature (°C)</th>
<th>Viscosity (seconds)</th>
<th>% of the mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25</td>
<td>20 - 100</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>75 - 400</td>
<td>9.6</td>
</tr>
</tbody>
</table>
Reproducibility -

<table>
<thead>
<tr>
<th>Test temperature (°C)</th>
<th>Viscosity (seconds)</th>
<th>% of the mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>20 - 100</td>
<td>15</td>
</tr>
<tr>
<td>50</td>
<td>75 - 400</td>
<td>21</td>
</tr>
</tbody>
</table>

**Coagulation value test (Test method in SANS 309 and 548)**

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

**Sieve test (Test method in SANS 309 and 548)**

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 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 309 and 548)**

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 subject 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.

**Tests on modified binders**

Test methods for modified binders are covered comprehensively in the 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 200mm. The elongated thread is then cut and the extent of its recovery after 1 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 homogeneous 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)
Chapter 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 covered in detail in Sabita Manual 8 - Guidelines for the safe and responsible handling of bituminous binders.

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 and hot modified 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 that although emulsions and cutback bitumens are by no means tar binders, they do contain cutters and fluxes that render them flammable under certain conditions.)

Users should note that bituminous binders surplus to requirements on site should either be returned to the supply depot or, if this is not feasible, disposed of only in landfill sites specifically permitted by the Department of the Environment and Tourism to accept the specific binders and additives.

Hazards

As bitumens are invariably handled and applied at elevated temperatures, a number of hazards are associated with these operations. Some of these hazards are briefly covered below.

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 PAH’s, 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 hot 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. Also, rapid boil-overs in a road tanker or sprayer will envelop anything (including persons) in the near vicinity with hot bitumen, causing severe damage, injury or loss of life.

Contact between bitumen and water should therefore be avoided by ensuring that tanks or containers are free of water before discharging bitumen into them. This is especially the case with road tankers previously used to transport bitumen emulsions.

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* and *Treatment of Bitumen Burns DVD420*. The purpose of this document is merely

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1 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 exposure to hazards of personnel working with bitumen is mitigated.
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 heat causing 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.
Chapter 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. 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, adjust to 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. Typical usages are shown in Table 7, Page 68.
Primes, tack coats, curing membranes and precoating fluids

A granular basecourse (whether unstabilised or stabilised with cement or lime) should be given a prime coat. Similarly, a tack coat should always be applied on any layer accommodating a hot mix asphalt overlay. The materials most commonly used for the prime coats are MC-30 cutback bitumen or invert bitumen emulsion. For guidance on the selection of the appropriate binder, refer to Sabita Manual 26 - *Interim guidelines for primes and stone precoating fluids*.

Specifications for tack coats invariably require low residual binder application rates. Stablemix bitumen emulsion (anionic or cationic) is most suited to this purpose as it can be further diluted with water.

For curing membranes to be effective, the residual bituminous layer needs to be continuous. Anionic stablemix bitumen emulsion is most suited to this purpose, given the typically relatively low application rates.

Bitumen-based precoating fluids, containing adhesion agents, are used to coat aggregates to promote adhesion to the bituminous binders, especially hot applied ones in chip seals.

Base courses

Base courses constructed with asphalt are used on heavily trafficked roads. In this instance, aggregate gradings that ensure proper packing, and hence interlock, are mixed with high-viscosity road grade bitumen. These include large aggregate mixes known as LAMBS or other high modulus asphalt layers. (Refer Sabita Manual 13: *LAMBS - The design and use of large aggregate mixes for bases.*)

Emulsions are often used to strengthen and waterproof granular materials and they also serve as an aid to compaction. Bitumen stabilisation of granular materials meeting specified engineering parameters is reviewed in Sabita Manual 21: *ETB - The design and use of emulsion-treated bases* and Manual 14: *GEMS - The design and use of granular emulsion mixes*.

Foamed bitumen is also used for stabilising sand and other sub-standard base course materials. During the foaming process a small controlled proportion of cold water is added to the hot bitumen, which results in the volumetric expansion of the binder prior to mixing with the base course material. The foamed bitumen is selective in its dispersion, and shows preferred adhesion to
the finer particles. During collapse of the foamed bitumen during mixing, only a limited amount of bitumen is available for partial coating of the larger aggregate particles and "spot welding".

**Wearing courses**

A wearing course could be constructed of hot mix asphalt, cold mix asphalt (including slurry) or a chip seal.

**Hot mix asphalt wearing courses**

For hot mix asphalts, the harder penetration grade bitumen such as 40/50 and 60/70 pen should be used as, in conjunction with the aggregate configuration, they impart the required stiffness to these mixtures.

For the construction of heavily-trafficked roads, only hot mix asphalts should be used, requiring the appropriate sophisticated mixing and laying equipment.

**Cold mix asphalt wearing courses**

For lightly trafficked roads (driveways or parking areas for instance) cold mix asphalt can be used. It provides for a longer construction period before it hardens and allows for more simple mixing and paving operations. Cold mix asphalt, based on cutback bitumen (MC3000) or bitumen emulsion, (Premix 60 or 65, Anionic Stablemix 60) with a storage life of up to six months, is produced for situations where only simple equipment is available for spreading and compaction. This type of mix is most suitable for patching.

**Chip seals**

Subject to certain basic principles, the specifications for surface treatments vary from a fog spray applied as a maintenance treatment, to multiple chip seals and slurry seals. A wide range of bituminous binders is used, such as penetration grade bitumen (80/100 and 150/200 pen), bitumen emulsions (Cationic Spray grades), cutback bitumen (MC3000) and modified binders.

Stablemix grade anionic and cationic bitumen emulsions are used for slurry application.
Also listed are typical densities at spray temperatures to facilitate the calculation of correct application volumes.

**Table 7: Typical application and handling temperatures for bituminous binders.**

**Binders for chip seals**

<table>
<thead>
<tr>
<th>Product</th>
<th>Sprayin g temp °C</th>
<th>Typical density at spray temp.</th>
<th>Max. time at spray temp. (hrs)</th>
<th>Min. road temp °C</th>
<th>Min. pumping temp °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>80/100</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>MC 3000</td>
<td>130 - 145</td>
<td>0.93</td>
<td>8</td>
<td>15</td>
<td>85</td>
</tr>
<tr>
<td>SBR hot modified</td>
<td>200 - 210</td>
<td>0.92</td>
<td>8</td>
<td>25</td>
<td>150</td>
</tr>
<tr>
<td>SBS hot modified</td>
<td>175 - 185</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>16</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>
</tbody>
</table>
### Binders for Priming Bases

<table>
<thead>
<tr>
<th>Product</th>
<th>Spraying temp °C</th>
<th>Typical density at spray temp.</th>
<th>Max. time at spray temp. (hours)</th>
<th>Min. road temp °C</th>
<th>Min. pumping temp °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC 30</td>
<td>55</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>
</tbody>
</table>

### Binders for Stabilisation

<table>
<thead>
<tr>
<th>Product</th>
<th>Spraying temp °C</th>
<th>Typical density at spray temp.</th>
<th>Max. time at spray temp. (hours)</th>
<th>Min. road temp °C</th>
<th>Min. pumping temp °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anionic or cationic stablemix 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>105</td>
<td></td>
</tr>
<tr>
<td>80/100</td>
<td>190</td>
<td>0.92</td>
<td>8</td>
<td>115</td>
<td></td>
</tr>
</tbody>
</table>
### Binders for hot mix asphalt

<table>
<thead>
<tr>
<th>Product</th>
<th>Mixing temp {\degree}C</th>
<th>Compaction temp. {\degree}C</th>
<th>Max. storage temp. &lt;24 hrs {\degree}C</th>
<th>Max. storage temp. &gt;24 hrs {\degree}C</th>
<th>Min. pumping temp. {\degree}C</th>
</tr>
</thead>
<tbody>
<tr>
<td>60/70</td>
<td>150 - 160</td>
<td>135 - 145</td>
<td>160</td>
<td>140</td>
<td>120</td>
</tr>
<tr>
<td>40/50</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>175 - 190</td>
<td>150 - 160</td>
<td>180</td>
<td>150</td>
<td>140</td>
</tr>
<tr>
<td>SBS modified</td>
<td>170 - 180</td>
<td>140 - 150</td>
<td>180</td>
<td>150</td>
<td>140</td>
</tr>
<tr>
<td>EVA modified</td>
<td>160 - 170</td>
<td>140 - 150</td>
<td>170</td>
<td>150</td>
<td>140</td>
</tr>
<tr>
<td>F-T 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>150</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>
Chapter 6: Bibliography

The following references will provide valuable additional information for those seeking more detail of bituminous products and their application.

SANS 307: Penetration grade bitumen - SABS
SANS 308: Cutback bitumen - SABS
SANS 309: Standard specification for anionic bitumen road emulsions - SABS
SANS 548: Standard specification for cationic bitumen road emulsions - SABS
SANS 1260: Standard specification for invert bitumen emulsions - SABS
TG1: The use of modified bituminous binders in road construction - The Asphalt Academy
SP-1: Performance graded asphalt binder specification and Testing Superpave Series No 1 - Asphalt Institute.
Manual 8: Guidelines for the safe and responsible handling of bituminous products - Sabita
Manual 25: Quality management in the handling and transport of bituminous binders - Sabita
Manual 26: Interim guidelines for primes and stone precoating fluids - Sabita

Health, safety and the environment guidelines for bitumen and coal tar products - Sabita

The Shell Bitumen Handbook - Fifth Edition - Shell UK Oil Products Ltd.

Hot mix asphalt materials, mixture design and construction - National Centre for Asphalt Technology
Chapter 7: Glossary

**Asphalt** - A mixture of inert mineral matter, such as aggregate, mineral filler and bituminous binder in predetermined proportions.

**Asphalt, continuously-graded** - Asphalt in which the aggregate and filler are distributed in size fractions from coarse to fine within a specified smooth grading envelope.

**Asphalt, gap-graded and semi-gap-graded** - Asphalt from which some intermediate aggregate sizes are omitted or limited to comply with a stepped grading envelope.

**Asphalt Open-Graded** - Asphalt constituted to give a high air void content and open surface texture in the compacted state.

**Asphalt, Recycled** - Asphalt which has been reclaimed from a road and with which (if required) a new binder, new aggregate and recycling additive (e.g. a rejuvenator) have been mixed in predetermined proportions under hot or cold conditions depending on the type of new binder used.

**Asphalt, Stone Mastic (SMA)** - An asphalt in which resistance to permanent deformation is provided by a stone skeleton “under-filled” with a binder rich mastic to provide durability.

**Binder, Bituminous** - Any bitumen material used in road construction to bind together or to seal aggregate or soil particles. The term explicitly excludes coal tar products.

**Binder, Modified** - Bitumen modified by the addition of compounds to enhance performance. Examples of modifiers are polymers, such as natural or synthetic rubbers.

**Bitumen** - A non-crystalline solid or viscous mixture of complex hydrocarbons that possesses characteristic agglomerating properties. Bitumen, which is obtained from crude petroleum by refining processes, softens gradually when heated and is substantially soluble in trichloroethylene.

**Bitumen, Cutback** - 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.

**Bitumen, Penetration Grade** - 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.
Bitumen Emulsion - An emulsion of bitumen and water with the addition of an emulsifier 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.

Bitumen Emulsion, Anionic - An emulsion where the emulsifier is an alkaline organic salt. The bitumen globules carry a negative electrostatic charge.

Bitumen Emulsion, Cationic - An emulsion where the emulsifier is an acidic organic salt. The bitumen globules carry a positive electrostatic charge.

Bitumen Emulsion Treated Base - Modification of sandy, granular or reclaimed pavement layers with bitumen emulsion. If the treated material conforms to specified engineering properties, it is classified as GEMS.

Bitumen Rubber - A blend of bitumen and approximately 20% by weight of crumb rubber, containing where necessary extender oil and/or diluent.

Bituminous Curing Membrane - A coat of bituminous material applied to a newly constructed cemented pavement layer to promote the curing of the layer.

Bituminous Surfacing - A layer consisting of a bituminous binder and aggregate with which traffic makes direct contact.

Bitumen-Treated Base - A base layer consisting of granular material mixed together with a bituminous binder.

Cape Seal - A single application of binder and stone followed by one or two applications of slurry.

Chip Seal - One or more applications of bituminous materials to a pavement surface with a cover of mineral aggregate.

Chip Seal, Single - An application of bituminous binder followed by a layer of stone or clean sand. The stone is sometimes covered with a fog spray.

Chip Seal, Double - An application of binder and stone or sand followed by a second application of binder and stone or sand. A fog spray is sometimes applied on the second layer of aggregate.

Distributor - A vehicle comprising an insulated tank with heating and circulating facilities, a spray bar and a pump capable of applying a thin, uniform and predetermined layer of binder.

Filler - Mineral matter composed of particles smaller than 0.075mm.

Fog Spray - 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.

Hydrocarbon - A chemical compound consisting mainly of hydrogen and carbon.

Overlay - A layer of asphalt applied to an existing surfaced road. This may be to strengthen the pavement or to improve the riding quality or skid resistance.

Polymer - A chemical compound consisting of molecules formed by a large number of repeated units of one or more compounds of low molecular weight.
Polymer-Modified Bitumen - Bitumen with improved physical properties obtained by the addition of a polymer.

Precoating fluid - A cutback bitumen with an adhesion agent which is used to coat aggregate to improve adhesion between the stones and the bitumen.

Premix - A mix of aggregate and bituminous binder. In South Africa, the term "premix" is the colloquial term for hot mix asphalt.

Prime Coat - Coat of suitable bituminous binder applied to a non-bituminous granular pavement layer as a preliminary treatment before the application of a bituminous base or surfacing. While adhesion between this layer and the bituminous base or surfacing may be promoted, the primary function of the prime coat is to assist in sealing the surface voids and bind the aggregate near the surface of the layer.

Reseal - A surface treatment applied to an existing bituminous surface.

Rejuvenator - A material (which may range from a soft bitumen to petroleum or oils) which, when applied to reclaimed asphalt or to existing bituminous surfacing, has the ability to soften aged, hard, brittle binders.

Seal - A term frequently used instead of "reseal" or "surface treatment". Also used in the context of "double seal" and "sand seal" where sand is used instead of stone.

Slurry - A mix of suitably graded fine aggregate, cement or hydrated lime, bitumen emulsion and water, used for filling the voids in the final layer of stone of a new surface treatment or as a maintenance treatment (also referred to as a slurry seal).

Surface Treatment - A general term incorporating chip seals, micro surfacing, fog sprays or tack coats.

Tack Coat - A coat of bituminous binder applied to a primed layer or to an existing bituminous surface as a preliminary treatment to promote adhesion between the existing surface and a subsequently applied bituminous layer, especially asphalt.

Wearing Course - The upper layer of a road pavement on which the traffic runs.
Appendix 1

Viscosity measurement

Dynamic viscosity is the measure of the resistance to flow of a liquid. The ratio between the applied shear stress and the rate of shear is called the coefficient of viscosity, dynamic viscosity, or simply viscosity. The SI unit of dynamic viscosity is the Pascal-second (Pa.s) which is 1N.sec/m², and the cgs unit is the gm/cm.s which is the poise (or more conveniently, centipoise cP), such that at a given temperature:

\[ 1 \text{ Pa.s} = 1 000 \text{ mPa.s} = 10 \text{ poise} = 1 000 \text{cP} \]

Kinematic viscosity \((\nu)\) is the ratio of the dynamic viscosity \((\eta)\) to the density \((\delta)\) of a liquid such that

\[ \nu = \eta / \delta \]

Where:

- \(\nu\) = kinematic viscosity in \(mm^2/s\)
- \(\eta\) = dynamic viscosity in \(Pa.s\)
- \(\delta\) = density in \(kg/l\) at the temperature under consideration.

The SI unit of kinematic viscosity is \(mm^2/s\) and the cgs unit is \(cm^2/s\) which is a Stoke or more conveniently, centiStoke (cSt), such that:

\[ 1 mm^2/s = 0,001cm^2/s = 1 \text{cSt} \]

Since densities of South African penetration grade bitumen vary between 0.970 and 1 040 kg/l at 60°C, a dynamic viscosity of 1 Pa.s would equate to a kinematic viscosity of between 962 and 1 031 mm²/s (at 60°C).

There are also empirical viscosity measures, which measure the time of flow for a measured amount of bitumen through a standard orifice. These measures can be converted to fundamental units using conversion factors.
Appendix 2

Classification of bituminous binders
Sabita members

Ordinary Members

AG Thomas (Pty) Ltd
A J Broom Road Products (Pty) Ltd
Akasia Road Surfacing (Pty) Ltd
Astec – Asphalt Technology
Bitumen Construction Services (Pty) Ltd
Bitumen Supplies & Services cc
Black Top Holdings (Pty) Ltd
BP Southern Africa (Pty) Ltd
Brisk Asphalt Surfacing (Pty) Ltd
Chevron SA (Pty) Ltd
Colas SA (Pty) Ltd
Concor Roads & Earthworks
Engen Petroleum Ltd
Javseal (Pty) Ltd
Milling Techniks (Pty) Ltd
More Asphalt
Much Asphalt (Pty) Ltd
National Asphalt
Nyanga Roads (Pty) Ltd
Phambili Road Surfacing (Pty) Ltd
Polokwane Surfacing (Pty) Ltd
Power Construction (Pty) Ltd
Rand Roads (a division of Grinaker-LTA Ltd)
Roadmac Surfacing (Pty) Ltd
Roadsmart (Pty) Ltd
Sasol Oil (Pty) Ltd
Shell SA Marketing (Pty) Ltd
Spray Pave (Pty) Ltd
Tarfix (Pty) Ltd
Tarspray cc
Tosas (Pty) Ltd
Total SA (Pty) Ltd
Van Wyk Tarmac cc
Zebra Bituminous Surfacing cc
Associate Members

Africon Engineering International (Pty) Ltd
AfriSam SA (Pty) Ltd
Arcus Gibb (Pty) Ltd
Asch Professional Services (Pty) Ltd
BCP Engineers (Pty) Ltd
Beosumbar & Associates
BKS (Pty) Ltd
Cape Peninsula University of Technology
Dick King Lab Supplies (Pty) Ltd
GMH/CPP Consulting Engineers
Goba (Pty) Ltd
HHO Africa
Iliso Consulting (Pty) Ltd
Jeffares & Green (Pty) Ltd
Kantey & Templer (Pty) Ltd
Kaymac (Pty) Ltd t/a Kaytech
Lafarge South Africa Ltd
Lidwala Consulting Engineers (SA) (Pty) Ltd
Ninham Shand (Pty) Ltd
PD Naidoo & Associates (Pty) Ltd
Rankin Engineering Consultants
Sasol Technology Fuels Research
Sasol Wax SA (a div of Sasol Chemical Industries)
Siyenza Engineers cc
Specialised Road Technologies
SSI Engineers & Environmental Consultants (Pty) Ltd
TPA Consulting cc
Tshepega Engineering (Pty) Ltd
Unitrans Fuel & Chemical (Pty) Ltd
Vaal University of Technology
Vela VKE Consulting Engineers (Pty) Ltd
WSP SA Civil & Structural Eng (Pty) Ltd

Affiliate Members

DMV Harrismith (Pty) Ltd
Mdubane Energy Services
MTTC (Pty) Ltd
Salphalt (Pty) Ltd