The publication of the first edition of Technical Guideline Nº 1 (TG1): The use of Modified Bituminous Binders in Road Construction in 2001 was a major step towards achieving a unified approach to the specification and use of modified binders in South Africa. The classification of modified binders into various generic classes which are, to some extent, “polymer blind”, is now firmly entrenched in the industry.

Since the introduction of TG1 in 2001, the modification of bituminous binders has become an increasingly more dynamic field. In addition, new modifiers have been introduced into the road construction sector and are being specified on a more regular basis. As a result, in 2005 the Road Pavement Forum (RPF) reconstituted a task group with a mandate to review the 2001 edition and to revise the document to reflect the improved knowledge obtained in promoting current industry best-practice.

This 2nd Edition (2007) is the culmination of the task group’s efforts. However, notwithstanding advances made internationally and locally with respect to an improved understanding and prediction of the “behaviour” of modified products, the ultimate goal of specifying pure performance-driven properties has not yet been fully realised. As a result, the product property requirements together with their associated limits, as recommended in this document, are still largely empirically based. Nevertheless, the sections covering aspects such as HSE, selection criteria, design influences as well as specific construction constraints have been considerably expanded in order to assist practitioners in optimising their use.

While it is felt that the requirements and/or limitations as recommended in this document should suffice in the majority of applications of these products, it is accepted that specifying agencies with adequate experience may prescribe other limits based on their own specific circumstances, environment and experiences.
ACKNOWLEDGEMENTS

On behalf of the road construction industry represented by the RPF, AsAc wishes to acknowledge, with thanks, the time and effort given by the following members of the Task Group responsible for compiling this important guideline document for the industry:

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Some of the aspects incorporated into the original document were based on guidelines developed by Austroads and the Australian Asphalt Pavement Association (AAPA). Their permission to do so is gratefully acknowledged.
This technical guideline covers the requirements for generic classes of homogenous (thermoplastic polymers) and non-homogenous (bitumen-rubber) modified binders for use in hot mix asphalt, surface seals and crack sealing applications. It includes recommendations related to the appropriate selection criteria, product property requirements, HSE and quality control measures for the procurement and application of modified binders.

Methods for the sampling, preparation and common test procedures of these products have been included as an Appendix to the document. The intention is that these tests will be incorporated into the South African National Standards (SANS) standard test methods for compliance with South African National Accreditation Systems (SANAS) requirements.

It should be noted that aggregate selection, mix design, final product composition and construction limitations are not addressed here. It is recommended that practitioners refer to the relevant manuals/guidelines, or appropriate research, covering these aspects. However, the scope of this document has been extended to include requirements for special applications related to fuel resistance, bond coats, high modulus asphalt and microsurfacing. These were not previously covered under the generic specification framework.

Furthermore a protocol for conducting a field evaluation for introducing new modified binder products is also provided as a guideline.

Similarly, proprietary products offering enhanced performance criteria above that of the generic classes proposed in this document are also not covered. It is expected that they would follow a certification process such as Agrément, which could possibly include the provision of appropriate performance guarantees.
## GLOSSARY OF TERMS

<table>
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<th>Term</th>
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<td>Base bitumen</td>
<td>Penetration grade bitumen of various grades conforming to SABS 307.</td>
</tr>
<tr>
<td>Bitumen-rubber binder</td>
<td>A blend of bitumen and rubber, containing, where necessary, extender oil and/or diluent, blended in such properties as to comply with the prescribed requirements.</td>
</tr>
<tr>
<td>COLTO</td>
<td>Committee of Land Transport Officials</td>
</tr>
<tr>
<td>Diluent/cutter</td>
<td>A petroleum hydrocarbon distillate.</td>
</tr>
<tr>
<td>Elastomer</td>
<td>A thermoplastic polymer which produces mainly elastic properties at in-service temperatures.</td>
</tr>
<tr>
<td>Ethylene Vinyl Acetate (EVA)</td>
<td>An ethylene and vinyl acetate co-polymer.</td>
</tr>
<tr>
<td>Extender Oil</td>
<td>A petroleum-derived material of high aromaticity.</td>
</tr>
<tr>
<td>F-T waxes</td>
<td>High molecular weight waxes derived for the Fischer-Tropsch process.</td>
</tr>
<tr>
<td>Homogenous binder</td>
<td>A blend of polymer and bitumen where two distinct phases cannot be detected.</td>
</tr>
<tr>
<td>Hydrocarbon modifiers</td>
<td>Naturally occurring hydrocarbon products.</td>
</tr>
<tr>
<td>Latex</td>
<td>Natural or synthetic emulsion containing rubber particles.</td>
</tr>
<tr>
<td>Morphology</td>
<td>Chemical structure of a material.</td>
</tr>
<tr>
<td>Non-homogenous binder</td>
<td>A blend of modifier and bitumen where there are two distinct, detectable phases in the final product.</td>
</tr>
<tr>
<td>Plastomer</td>
<td>A thermoplastic polymer where the elastic deformation is accompanied by a component of permanent deformation.</td>
</tr>
<tr>
<td>Rubber crumb</td>
<td>Vulcanised rubber, from recycled pneumatic tyres that has been reduced to small particles by mechanical means.</td>
</tr>
<tr>
<td>Sabita</td>
<td>Southern African Bitumen Association</td>
</tr>
<tr>
<td>SANS</td>
<td>South African National Standards</td>
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<tr>
<td>SANAS</td>
<td>South African National Accreditation System</td>
</tr>
<tr>
<td>SHRP</td>
<td>The Strategic Highway Research Programme of the US Federal Highway Authority.</td>
</tr>
<tr>
<td>Styrene Butadiene Rubber (SBR)</td>
<td>A random co-polymer of styrene and butadiene.</td>
</tr>
<tr>
<td>Styrene Butadiene Styrene (SBS)</td>
<td>A di-block or tri-block copolymer of styrene and butadiene.</td>
</tr>
<tr>
<td>Thermoplastic Polymers</td>
<td>Polymers that liquefy and become malleable. Reversible when heated.</td>
</tr>
<tr>
<td>TRH</td>
<td>Technical Recommendations for Highways: Committee of Land Transport Officials.</td>
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## PROTOCOL FOR INTRODUCING A NEW MODIFIED BINDER

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1 INTRODUCTION

Modified binders have the ability to offer improved performance over conventional binders, but are not a solution or panacea for all situations. Benefits that may be derived from binder modification include:

- Improved consistency;
- Reduced temperature susceptibility;
- Improved stiffness and cohesion;
- Improved flexibility, resilience and toughness;
- Improved binder-aggregate adhesion;
- Improved resistance to in-service ageing.

However, irrespective of the improvement in binder characteristics, the fundamental rules of mix design for hot-mix asphalt or surface dressings (including aggregate quality, mix stiffness/flexibility and workability) should not be ignored.

Modified binders are generally more expensive than conventional binders; hence, their correct application does not lie in the simple substitution of conventional binders, but requires appropriate design of the final product in order to maximise the benefits appropriate to the specific need. Very often performance requirements for routine situations can be met with the use of appropriate conventional binders. There are, however, particular situations where modified binders could offer cost-effective solutions. Typical conditions where such binders should be considered are as follows:

**Surface Seals**

- In areas of high stress such as heavy traffic, steep inclines, intersections (modified tack coat for Cape Seals) and sharp curves;
- In areas experiencing large daily/seasonal temperature fluctuations or high ambient temperatures for long periods;
- As a Stress Absorbing Membrane Interlayer (SAMI);
- For sealing over active cracks of up to 3 mm without pre-treatment (Stress Absorbing Membrane, SAM);
- In slurry seals for heavy duty applications (e.g. rut filling);
- In remote areas where improved durability is required.

**Hot-Mix Asphalt**

- On relatively highly flexible pavements;
- In areas of high stress such as heavy traffic, steep inclines, intersections and sharp curves;
- In asphalt bases which are subjected to high loading under slow moving traffic;
- In areas experiencing large daily/seasonal temperature fluctuations or high ambient temperatures for long periods;
- In areas that are subjected to fuel spillages;
- In open graded mixes requiring a high film thickness;
- In areas where thin layer overlays are required.
Tack Coat
» As a tack coat under very thin asphalt surfacings to reduce the risk of de-lamination.

Crack Sealing
» For cracks wider than 3 mm;
» For highly active cracks.
Technical Guideline: 
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2 OCCUPATIONAL HEALTH, SAFETY AND THE ENVIRONMENT

Hot modified binders are generally applied at higher temperatures than conventional binders to offset the increase in viscosity. The concomitant use of extender oils and additives with higher temperatures tend to produce an increase in the fumes. Hence, extreme care is required to reduce the worker’s exposure to these fumes and it is the responsibility of the binder manufacturers to exclude the use of ingredients which have known adverse effects on workers’ health. Similarly, it is the responsibility of the applicator to ensure that the relevant precautions as set out in the supplier’s Material Safety Data Sheet are followed.

The main hazards and dangers associated with the handling of modified binders are similar to that of conventional binders, namely the risk of workers being burnt when their skin comes into contact with the hot product. To this end the wearing of appropriate Personnel Protective Equipment (PPE) is recommended at all times when handling hot modified binders in order to protect workers against being burnt.

Modified binders are handled below their minimum flash point requirement of 230°C (Pensky-Martens closed cup – ASTM D93) and therefore if handled correctly present a low fire risk. However the risk of a fire or explosion occurring is increased if petroleum cutters are used to reduce the viscosity of the binder for spraying or cleaning operations. For more details on “Guidelines for the safe and responsible handling of bituminous products” refer to Sabita Manual 8.

2.1 Manufacture of modified binders

The blending of modified binders is usually carried out in a factory but may sometimes be carried out on site in a mobile blending plant. It is important that all the workers associated with the blending and handling of modified binders undergo safety training in order to be made aware of the potential hazards and dangers.

2.1.1 Modifiers

The handling of the modifiers used in the manufacture of modified binders requires special attention. The most commonly used modifiers are:

» Rubber crumbs;
» Styrene Butadiene Styrene (SBS) pellets or powder;
» Ethylene Vinyl Acetate (EVA) pellets;
» Styrene Butadiene Rubber latex;
» Natural hydrocarbon modifiers;
» F-T synthetic waxes.

Care must be taken to ensure that the rubber crumbs are dry as the presence of moisture could lead to a boil-over during blending with the hot bitumen. The addition of SBR latex into hot bitumen also requires special blending equipment to eliminate the entrapment of moisture which can result in excessive foaming during the blending process. SBS and EVA polymers are very flammable and must be stored in a location where they will not be exposed to a source of heat or ignition.
2.1.2 Extender oils

Small quantities of extender oils are used in the manufacture of bitumen rubber and some SBS modified binders. Some of these extender oils contain high concentrations of harmful Polycyclic Aromatic Hydrocarbons (PAH’s) and every precaution must be taken to reduce the exposure of workers to fume inhalation and/or skin contact.

2.1.3 Adhesion agents

It is becoming more common for chemical additives to be incorporated into the binder to improve the adhesion characteristics of relatively highly modified binders, or where difficult aggregates are to be utilised. Information on the composition and handling conditions for these agents must be obtained from the suppliers as certain additives could be toxic.

2.2 Spraying operations

The spraying of bitumen rubber or hot polymer modified binders by hand is not recommended as the spray temperature of the product is in the region of 200°C. In the event that small areas need to be sprayed during the application of hot modified binders, then a sprayer which allows individual nozzles to be cut off should be used. Alternatively, the use of low viscosity emulsion (SC-E1) modified binders with binder contents in the range of 65–68% are recommended as the required product application temperature is only 60°C.

If the modified binder has to be cutback due to the onset of cooler weather, then the blending of the cutter should be undertaken in a blending plant. In the event that the latter is not practical, then the cutting back of hot binder in a sprayer on site should only be permitted if a method statement is provided by the binder supplier for undertaking this operation.

No heating of the product should take place during transportation or spraying operations. The heating of the product must only take place:

- In a storage tank, a stationary haulier or sprayer whilst under supervision.
- When the flue pipes are covered by at least 200mm of product and the product is being circulated.

If a load is discharged within an hour, the burners must be switched off and the product circulated for an hour before commencing the spray work.

Heating of uncovered burner flue pipes must be prevented as this will cause self ignition of the vapour space resulting in an explosion.

Drip trays should be used on site for testing spray bars. The sprayed product in the drip tray must be sucked back immediately into the spray tanker for reuse. Any spillages that occur during product transfer or due to leakages and the associated waste products resulting from the cleaning up operations (eg soiled bituminous paper) must be collected and disposed of at a legal waste disposal site. Contact Sabita or visit www.sabita.co.za for a list of waste disposal sites to identify the site closest to the project.
3 COMPOSITION AND CHARACTERISTICS

Bituminous binders behave differently under different temperature and load conditions. At lower temperatures or short duration of loading, the binder tends to be stiff and elastic while at higher temperatures or prolonged loading, there is more flow or plastic behaviour. At intermediate cases of temperature and loading, the binder will act as a combination of the two behaviour conditions. Further details of the viscoelastic characteristics of bitumen can be found in Sabita Manual 2.

Similar to conventional binders, the physical properties of modified binders are largely controlled by the fundamental properties related to temperature, viscosity and phase transition. The purpose of the modifier is to extend the plastic phase and depending on the type, concentration and modifier used, the viscoelastic range will vary. Modified bitumen provides the technology to produce a bituminous binder with improved viscoelastic properties which remain in balance over a wider temperature range and loading conditions.

There are four distinct modes of interaction between bitumen and modifiers:
» The modifier is present as a separate phase within the bitumen.
» The bitumen is present as a separate phase in the modifier and the product will display the properties of the modifier rather than the bitumen.
» The modifier will form an interface with the bitumen giving greater elasticity due to changes in the mechanical structure of the material.
» The modifier will form a molecular bond with the bitumen giving greater elasticity and stiffness to the material.

3.1 Composition of bitumen modifiers

Modified binders have been divided into the following two broad compositional groups:

» Homogenous binders which are defined as a blend of polymer and bitumen where two distinct phases cannot be detected on a microscopic level, or, where the two phases are interwoven to such an extent that the material behaves as a single-phase material from a small, localised viewpoint. Examples of homogenous binders are EVA, SBR and SBS polymer modified binders;
» Non-homogenous binders are where there are two distinct, detectable phases and where there will be localised differences in properties depending at what stage a test is performed. Bitumen-rubber falls into this category as it consists of rubber crumbs partially dissolved in a bitumen matrix.

They can also be considered in two distinct areas; those which are hot applied and those which are cold applied either by emulsifying and/or cutting back.

In terms of hot applied modified binders, polymer modification and rubber modification was until recently the only two types of modification considered. However, in recent times, naturally occurring hydrocarbons (with high asphaltene contents) and long chain, high molecular weight paraffin (polyalkanes) components are also used to introduce other unique features into the rheological behaviour of bituminous binders and will be considered separately in this chapter.
Cold applied products in the form of bitumen emulsion or cutback bitumens are also available for use in the road building industry. Only bitumen emulsions are normally modified to improve the residual bitumen's viscoelastic properties. Cutters are sometimes added to hot binders to reduce their viscosity and improve their ability to wet the stone aggregates during chip and spray applications in cooler weather conditions.

The homogenous polymer modifiers typically used in bitumen modification are thermoplastic polymers such as:

- Styrene-butadiene-styrene (SBS) block copolymers (Elastomeric).
- Synthetic styrene-butadiene-rubber (SBR) latex (Elastomeric).
- Natural rubber latex (Elastomeric).
- Ethylene-vinyl-acetate (EVA) block copolymers (Plastomeric).

The non-homogenous bitumen rubber utilises crumbled rubber from recycled tyres.

For cold applied products, the rheological properties of bitumen in the emulsion can either be modified by the pre-modification of bitumen or by the post-modification of the bitumen emulsion. In South Africa, the post-modification of the bitumen emulsion is the most popular practice. Natural rubber or synthetic rubber latexes such as SBR or SIR (Styrene Isoprene Rubber) can be used to improve the properties of bitumen in the various applications.

Each of the different types of modified bitumens will be discussed separately in order to describe the benefits and sensitivity to use of each of the various modifiers.

NOTE: MODIFICATION OF FOGSPRAY EMULSIONS IS NOT RECOMMENDED. The latex emulsion breaks first, forms a skin and prevents the bitumen emulsion from breaking. This causes the rubber to lie on top of the road surface, where it is picked up by traffic.

### 3.1.1 Homogenous Binders

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

SBS is a block copolymer and can be classified as either linear or radial. A radial blocked copolymer results in much higher viscosities and softening point for the same addition of polymer making it more difficult to mix with bitumen, compared with the linear block copolymers.

SBS can be considered as a thermoplastic rubber and is characterised by its glass transition point (Tg). Coherent cross-linking points provide high stiffnesses below the glass transition point. The process is reversed by melting (> 100°C) the copolymer which causes it to dissociate, become soft and start to flow. On cooling the copolymer, it regains strength and elasticity.

Styrene and butadiene are mutually incompatible and attempt to separate in the modified binder mix. However, as the copolymers are chemically linked, styrene end blocks agglomerate and form three dimensional cross-linked polystyrene domains which give the polymer mechanical properties comparable to cross-linked rubber (vulcanisation). Since the cross-linking is physical rather than chemical, the process is reversible.

At elevated temperatures above the glass transition point of the polystyrene domains, the physical cross-links dissociate. On cooling, the domains reform and the physical cross-links with long continuous elastic networks reform and are restored within the bitumen.
SBS absorbs the maltenes in the bitumen, swells and, at higher dosage levels, forms a continuous molecular network in the bitumen phase which makes up a major fraction of the bitumen by volume. At lower concentrations (3 to 4%) the SBS will only form a fragmented molecular network. At higher concentrations (4 to 6%) a continuous network forms which results in a dramatic increase in the softening point. The molecular networks increase the elastic component of bitumen which assists with recovery after deformation. As the SBS content is increased, the elastic recovery also increases.

The effect that an increase in the amount of SBS polymer on the softening point of a base bitumen with varying asphaltene contents is shown in Figure 1. The rate of increase in the softening point and thus, the shape of the curve, is dependent mainly on the asphaltene content of the base bitumen, the type and grade of the SBS polymer and the percentage thereof. Typically, the curve assumes an S-shape as the SBS structure changes from a fragmented form to a continuous network in the modified binder.

![Figure 1: Typical effect of SBS on the softening point of bitumen with different asphaltene contents](image)

There is a direct correlation between elastic recovery and deformation resistance in that an increase in elastic recovery provides for better deformation resistance. Cohesive strength also increases with the increased elastic recovery. SBS hot modified binders are generally preferred to SBR due to there higher softening points and higher elastic recovery properties, which in turn can be applied at lower temperatures as a result of there lower relative viscosities.

At low temperatures, the addition of SBS improves the flexibility of the bitumen which inhibits cracking and improves the resistance of the binder to crack reflection.

**Styrene-Butadiene-Rubber (SBR)**

SBR latex consists of styrene butadiene polymer which is emulsified with a solids content greater than approximately 50% depending on the grade. The SBR latex is manufactured through the copolymerisation of the hard styrene monomer and the soft butadiene monomer. The butadiene contributes to the elasticity and makes the binder more flexible whereas the styrene gives stiffness and strength to the material.
The use of Modified Bituminous Binders in Road Construction

The mechanical bonding mechanisms and chemistry of SBRs is very similar to that of SBS with the exception that during the co-polymerisation of the butadiene, the poly-butadiene molecules are not blocked by the polystyrene at both ends of the elastomeric butadiene strands. In this case, the polystyrene and poly-butadiene is “intermingled” and therefore, to a large extent, cross-linking points are absent.

SBR latex is used in both hot and cold modified binders. However, the emulsifier type becomes very important when selecting the SBR-latex for the modification of bitumen emulsions. Anionic latex emulsifiers are used with anionic emulsion and similarly, cationic latex emulsions are used with cationic bitumen emulsion grade.

SBR modified binders are predominantly used in cold applied binders for seals, bond coats, crack sealants and microsurfacing. Hot modification of bitumen with SBR is still commonly used for seals and to a lesser extent in asphalt. With the modification of hot bitumen the amount of SBR latex that can be added is limited by:

- the rapid increase in the binders viscosity which is in turn restricted by the spray temperature;
- and
- the evaporation of the water content of the latex when blending with the hot bitumen.

SBR polymers improve adhesion of the binder with the aggregate in sealing applications which results in better chip retention. It also provides improved elasticity and flexibility to the binder, seals cracks and prevents water ingress into the pavement. In hot mix asphalt applications they reduce the deformation resistance, enhance fatigue properties and retard crack reflection.

Natural Rubber

Natural rubber latex consists of polymerised isoprene monomers which increase the elasticity of the bitumen. However, the natural rubber latex is more sensitive to heat and is therefore mainly used in the modification of cold bituminous binders. The addition of latex to emulsion also provides an excellent cold product which can be used for the sealing of small cracks less than 3mm width.

EVA (Ethylene-Vinyl-acetate)

EVA is a polymeric plastomer which consists of two monomers ethylene and vinyl-acetate (VA). The two monomers form long crystalline molecular strings which dissociate when the temperature is increased above the material’s glass transition point.

The morphology of EVA is semi-crystalline and interconnected by polyethylene crystalline molecules and vinyl-acetate molecules which form amorphous chains contributing to the flexibility.

The polyethylene provides the stiffness to the material with cohesion provided by the crystallinity and chain length. The copolymers are polar and together with the maltenes from the bitumen will dictate the compatibility and adhesive properties of the binder. The following main parameters control the properties of EVA:

- **VA content:** The more the VA content increases, the higher the proportion of rubbery regions (ie an increase in flexibility) and the lower the proportion of crystalline regions (ie a decrease in stiffness).
- **Molecular weight:** Standard practice for EVA’s is to measure melt flow index (MFI); the higher the MFI the lower the molecular weight and viscosity.
EVA modified bitumens have the ability to provide improved resistance to rutting in hot-mix asphalt compared to conventional bitumen along with improved compatibility, safer handling and better workability compared to the SBS and SBR modifiers. Some grades of EVA also increase the resistance to damage caused by fuel spillages and pose no problems with future recycling of the material. However, it should be noted that the properties of EVA vary for different grades depending on the chain length and molecular weight of the polymer, the vinyl acetate (VA) monomer content and the crystallinity. In terms of the EVAs the VA content and melt flow rate (MFR) are as important as the Styrene content and linear or radial structure in SBSs, when determining specific properties.

EVA modified bitumen is also more heat stable and does not deteriorate at elevated temperatures during storage as fast as SBR and SBS modified bitumen products. Storage stability will therefore be better than that of SBS and SBR.

3.1.2 Non-Homogenous Binders

Bitumen Rubber

Bitumen rubber products combine rubber crumbs (with a specific, grading, morphology and composition) with bitumen at high temperatures to achieve a complex two phase product which has both the elasticity and stiffness of tyre rubber, and the flow characteristics of bitumen. However, it is important to note that the type of tyre rubber varies depending on the sources and make of the tyre. The natural rubber and synthetic rubber content will also vary depending on the source. The morphology of the rubber particles significantly influences the composition of crumbled rubber after mechanical grinding. Table 1 shows the requirements for rubber crumbs for modified bitumen.

<table>
<thead>
<tr>
<th>Property</th>
<th>Requirement</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sieve analysis (% mass)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passing screen (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.180</td>
<td>100</td>
<td>MB - 14</td>
</tr>
<tr>
<td>0.600</td>
<td>40 - 70</td>
<td></td>
</tr>
<tr>
<td>0.075</td>
<td>0 - 5</td>
<td></td>
</tr>
<tr>
<td><strong>Poly-Isoprene content (%m/m total hydrocarbon)</strong></td>
<td>25 min</td>
<td>Thermo Gravimetric Analysis</td>
</tr>
<tr>
<td>Fibre length (mm)</td>
<td>6 max</td>
<td></td>
</tr>
<tr>
<td><strong>Bulk density (g/cm³)</strong></td>
<td>1.10 – 1.25</td>
<td>MB - 16</td>
</tr>
</tbody>
</table>

The rubber crumbs and bitumen are blended at a temperature in excess of 180°C and involves the absorption of some of the maltene-fraction of bitumen into the rubber. The rubber particles swell with some becoming totally digested by the bitumen, but most are only partially digested and increases the viscosity of the bitumen dramatically.

Digestion of the rubber is a continuous process and occurs at a higher rate at higher temperatures. Should the rubber crumbs become totally digested by the bitumen, the desired properties that the rubber crumbs give to the bitumen will be lost. Hence, special care is required during the manufacture
and application of bitumen rubber. The product will have a shelf-life that varies depending on the manufacturers’ technology, time and temperature at which the product is stored.

When the bitumen rubber blend cools down the course rubber particles form a rubber network which is filled with bitumen and it is the rubber network that contributes to the improved cohesion, elasticity, flexibility, re-healing capabilities and strength of the material. Bitumen rubber has been used successfully in seal and hot-mix asphalt applications due to its improved elasticity and stiffness and can be used as a stress absorbing membrane interlayer (SAMI). The stone retention properties, resistance to bleeding and resistance to deformation are also enhanced.

The typical composition of bitumen rubber is shown in Table 2. However, the ratio of components varies depending on the bitumen source, the climatic conditions and the application. With the addition of extender oil the maltenes in bitumen remains virtually unaffected and improves the fatigue and durability characteristics of the binder. The requirements of the extender oil are such that it should have a flash point of greater than 180°C and the percentage by mass of aromatic unsaturated hydrocarbons be greater than 55.

<table>
<thead>
<tr>
<th>Component</th>
<th>% by mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bitumen – 80/100</td>
<td>72-82</td>
</tr>
<tr>
<td>Extender oil</td>
<td>0-4</td>
</tr>
<tr>
<td>Rubber crumbs</td>
<td>18-24</td>
</tr>
</tbody>
</table>

The rubber crumbs also contain other components that may improve the properties of bitumen. For example, the crumbs contain in excess of 30% carbon black which has been shown to add reinforcing properties to bitumen and antioxidants in the rubber contribute to the durability of bitumen rubber.

### Naturally Occurring Hydrocarbon Modifiers

Naturally occurring hydrocarbon products are mainly used to reduce the temperature susceptibility of asphalt mixes by increasing the softening point, stiffening or hardening the bitumen giving increased viscosity and reduced penetration values.

North American Asphaltum is a natural, resinous hydrocarbon found in Utah, USA, soluble in aromatic and aliphatic solvents and is frequently used to harden petroleum products. The black, shiny, free-flowing, granular substance is brittle and easily crushed into a dark brown powder that is fully compatible with bitumen, has a high asphaltene (71%) and nitrogen (3%) content and essentially sulphur-free (0.3%). It is 99% pure in its natural state, is low in toxicity and is non-carcinogenic.

South American Asphaltums originate from Argentina and are natural bitumens of high purity, composed of hydrocarbons, asphaltenes and aromatics of high molecular weight. Table 3 shows a comparison of the composition between Asphaltums and a typical bitumen.
Table 3: Comparison of the composition of naturally occurring hydrocarbons

<table>
<thead>
<tr>
<th>Component %</th>
<th>Asphaltum Ex North America</th>
<th>Asphaltum Ex South America</th>
<th>Typical Bitumen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphaltenes</td>
<td>71</td>
<td>&gt;80%</td>
<td>8-18</td>
</tr>
<tr>
<td>Resins &amp; Aromatics</td>
<td>27</td>
<td>High molecular weight aromatics</td>
<td>70-90</td>
</tr>
<tr>
<td>Saturates</td>
<td>2</td>
<td></td>
<td>4-10</td>
</tr>
</tbody>
</table>

Asphaltum can provide increased mix stability, helps to reduce rutting and shoving because it increases the load bearing capability, reduces temperature susceptibility of hot-mix asphalt, improved aggregate adhesion and improved resistance to water stripping. It is fully compatible with bitumen allowing for good stability in storage.

3.1.4 High molecular weight waxes

In general, practitioners will not generally consider waxes for use in bitumen. However, there is a very distinct difference between wax derived from a crude source and the high molecular weight waxes from the Fischer-Tropsch (F-T) process which are used as bitumen modifier.

The F-T waxes are long carbon chain alkanes or iso-alkanes which originate from the coal gasification process. The chain lengths of these waxes are between 40 and 100 carbon atoms compared to crude wax with typical carbon numbers between 20 and 40 carbon atoms.

The F-T waxes acts as a flow “improver” and have the ability to reduce the viscosity of the modified bitumen during mixing and compaction of hot-mix asphalt and do not have a negative effect on the bitumen’s characteristics at low temperatures.

At service temperatures below 80°C the F-T waxes increase the softening point and decrease the penetration value, improving the high temperature performance and deformation resistance of hot mix asphalt.

Figure 2 shows the effect of viscosity change of F-T wax modified binder compared to a conventional bitumen over the in-service and application temperatures zones.
The F-T wax modified bitumen has good aggregate adhesion, provides satisfactory stiffness at the higher operating temperatures and resistance to cracking at low operating temperatures. It also has the ability to allow for lower compaction temperatures through the reduced viscosity of the bitumen, yet it produces a bituminous binder that has a much higher stiffness at high service temperatures than conventional bitumen. F-T modified bitumen is also fuel resistant.

The F-T waxes are completely compatible with bitumen and are stable in storage. They can also be used as a co-modifier with polymer modified bitumen to produce hybrid products that could be tailored for specific engineering requirements to improve the long-term performance of asphalt pavements.

### 3.2 Behavioural Characteristics

The main purpose of bituminous products is:

- To act as an organic glue and water proofing agent when combined with naturally occurring inorganic stone and sand.
- To provide appropriate behavioural characteristics to the materials in service that will improve their ability to withstand the environmental conditions to which they may be exposed.

The most important characteristics that will be considered are:

- Rheology
- Elasticity
- Cohesion
- Adhesion
- Ageing and durability
3.2.1 Rheology (flow behaviour)

Rheology is the study of the flow and deformation behaviour of materials. Bituminous binders behave as visco-elastic materials, with their behaviour influenced by the loading time as well as the temperature. At high temperatures or long loading times, binders behave as viscous liquids, and consequently produce large permanent deformation. At low temperatures or short loading times, binders behave as elastic (brittle) solids, with most deformation recovered at the end of the loading period.

The rheology of unmodified binders is relatively simple, and behaviour can be predicted through the use of simple tests such as Penetration, Softening Point and Viscosity at various temperatures. The rheology of modified binders on the other hand is highly complex, and, although the results from conventional tests may indicate a significant improvement in properties, the in-service performance of these binders is not easily categorised. The typical influence of type, as well as amount of modifier on viscosity and softening point properties is shown in Figures 3 and 4, respectively.

Figure 3: The typical effect of various modifiers on bitumen viscosity

Figure 4: The typical effect of various modifiers on bitumen softening point
Selection of polymer type and grade as well as the amount will be dictated largely by the need to satisfy the minimum softening point requirement as well as achieving the specified application viscosity within the recommended maximum temperature limits, to prevent degradation of the product. This certainly is the case with SBR modified binders, as can be seen in Figures 3 and 4, and users must be cautioned that by increasing the amount of polymer to meet the minimum softening point requirement will lead to a concomitant dramatic increase in the viscosity rendering the final product difficult to apply.

Experience has shown that there is a general tendency for the softening point values of polymer modified binders to decrease in storage over time. Where long haul distances, or lengthy delays, are expected, it may be necessary to slightly increase the percentage of modifier added. When assessing the acceptability of this product property (as with any other properties) cognisance should always be taken of the inherent standard deviation applicable to the test method.

Unlike conventional bitumen which displays Newtonian behaviour above its softening point temperature, modified binders tend to display shear thinning behaviour thus rendering dynamic viscosity measurements at normal shear rates of limited usefulness, particularly below application temperatures. Thus the use of the standard protocol of the Brookfield viscosity test at one shear rate to determine asphalt mixing and compaction temperatures for modified binders is not appropriate. Using the viscosity limits commonly used for conventional binders, based on a single shear rate, lead to too high temperatures when compared to field experience and producers’ recommendations. The international tendency is to replace the Brookfield test with the Low Shear Viscosity test to determine temperature viscosity measurements at low shear rates. There is also a concept for using the Dynamic Shear Rheometer to determine dynamic viscosity at a specified shear stress for estimating the mixing and compaction temperatures for modified binders.

In most instances, the addition of a polymer results in the binder having lower moduli at low temperatures, and is therefore more flexible. At high temperatures, however, the binder exhibits an improved stiffness and elasticity when compared to the unmodified bitumen. The most common way of measuring rheological properties was through the use of the Dynamic Shear Rheometer (DSR), which applies a range of shear stresses at various frequencies (loading time) and temperatures. However there are serious doubts about the use of the complex modulus and phase angle for accurate prediction of the effect of modified bitumens on rutting resistance. The failure of these parameters to take into account the asymmetric behaviour of the stiffness during loading and unloading of a modified binder for a variety of loading intensities and temperature conditions has lead to a search for a more reliable test to replace the protocol of modulus and phase angle used in the DSR or to amend the DSR measurement with an elastic recovery test. A creep and recovery procedure called the Multiple Stress. Creep and Recovery (MSCR) has been introduced as an AASHTO standard in early 2007.

3.2.2 Elasticity

Elastic behaviour indicates that the binder recovers most or all of its initial shape when the load that caused the deformation is removed. The elastic recovery of a binder is commonly used to measure the fatigue resistance of a binder or its ability to absorb large stresses without necessarily cracking or deforming. Particular modifiers have unique elastic recovery characteristics depending on the morphology of the modifier/binder system. For example, SBS forms a three-dimensional network of highly elastic, butadiene chains connecting stiff styrene domains, resulting in very high elastic recoveries. SBR has random styrene/butadiene molecules, resulting in relatively lower elastic recovery. EVA forms a rigid three-dimensional network, imparting no elastic recovery properties to the base binder but provides a high stiffness.
The elastic property of a binder is generally influenced by the type of modifier as well as the degree of modification and is determined by measuring the recovery of a sample which has been extended in a low temperature ductilometer. In general, there is a direct relationship between elastic recovery and the degree of modification.

### 3.2.3 Cohesion

Cohesion is a measure of the tensile stress required to break the bond between molecules of the bituminous binder. The inherent strength, tenacity and toughness of the bituminous binders are improved by modification with thermoplastic polymers and rubber crumbs. Hence, a greater force or tensile stress is required to break the molecular bonds of modified binders and cause failure compared with a lower tensile stress required to break the bonds of conventional binders.

A force-ductility test is used to determine the cohesive strength of a modified binder and involves the elongation of a sample with the force measured at very small elongation intervals. Figure 5 shows a graph of the typical profile of various modified binder types obtained during the test.

![Figure 5: Typical force-ductility curves for various modified binders](image)

As shown in Figure 5, the maximum force is reached early in the elongation process. The elastic phase is represented by the area before the initial peak and the total area under the curve can be used to calculate toughness. This is a good indication of the energy required to extend the binder and therefore provides a good estimation of resistance to cracking.

The energy required to elongate elastomeric modified binders is generally significantly more than that for conventional binder. Plastomeric modified binders will impart stiffness to the bituminous binders but not necessarily improve its cohesive nature. Such modified binders may well perform in a brittle manner in tension.

The cohesive properties of modified binders provides guidance to practitioners related to how soon after construction a seal could be opened to traffic as well as providing an assessment of the ability of the binder to withstand shear stresses imparted by heavy traffic.
3.2.4 Adhesion

Adhesion is the measure of the stresses required to break the bonds between the bituminous binder and mineral aggregate. It is largely dependent on the physical chemistry as well as the chemical nature of the bituminous binder and aggregate type when combined for application.

The following factors have an impact on adhesion at the stone/bitumen interface:

» The presence of dust and/or moisture which could reduce adhesion at the bitumen/aggregate interface.

» The level of modification that influences the viscosity of bitumen which in turn affects the wetting ability or time to coat the road stone with bituminous binder. Wetting is an instantaneous process but if the viscosity of modified binder is too high during application, wetting takes longer and poor adhesion can be expected.

» Ambient road and air temperatures and, especially overnight temperatures. Temperature related adhesion failures of surfacing seals are typically associated with two factors:

  • For homogenous modified binders, the higher the level of modification, the higher the risk of adhesion failure due to decreased wetting ability and increased stiffness.
  • At colder temperatures, the higher stiffness of the binder results in a decreased adhesion.

By increasing the film thickness of the binder layer the adhesion is improved. The film thickness of the binder layer can be increased by:

» Reducing the time-lag between the binder application and the stone application in surfacing seals.

» Using pre-coated stone.

» Using emulsion cover (fog) sprays to increase or correct the final binder application rate.

» Pre-blending an adhesive agent with the modified binder prior to spraying.

Temporary reduction of the viscosity by the addition of cutters during colder weather conditions also improves the adhesion properties. However, care should be taken in areas with hot humid climates and/or heavy traffic conditions.

It should also be noted that different types of aggregates exhibit different adhesion behaviour depending on the chemical nature of the parent rock in terms of its hydrophilic (water-attractive) or oleophobic (oil-repelling) nature. Depending on the chemistry of the parent rock, the nature of the aggregate could vary. However, bitumen is oleophilic (oil-attracting) or hydrophobic (water-repelling). Therefore, based on the inherent character of the aggregate it may or may not react (form chemical, charge-related bonds) with water but the presence of water will have a negative influence on the adhesion properties and it will repel the bitumen.

Acidic aggregates are more hydrophilic than basic aggregates. Acidic aggregates will therefore have poor adhesion properties in the presence of water. Cationic spray grade emulsion overcomes this tendency when the free electrons on the aggregate form physical/electrical bonds with the positively charged bitumen and SBR latex droplets as shown if Figure 6.

Similarly and, especially in high risk applications and under difficult construction conditions, surface active chemicals in commercially approved adhesion promoters and pre-coating fluids have been used effectively to improve the adhesion properties. However, if these are used in conjunction with bitumen emulsions in the construction of a surfacing seal, they are known to retard the breaking characteristics of the emulsion.
3.2.5 Ageing and durability

The change in properties of bituminous binders over time is termed ageing and is normally expressed as the difference between the original properties and the derived properties exhibited over time. Typical factors affecting the ageing of bituminous binders are the temperature and time-related conditions which results in a change in the viscoelastic behaviour. In-service ageing describes the hardening (increase in stiffness and reduction of elastic properties) of a binder during its life on the road when exposed to constant traffic and ultra-violet radiation.

Degeneration and adverse changes in the properties of modified binders are also observed when bituminous products are stored at high temperatures. Durability of bituminous binders therefore relates to the ability of a particular binder in a specific application to resist the negative influence of ageing.

Temperature susceptibility

This is characterised by the variation in consistency (stability) of the bitumen related to temperature and is governed by the softening point at high temperatures and the fragility point at lower temperatures. The window between the two extremes is called the service temperature of the bitumen with the two extremes being dependent on the crude source and bitumen grade. Should the binder be exposed to temperatures above the softening point bleeding/rutting could occur and below the fragility point, cracking may be observed (see Figure 7).
By adding polymers to bitumen the in-service temperature range is widened. The increased stiffness compared to conventional bitumen enhances the performance characteristics of the modified bitumen and provides better protection against increased traffic loads and adverse climate conditions. In addition, thinner asphalt layers could be considered during design and construction/rehabilitation to reduce the cost of the pavement.

Bitumen rubber, SBS and SBR materials are generally sensitive to oxidation and thermal degradation. It is therefore important to carefully monitor temperature during all stages from production, storage, mixing and the laying of these modified materials.

Compatibility and stability
Chemical compatibility relates to a stable homogenous blend which is important during handling and storage. The polymers must be chemically stable at the standard bitumen processing temperatures.

The definition of compatibility is the ability of a polymer to remain distributed in the bitumen without phase separation occurring. However, the degree of compatibility varies by bitumen and by type and grade of polymer used in the formulation of the polymer modified product. Compatibility also varies with concentration of the polymer and the higher the concentration of the polymer, the lower the degree of compatibility. Should total incompatibility occur, this could result in segregation and even gelling.

In the modified bitumen there is competition between the modifier (rubber crumbs, SBS or SBR) and the naturally occurring asphaltenes for the available maltene portion (resins and aromatics) of the bitumen. This competition varies with the type and source of both the bitumen and the polymer and this will affect the compatibility of the final product. Therefore any changes in the crude type and refining process used during the manufacture of the base bitumen could affect the compatibility of the polymer bitumen system.
The stability or homogeneity test as described in MB-6 is used to determine the hot storage stability of a material which, in effect, is an indication of compatibility. The use of mechanical stirring will prevent the segregation of the different components during storage. As a guide to manufacturers, the stability test should be used as an indicator of whether stirring is required or not. The tests should be conducted to determine the suitability of the base bitumen with the polymer. Whenever there is any reason to believe that the chemistry of the base bitumen has changed, the test should also be conducted.

### 3.3 Use of cutters

As discussed in the previous sections, modification of bitumen with polymers or rubber crumbs tends to increase the binder’s cohesion and render them more viscous at the expense of reducing the binder’s ability to ‘wet’ the aggregate, resulting in the possible reduction of adhesion between the binder and stone. The reduction in adhesion could become critical when constructing a seal during cooler weather conditions. It is not uncommon for some modified binder seals to perform adequately in warm and dry conditions but lose a considerable portion of aggregate during the first cold wet weather if appropriate work practices are not adhered to.

Polymer modified binders are normally produced with 80/100 penetration grade bitumen. During lower temperature conditions it is necessary to soften the binder by utilizing an appropriate hydrocarbon cutter, such as illuminating paraffin, to prevent stone loss by improving the adhesion properties of the binder and promoting the early formation of a stable mosaic of aggregate.

It is also possible to manufacture the binder with 150/200 penetration grade bitumen, but this grade is unfortunately not always available from the refineries and it may also, to some degree, negate the improved in-service performance properties required of the binder. For light traffic conditions the modified binders can be softened with up to 5% cutter by volume of binder, but for heavier traffic conditions it is recommended that not more than 3% cutter be added.

From a safety perspective, the practice of cutting back hot binders is a hazardous operation as the blending temperature of the binder is well in excess of the cutters flash point. Ideally, this operation should only be undertaken under controlled conditions such as in a blending plant. However, if the blending of the cutter has to be undertaken on site in a sprayer, then the binder supplier must produce a written method statement of his blending procedures for cutting back modified bitumen.

It should also be noted that there is always the real risk that the use of a cutter can lead to bleeding of the newly constructed seal with the onset of warmer weather conditions under heavy traffic. Thus special care must be taken of all the factors that could affect the performance of the new seal if the modified binder is cutback.

#### 3.3.1 Factors affecting the cutting back of modified binders

The following factors will influence whether it is necessary to cut back binder and provides guidance on the appropriate quantity of cutter to use.

**Road surface temperature**

The road surface temperature at time of spraying and the projected temperature for the next 24 hours is a critical factor with respect to risk of early stone loss. If the traffic spectrum dictates that the use of cutters would be inappropriate then no spraying of hot modified binders should be done if:
The expected maximum road temperature does not exceed 30°C for several hours during the application period. Sealing should only commence when the road surface temperature reaches 25°C and continues to rise above 30°C; or

The expected minimum air temperature in the following 48 hours is expected to drop below 10°C. To this end the weather forecast for the ensuing week should be obtained to ensure that the minimum temperatures are not expected to fall below this value.

**Shady areas**
Where the road will be in shade during the day it is likely that the maximum road temperature in the shaded area would be below 25°C. In such locations cutting back should be considered provided that the areas are large enough. However, these areas are often isolated in comparison to the overall project e.g. areas under bridge decks and thus the following options are recommended in place of cutting back:

- Increase the binder application rate by up to 20% for large areas. Otherwise, split the binder application by reducing the application rate of the tack spray and spraying a diluted emulsion as a cover spray.
- Start the application in the shaded areas and ensure that the distance between the sprayer and chip spreader is kept to a minimum.
- Where a significant length of the project is expected to be in shade, consider using an emulsion for the project and covering the seal with no-fines grit after the emulsion has broken and keep the shaded areas of the road closed to traffic for 48 hours. Care must be taken when using modified emulsions in cooler locations because the latex in the emulsion forms a skin which inhibits the breaking process.

**Time of the year**
Cutting back of binders should not take place later than the beginning of September because it can take up to 3 months for the volatile fractions of the cutters to evaporate from the layer. The amount of cutter used should also be tapered off with the onset of warmer weather as spring approaches. As some areas in South Africa experience night temperatures below 10°C in March it is recommended that the minimum temperatures from the closest weather station for the preceding 10 year period be obtained prior to making any decisions as to whether to cutback or not.

**Type of surfacing**
The type of surfacing will also influence whether or not a cutter can be used. Cutters should not be used in the spray applications for:

- Cape seals, tack sprays for double seals, geofabric seals and SAMIs as they will be covered by a slurry, binder or asphalt which would lead to the entrapment of the volatiles.
- Seals to be placed over fresh asphalt or slurry surfaces (excluding texture slurries of less than 2mm) as it could lead to premature embedment of the new seal. A ball penetration test should be done to determine the hardness of a new asphalt or slurry surface before resealing with a cutback modified binder.

Spray grades of modified emulsions usually contain 2 - 4% m/m of cutter (flux), which is varied seasonally to enhance the breaking and adhesion characteristics. The presence of cutter in the emulsion may cause bleeding in cape seals carrying very heavy traffic as well as instability in geofabric seals during warmer weather.

**Expected traffic volume**
The expected traffic volume, especially the number, type and load of heavy trucks and the speed at which they will travel on the seal is a critical factor in determining whether to cut back or not. Modified
binders that have been cut back tend to bleed where there is a high volume of heavy vehicles travelling at speeds below 40 km/h.

As a general guide, the use of cutters should be restricted to roads carrying less than 5 000 elv/day and the amount of heavies should be less than 15% of the traffic volume. Furthermore their use in high stress areas like climbing lanes and busy intersections should be avoided. The application of modified binders incorporating a cutter on residential streets during cooler temperatures as experienced in the winter months generally presents a low risk for bleeding.

Modified binder seals incorporating up to 3% cutter have been successfully applied on roads carrying relatively high traffic. A reduction in the amount of cutter which would normally be added, as well as a possible reduction in binder application rate, must be made to accommodate the effects of heavier and higher traffic volumes over and above 5 000 elv/day.

**Amount of cutter**
In the absence of a proven test method to determine the equivalent low temperature adhesion properties of modified binders with cutters, it is recommended that reference is made to the binder supplier for guidelines on the amount and type of cutter to be used for the respective modified binder in accordance with the expected road temperature.

**Construction constraints**
The cutting back of modified binders does not negate the need to follow good construction practices. Specific constraints based on local experience are given in Chapter 8: Construction
MANUFACTURE

The processes being used to manufacture polymer modified bitumens are proprietary and different processes are used by the various suppliers. Some aspects are, however, common to all manufacturers and the basic requirements for a blending plant for homogenous polymer modified bitumen are:

- Mixing vessels should ideally be heated with hot oil coils, instead of direct flame heating, to minimize the degradation of the polymer at the factory. Once on site, flame heating is the norm.
- The heating mechanism should be capable of raising the temperature of the contents of the tank from 5 to 10°C per hour.
- The manufacturing vessels should be fitted with:
  - Calibrated thermometers and temperature controllers;
  - A mixing system which is capable of effectively mixing the polymer into the bitumen;
  - A mechanism for feeding the polymer into the bitumen;
  - A calibrated dipstick.

A general overview of the manufacture of the various types of polymer modified binders is given below:

4.1 Homogenous binders

4.1.1 SBR modified bitumen

This type of binder is produced by adding SBR latex, containing approximately 35% water, to hot penetration grade bitumen and, being a liquid, the latex is usually pumped into the hot bitumen. During the addition of the latex, the water component is converted to steam with concomitant frothing and an increase in the volume of the binder. The addition rate of the latex is usually carefully controlled to prevent boil-over in the manufacturing vessel. Plants used for the manufacture of the SBR modified binder should be designed in such a way to enable the steam component to escape from the manufacturing vessel to avoid entrapment of the moisture in the binder.

The residual SBR component is dissolved in the bitumen by agitation and pump circulation. The agitation/circulation time and manufacturing temperature required is a function of the polymer/bitumen compatibility, with extended mixing times and higher mixing temperatures being required for less compatible bitumens.

If the heated, manufactured product has to be stored in the manufacturing vessel for any reason, it is advisable to agitate/circulate the final product during storage, to prevent possible polymer segregation.

It is important that the water is completely expelled in the manufacturing vessel before discharge. Residual water can cause further foaming during heating in binder distributors and hauler tanks, with the possibility of boil-over.

4.1.2 SBS modified bitumen

SBS polymers are available in pellet, in crumb or powder form. If pellet or crumb polymer is used, the manufacturing plant should be fitted with a high speed shearing device that will reduce the polymer
particles suspended in bitumen, to a size suitable for easy solubility in the binder. The powdered grade is already of the correct particle size and can be incorporated into the binder by simple agitation at the required temperature. The manufacturing temperature and time required for dissolving of the polymer is lower than that required for SBR modified bitumen. Polymer degradation is thus considerably slower.

The addition of the polymer to the manufacturing vessel should be carefully controlled. If the addition rate is too high, polymer conglomerates could form on the surface, resulting in lumps, which could be problematic during application of the binder.

Similar to SBR modified bitumen, it is advisable to have some means of circulation in the vessel to prevent possible polymer segregation during storage of the heated binder.

4.1.3 EVA

EVA polymer is incorporated into the bitumen by adding the polymer pellets while stirring or circulating the contents of the mixing vessel. The polymer melts into the bitumen and a short period is required for the polymer to completely dissolve in the bitumen. As with SBR and SBS modified bitumen, the compatibility of EVA with the base bitumen should be assessed.

4.1.4 Hydrocarbon modified binders and high molecular weight waxes

Hydrocarbon modifiers and high molecular weight waxes can be added to the heated bitumen while stirring or circulating the contents of the mixing vessel. Similar to EVA, the hydrocarbon modifier dissolves in the bitumen after a short mixing period. No compatibility problems have been detected in with modification of locally produced bitumens.

4.1.5 General

The quantity of polymer required is derived from either the mass of binder placed in the mixing vessel or volumetrically, using the necessary temperature correction factors to determine the mass of the binder. The quantity of polymer required should be weighed off accurately or the number of bags or drums of polymer required should be established.

The final product should be inspected visually to confirm that the polymer has been completely dissolved. The product can also be examined microscopically to assess the degree of solution of the polymer. A Ring and Ball softening point test will also confirm that the correct quantity of polymer has been added and that the polymer has been completely dissolved.

Should small quantities of modified binders be required for carrying out emergency work, SBR latex or natural occurring hydrocarbon modifiers can be added directly into the pugmill during mixing of hot asphalt.

4.2 Non-homogenous polymer modified binder

Bitumen-rubber is manufactured by adding graded crumbed rubber, obtained from grinding vehicle tyres, to hot bitumen which contains a quantity of heavy extender oil. Following the addition of the rubber, a digestion period is required for the rubber to swell and partially dissolve in the bitumen/extender oil blend. The rubber never completely dissolves in the bitumen and the product is thus classed as a non-homogenous binder.
Special manufacturing equipment is required to manufacture this highly viscous material. The product has a limited useable life of 4 to 6 hours and therefore, manufacture usually takes place on-site or very close to the construction site.

Bitumen rubber binder can be used for surface dressing operations, in which case it is applied with binder distributors specially designed to handle this highly viscous binder. For surface dressing applications, the bitumen-rubber binder is manufactured using the “wet method”. Two processes can be employed for the manufacture of bitumen-rubber hot-mix asphalt, the wet method and the dry method with the wet method being used in the majority of cases.

4.2.1 The Wet Method

A typical bitumen-rubber blending unit (Figure 8) consists of:

» a tank for super-heating the bitumen;
» a blending unit;
» a suitable rubber feeding mechanism;
» transfer pumps;
» a digestion tank equipped with an agitators and a super-heater.

The extender oil could either be added to the penetration grade bitumen before delivery or to the bitumen on site. The bitumen is pumped into the small blending tank at a temperature of not more than 220°C for short periods before the introduction of rubber; where the rubber is added in proportion to the bitumen flow rate. The blending unit consists of a small tank equipped with a high speed stirring device that ensures proper “wetting” of the rubber by the binder and prevents the formation of rubber lumps in the final product. During the addition of the rubber component, the blend cools down considerably and has to be re-heated to a temperature of 190 to 200°C to ensure proper digestion of the rubber in the bitumen. From the blending tank the product is transferred to a digestion tank which could also be a specialised binder distributor. In the digestion tank the product is continually agitated while being heated to the final temperature.

On completion of the digestion period, a hand-held Haake viscometer is used to perform a viscosity test on the product to confirm that sufficient digestion has taken place. If approved, the product is ready for application.
4.2.2 The Dry Method

The dry method is only used with a hot-mix plant using a batch mixer and not with a drum or continuous type mixer. The plant must also be fitted with the necessary equipment to feed accurate quantities of crumbled rubber directly into the pugmill. The temperature of the aggregate in the pugmill should be within the range 90 – 210ºC. The correct quantity of crumbled rubber is added to the hot aggregate in the pugmill and mixed for 5-7 seconds, following which, the bitumen is added.

Sufficient mixing time should be allowed to ensure acceptable distribution of the bitumen throughout the aggregate/rubber blend. The bitumen temperature should be 145–165ºC and the asphalt leaving the pugmill should be at a temperature ranging from 190–210ºC. The mix is then transferred to the hot-storage bins where it is left for at least an hour to allow for the digestion of the rubber by the bitumen. The asphalt is drawn from the bins and transported to site as required.

Practitioners tend to be sceptical of the dry blend method, because of the inability to determine the properties of the bitumen-rubber binder in the mix. The use of this method is generally only justified if small quantities of bitumen-rubber asphalt are required for emergency repairs. The wet blend method usually involves substantial establishment costs of the blending unit, which are only justified for larger demands.
5 MODIFIED BINDER CLASSIFICATION

The intention is to provide a binder classification system that does not dictate the type and quantity of polymer to be used but rather focuses on the end property performance requirements of the binder. To this end a generic system has been developed for classifying modified binders according to four main criteria based on application type and temperature, polymer used and a numerical value. To this end the following codes are used to designate the different classes of modified binders:

- The type of application in which they are intended to be used
  - Seal (S),
  - Asphalt (A)
  - Crack sealant (C)

- The type of binder system
  - Emulsion (colder applied) - If the product is an emulsion then the letter C would follow directly after the letter indicating the type of application.
  - Hot applied – No letter is used after the letter indicating the type of application.

- The predominant type of modifier used
  - Elastomer (E) eg A-E1
  - Plastomer (P) eg A-P1
  - Rubber (R) eg A-R1
  - Hydrocarbon (H) eg A-H1

- The level of modification
  The higher the numerical number the higher the softening point value but this does no necessarily imply improved overall performance properties. The intention is that higher order modified binders should be able to be included in the classification framework in future should the need arise by increasing the numerical value.

The following additional code can also be used for classification purposes to indicate whether or not the use of a fluxing agent or cutter is permitted:

- Should the binder application not permit the use of flux or cutter the letter "t" should be shown in brackets after the classification.

For example a classification of SC-E2(t) indicates that the binder is:

S - intended to be used for a surfacing chip seal
C - it is an emulsion
E - the main modifier is an elastomer
2 - it has a higher softening point than an SC-E1
(t) - the use of a fluxing agent or cutter is prohibited

Table 4 summarises the different classes of generic modified binders according to their end application.
### Table 4: Modified Binder Classification System

<table>
<thead>
<tr>
<th>Modified Binder Class</th>
<th>Application – Surface Seal</th>
</tr>
</thead>
<tbody>
<tr>
<td>S – E1</td>
<td>Surface seal – hot applied elastomer modified</td>
</tr>
<tr>
<td>S – E2</td>
<td>Surface seal – hot applied elastomer modified</td>
</tr>
<tr>
<td>S – R1</td>
<td>Surface seal – hot applied bitumen rubber</td>
</tr>
<tr>
<td>SC – E1</td>
<td>Surface seal – emulsion elastomer modified</td>
</tr>
<tr>
<td>SC – E2</td>
<td>Surface seal – emulsion elastomer modified</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Modified Binder Class</th>
<th>Application – Premixed Asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td>A – E1</td>
<td>Hot mix asphalt – elastomer modified</td>
</tr>
<tr>
<td>A – E2</td>
<td>Hot mix asphalt – elastomer modified</td>
</tr>
<tr>
<td>A – P1</td>
<td>Hot mix asphalt – plastomer modified</td>
</tr>
<tr>
<td>A – H1</td>
<td>Hot mix asphalt – hydrocarbon modified</td>
</tr>
<tr>
<td>A – H2</td>
<td>Hot mix asphalt – hydrocarbon modified</td>
</tr>
<tr>
<td>A – R1</td>
<td>Hot mix asphalt – bitumen rubber</td>
</tr>
<tr>
<td>AC – E1</td>
<td>Microsurfacing – emulsion elastomer modified</td>
</tr>
<tr>
<td>AC – E2</td>
<td>Microsurfacing – emulsion elastomer modified</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Modified Binder Class</th>
<th>Application – Crack Sealant</th>
</tr>
</thead>
<tbody>
<tr>
<td>C – E1</td>
<td>Crack sealant – hot applied elastomer modified</td>
</tr>
<tr>
<td>CC – E1</td>
<td>Crack sealant – emulsion elastomer modified</td>
</tr>
<tr>
<td>C – R1</td>
<td>Crack sealant – hot applied bitumen rubber</td>
</tr>
</tbody>
</table>

**Notes**

1. These emulsions have the option of being made with or without cutters depending on their application.
2. Some of the modifiers in these generic classification classes are also capable of imparting fuel resistant properties.

More details pertaining to the selection and properties of these modified binders and their specialist application are covered in Chapter 7.
6 PRODUCT REQUIREMENTS

In developing the product requirements for each generic class of binder an attempt has been made to use, where possible, the same testing regime and change the performance requirements accordingly. However, this is not the case for polymer modified binders compared to bitumen rubber due to the varying nature of their composition and behaviour.

The tests prescribed in the specification framework have been selected to ensure that:

» The consistency properties of the binders are controlled at the various in-service temperatures’ performance zones:
  • Low temperature to limit fatigue cracking (Elastic recovery @ 15°C)
  • Elevated temperature to limit rutting and bleeding (Ring & Ball softening point)

Modified binders used in road surfacings can be expected to perform in various climatic and traffic conditions. The specification framework has been based on a wide range of softening point values to accommodate South Africa’s typically hot climate.

» The binder is pumpable (Viscosity @ 165°C), safe (Flash point) and stable (Stability @160°C) during normal handling and storage conditions.

» The performance is within acceptable limits after ageing when subjected to the rolling thin film oven test (RTFOT).

The test limits prescribed are empirically based from observed performance in the field over several years and reflect current production trends in South Africa. While the ultimate goal rests in performance related specifications, the industry is currently not in a position to prescribe tests and concomitant limits which would render this possible. However for a given project, where the situation dictates, it may be necessary to perform additional tests to rank the properties of the various binders in order to reduce the risk factor. Some tests are included in the specifications for this purpose but no limits are given and the values should be recorded for reporting purposes only as they may be used in future specifications. Force ductility is such a test which provides a measure of the binder cohesion properties at low in-service temperatures (5°C) in the absence of a reliable low temperature binder/aggregate adhesion test.

The properties for the various modified binders and their respective applications are given in Tables 5 to 10.
Table 5: Properties of hot applied polymer modified binders for surfacing seals

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Test Method</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Before ageing</strong></td>
<td></td>
<td></td>
<td>S-E1</td>
</tr>
<tr>
<td>Softening Point¹</td>
<td>°C</td>
<td>MB-17</td>
<td>50–60</td>
</tr>
<tr>
<td>Elastic recovery @ 15°C</td>
<td>%</td>
<td>MB-4</td>
<td>&gt; 50</td>
</tr>
<tr>
<td>Force ductility @ 5°C</td>
<td>N</td>
<td>EN 13703</td>
<td>report²</td>
</tr>
<tr>
<td>Dynamic Viscosity @ 165°C</td>
<td>Pa.s</td>
<td>MB–18</td>
<td>≤ 0.55</td>
</tr>
<tr>
<td>Stability @ 160°C</td>
<td>°C</td>
<td>MB-6</td>
<td>≤ 5</td>
</tr>
<tr>
<td>Flash Point</td>
<td>°C</td>
<td>ASTM D93</td>
<td>≥ 230</td>
</tr>
<tr>
<td><strong>After ageing (RTFOT)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass change</td>
<td>%</td>
<td>MB-3</td>
<td>≤ 1.0</td>
</tr>
<tr>
<td>Difference in Softening Point</td>
<td>°C</td>
<td>MB–17</td>
<td>-2 to +8</td>
</tr>
<tr>
<td>Elastic recovery @ 15°C</td>
<td>%</td>
<td>MB-4</td>
<td>&gt; 40</td>
</tr>
</tbody>
</table>

**Notes**

1. The prescribed test method is based on not using stirrers although it has been reported that the use of stirrers has shown no difference in test results. For refereeing purposes no stirrers should be used.
2. No values provided but the test can be used to rank various binders according to their low temperature cohesion properties.
3. The softening point values obtained for bitumen modified with SBS will tend to fluctuate over time and on reheating.
### Table 6: Properties of polymer modified emulsions for surfacing seals

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Test Method</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>SC-E1</td>
</tr>
<tr>
<td><strong>Binder content (m/m)</strong></td>
<td>%</td>
<td>MB–22</td>
<td>65-68</td>
</tr>
<tr>
<td><strong>Saybolt Furol viscosity @ 50°C</strong></td>
<td>Sec</td>
<td>MB–21</td>
<td>51-200</td>
</tr>
<tr>
<td>Residue on sieving¹ (/100 ml)</td>
<td>g</td>
<td>MB-23</td>
<td>≤ 0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>≤ 0.5</td>
</tr>
<tr>
<td><strong>Particle charge</strong></td>
<td></td>
<td>MB–24</td>
<td>positive</td>
</tr>
<tr>
<td><strong>Sedimentation after 60 rotations</strong></td>
<td>°C</td>
<td>SANS 309</td>
<td>nil</td>
</tr>
<tr>
<td><strong>Recovered binder residue</strong></td>
<td></td>
<td>MB-20³</td>
<td></td>
</tr>
<tr>
<td><strong>Softening point²</strong></td>
<td>°C</td>
<td>MB–17</td>
<td>≥ 48</td>
</tr>
<tr>
<td><strong>Elastic recovery @ 15°C</strong></td>
<td>%</td>
<td>MB-4</td>
<td>≥ 50</td>
</tr>
<tr>
<td><strong>Force ductility @ 5°C</strong></td>
<td>N</td>
<td>EN 13703</td>
<td>report³</td>
</tr>
</tbody>
</table>

### Notes

1. Either the rotary vacuum or the simple evaporation method can be used. For on site testing the simple method is more practical and is thus recommended. The simple method retains a very small portion of the fluxing oils whereas these are removed in the rotary vacuum method. The latter method renders a better indication of the binder properties after in-service curing.
2. The prescribed test method is based on not using stirrers although it has been reported that the use of stirrers has shown no difference in test results. For refereeing purposes no stirrers should be used.
3. No values given but the test can be used to rank various binders according to their low temperature cohesion properties.
4. Pour the emulsion through the larger sieve to remove the skin and larger particles before passing the emulsion through the finer sieve.
### Table 7: Properties of polymer modified binders for hot mix asphalt

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Test Method</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Before ageing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Softening point¹</td>
<td>°C</td>
<td>MB-17</td>
<td>55-65</td>
</tr>
<tr>
<td>Elastic recovery @ 15°C</td>
<td>%</td>
<td>MB-4</td>
<td>&gt; 50</td>
</tr>
<tr>
<td>Force ductility @ 5°C</td>
<td>N</td>
<td>EN 13703</td>
<td>report³</td>
</tr>
<tr>
<td>Dynamic viscosity @ 165°C</td>
<td>Pa.s</td>
<td>MB-18</td>
<td>≤ 0.6</td>
</tr>
<tr>
<td>Storage stability @ 160°C</td>
<td>°C</td>
<td>MB-6</td>
<td>≤ 5</td>
</tr>
<tr>
<td>Flash point</td>
<td>°C</td>
<td>ASTM D93</td>
<td>≥ 230</td>
</tr>
<tr>
<td><strong>After ageing (RTFOT)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass change</td>
<td>%</td>
<td>MB-3</td>
<td>≤ 1.0</td>
</tr>
<tr>
<td>Difference in Softening point</td>
<td>°C</td>
<td>MB-17</td>
<td>-2 to +8</td>
</tr>
<tr>
<td>Elastic recovery @ 15°C</td>
<td>%</td>
<td>MB-4</td>
<td>&gt; 40</td>
</tr>
<tr>
<td>Dynamic viscosity @ 165°C</td>
<td>Pa.s</td>
<td>MB-18</td>
<td>report²</td>
</tr>
</tbody>
</table>

### Notes

1. The prescribed test method is based on not using stirrers although it has been reported that the use of stirrers has shown no difference in test results. For refereeing purposes no stirrers should be used.
2. No limits are given and the values should be recorded for reporting purposes only as they may be used in future specifications.
3. No values given but the test can be used to rank various binders according to their low temperature cohesion properties.
Table 8: Properties of bitumen rubber for surfacing seals and asphalt

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Test Method</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>S-R1</td>
</tr>
<tr>
<td>Softening point(^1)</td>
<td>°C</td>
<td>MB-17</td>
<td>55–62</td>
</tr>
<tr>
<td>Dynamic viscosity @ 190°C</td>
<td>dPa.s</td>
<td>MB-13</td>
<td>20–40</td>
</tr>
<tr>
<td>Compression recovery 5 minutes</td>
<td>%</td>
<td>MB-11</td>
<td>&gt;70</td>
</tr>
<tr>
<td>Compression recovery 1 hour</td>
<td>%</td>
<td>MB-11</td>
<td>&gt;70</td>
</tr>
<tr>
<td>Compression recovery 4 days</td>
<td>%</td>
<td>MB-11</td>
<td>&gt;25</td>
</tr>
<tr>
<td>Resilience @ 25°C</td>
<td>%</td>
<td>MB-10</td>
<td>13–35</td>
</tr>
<tr>
<td>Flow</td>
<td>Mm</td>
<td>MB-12</td>
<td>15–70</td>
</tr>
</tbody>
</table>

Notes
1. The prescribed test method is based on not using stirrers although it has been reported that the use of stirrers has shown no difference in test results. For refereeing purposes no stirrers should be used.
Table 9: Properties of hydrocarbon modified binders for hot mix asphalt

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Test Method</th>
<th>Class</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Before ageing</strong></td>
<td></td>
<td></td>
<td>A-H1</td>
<td>A-H2</td>
</tr>
<tr>
<td>Softening point¹</td>
<td>°C</td>
<td>MB-17</td>
<td>55-70</td>
<td>70-90</td>
</tr>
<tr>
<td>Penetration @ 25°C</td>
<td>dmm</td>
<td>ASTM D5</td>
<td>20-35</td>
<td>report²</td>
</tr>
<tr>
<td>Force ductility @ 5°C</td>
<td>N</td>
<td>EN 13703</td>
<td>report³</td>
<td>report³</td>
</tr>
<tr>
<td>Dynamic viscosity @ 165°C</td>
<td>Pa.s</td>
<td>MB–18</td>
<td>≤ 0.80</td>
<td>≤ 0.30</td>
</tr>
<tr>
<td>Storage stability @ 160°C</td>
<td>°C</td>
<td>MB-6</td>
<td>≤ 5</td>
<td>≤ 5</td>
</tr>
<tr>
<td>Flash point</td>
<td>°C</td>
<td>ASTM D93</td>
<td>≥ 230</td>
<td>≥ 230</td>
</tr>
<tr>
<td><strong>After ageing (RTFOT)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass change</td>
<td>%</td>
<td>MB-3</td>
<td>≤ 1.0</td>
<td>≤ 1.0</td>
</tr>
<tr>
<td>Difference in Softening point</td>
<td>°C</td>
<td>MB–17</td>
<td>-2 to +8</td>
<td>-2 to +8</td>
</tr>
<tr>
<td>Retained penetration (% of original)</td>
<td>%</td>
<td>ASTM D5</td>
<td>&gt; 60</td>
<td>report²</td>
</tr>
<tr>
<td>Dynamic viscosity @ 165°C</td>
<td>%</td>
<td>MB–18</td>
<td>report²</td>
<td>report²</td>
</tr>
</tbody>
</table>

**Notes**

1. The prescribed test method is based on not using stirrers although it has been reported that the use of stirrers has shown no difference in test results. For refereeing purposes no stirrers should be used.
2. No limits are given and the values should be recorded for reporting purposes only as they may be used in future specifications.
3. No values given but the test can be used to rank various binders according to their low temperature cohesion properties.
### Table 10: Properties of modified binder crack sealants

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Test Method</th>
<th>Class</th>
<th>C-E1</th>
<th>CC-E1</th>
<th>C-R1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Softening point¹</td>
<td>°C</td>
<td>MB-17</td>
<td>≥80</td>
<td>≥80²</td>
<td>55 – 65</td>
<td></td>
</tr>
<tr>
<td>Elastic recovery @ 15°C</td>
<td>%</td>
<td>MB-4</td>
<td>≥80</td>
<td>≥60²</td>
<td>report³</td>
<td></td>
</tr>
<tr>
<td>Dynamic viscosity @ 190°C</td>
<td>dPa.s</td>
<td>MB-13</td>
<td>-</td>
<td>-</td>
<td>20–40</td>
<td></td>
</tr>
<tr>
<td>Dynamic viscosity @ 165°C</td>
<td>Pa.s</td>
<td>MB-18</td>
<td>≤0.65</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Dynamic viscosity @ 25°C</td>
<td>Pa.s</td>
<td>MB-18</td>
<td>-</td>
<td>≤0.8</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Resilience @ 25°C</td>
<td>%</td>
<td>MB-10</td>
<td>-</td>
<td>-</td>
<td>13–40</td>
<td></td>
</tr>
<tr>
<td>Flow</td>
<td>mm</td>
<td>MB-12</td>
<td>-</td>
<td>-</td>
<td>15–70</td>
<td></td>
</tr>
<tr>
<td>Binder content (m/m)</td>
<td>%</td>
<td>MB-22</td>
<td>-</td>
<td>≥55</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

**Notes**
1. The prescribed test method is based on not using stirrers although it has been reported that the use of stirrers has shown no difference in test results.
2. Value to be determined on the residue after recovery of the binder by evaporation method MB-20.
3. No limits are given and the values should be recorded for reporting purposes only as they may be used in future specifications.

### 6.1 Special Applications

Some modified binders are used in special applications where the properties or product requirements are not covered under the generic classification. This section deals with such specialist applications, and recommendations are made based on proven empirical experience as observed in the field after many years of performance in South Africa.

#### 6.1.1 Modified emulsions for microsurfacings

The use of modified emulsions in the application of microsurfacings for overlays and rut-filling of existing bituminous surfaces has been common practice in South Africa since the early 1980's. The use of an elastomeric modified emulsion in microsurfacings renders advantages over conventional slurry seals in that microsurfacings can be applied in greater thicknesses in a single pass, and that the surface texture is maintained for a longer period due to improved binder cohesion and temperature susceptibility. Emulsions used in conventional slurries are manufactured from 80/100 bitumen which only has a minimum softening point of 42°C.

The elastomer helps improve the adhesion of the binder to the aggregate thus reducing the loss of aggregate, especially in the early life of the seal. In the case of rut-filling, the elastomer in conjunction with a harder base bitumen will increase the consistency of the binder at high in-service temperatures and thus increase the rut resistance of the mix. It must be noted that the elastomer component in the mixture is not sufficient to prevent reflective cracking from reappearing in the new surface.
The recommended limits given in Table 11 are for a quickset cationic bitumen emulsion modified with an elastomer which is used with a continuously graded crusher dust and applied by a continuously mixing machine. The emulsion must be specially formulated to allow for a time of between 90 and 120 seconds when mixed with the selected aggregate, to ensure sufficient setting time of the mix during placing.

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Test Method</th>
<th>Class</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>AC-E1 (Overlay)</td>
<td>AC-E2 (Rut filling)</td>
</tr>
<tr>
<td>Binder content (m/m)</td>
<td>%</td>
<td>MB–22</td>
<td>62-65</td>
<td>62-65</td>
</tr>
<tr>
<td>Residue on sieving(^3) (/100 ml)</td>
<td>g</td>
<td>MB-23</td>
<td>(\leq 0.1)</td>
<td>(\leq 0.1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(\leq 0.5)</td>
<td>(\leq 0.5)</td>
</tr>
<tr>
<td>Particle charge</td>
<td></td>
<td>MB–24</td>
<td>positive</td>
<td>positive</td>
</tr>
<tr>
<td>Sedimentation after 60 rotations</td>
<td>°C</td>
<td>SANS 309</td>
<td>nil</td>
<td>nil</td>
</tr>
<tr>
<td>Recovered binder residue</td>
<td></td>
<td>MB-20(^1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Softening point(^2)</td>
<td>°C</td>
<td>MB–17</td>
<td>(\geq 48)</td>
<td>(\geq 55)</td>
</tr>
<tr>
<td>Elastic recovery @ 15°C</td>
<td>%</td>
<td>MB-4</td>
<td>(\geq 50)</td>
<td>(\geq 55)</td>
</tr>
</tbody>
</table>

**Notes**
1. Either the rotary vacuum or the simple evaporation method can be used. For on site testing the simple method is more practical and is thus recommended. The simple method retains a very small portion of the fluxing oils whereas these are removed in the rotary vacuum method. The latter method renders a better indication of the binder properties after in-service curing.
2. The prescribed test method is based on not using stirrers although it has been reported that the use of stirrers has shown no difference in test results. For refereeing purposes no stirrers should be used.
3. Pour the emulsion through the larger sieve to remove the skin and larger particles before passing the emulsion through the finer sieve.

### 6.1.2 Hydrocarbon modified bitumen for high modulus asphalt

High modulus asphalt mixes manufactured with natural occurring hydrocarbon modified binders have been used successfully in pavements carrying heavy traffic or required to perform under high loading conditions such as climbing lanes and intersections. These mixes tend to render higher resilient modulus values when compared to those modified with elastomers or rubber crumb. Similarly the higher softening point and viscosity properties at the maximum road in-service temperature of hydrocarbon modified binders improves the deformation resistance of asphalt mixes vis-à-vis those manufactured from conventional penetration grade bitumen. The use of hydrocarbon modified binders is a cost effective way to improve the rut resistance of asphalt bases and wearing courses in hot climates. The use of hydrocarbon modified mixes is not recommended in pavements with high deflections.
The properties recommended for hydrocarbon modified binders for use in high modulus hot mix asphalt are shown in Table 9.

6.1.3 Modified binders for fuel resistant surfacings

Bituminous binders are soluble in petroleum solvents and thus all bituminous surfacings are susceptible to damage from spillages of diesel, petrol and solvents. However some modifiers can improve the fuel resistant properties of bituminous mixes. Asphalt surfaces used in areas such as climbing lanes, busy intersections, bus depots, toll plazas or airport aprons are more prone to damage from fuel spillage. In such situations, where there is a high risk of fuel spillage, the use of a binder with fuel resistant properties is recommended.

Tests have been developed for measuring the fuel resistant properties of asphalt mixes. Two standards are in use in Europe, one being the CEN standard EN 12697-43:2005 and the other the French standard NF P 98-251-1. The CEN method involves soaking the asphalt briquette in fuel for a period followed by brushing in a Hobart mixer. The material loss of the briquette is a measure of the resistance to fuel for that asphalt. The French method is based on the Duriez test and involves soaking an asphalt briquette in kerosene for 7 days and comparing the dry strength to the soaked strength similarly to the immersion index for adhesion.

When requesting a fuel resistant binder for asphalt wearing course, it is recommended that the supplier quantifies the fuel resistant properties of the binder in accordance with these two standards in terms of percentage mass loss and retained stability. This will provide the Engineer with a tool to rank the fuel resistance of the different binders along with the other performance parameters which are being considered for the project.

6.1.4 Modified bitumen emulsion for tack coat

The use of modified emulsion tack coats has been on the increase since the late 1990s with the popularisation of thin asphalt friction courses (UTFCs). The emulsion must be formulated to enable it to be applied through a spray bar positioned on the asphalt paver, immediately preceeding the placing of the asphalt. The properties of the residual binder are enhanced by the elastomer whilst the viscosity of the emulsion should be low enough to allow the product to be easily sprayed. The enhanced binder consistency must be such that it minimises the migration of the binder into the new thin layer to prevent flushing and the subsequent closing up of the surface texture under traffic. The elastomer also helps improve the adhesion of the new thin layer to the existing substrate under severe traffic action.

The properties of a modified emulsion used as a tack coat for UTFCs is the same as that for SC-E1 (65-68% binder content) shown in Table 6 outlining the properties for polymer modified emulsions for surfacing seals. It must, however, be noted that although this requirement is similar for spray sealing, the following should be noted:

- No cutter must be used in the formulation of the emulsion as this will lead to solvent entrapment in the new surface, increasing the risk of bleeding;
- The viscosity requirements are lower (ie 21-100 SFs @ 50°C) given the need for the emulsion to be sprayed at lower application rates and to be able to flow more readily on application.
Modified binders are more expensive than conventional binders. The decision to utilise a modified binder should always be done on the basis of “value engineering” and not “fashion”. However, the cost premium of utilising these binders can frequently be justified by improved performance and/or extended service life of the constructed layer. Table 12 provides a guideline to advantages and disadvantages of modified binders compared with conventional binders to assist in the selection process.

The characteristic/behaviour of modified bitumen can differ significantly to that of conventional bitumen. As discussed in Chapter 3, they are generally more viscous, cohesive and resilient which can influence, to a greater or lesser degree, aspects such as surfacing seal/asphalt mix design protocols, handling and storage of the binder, climatic condition limitations during construction as well as construction techniques. Thus, the simple substitution of conventional bitumen with a modified product, without taking cognisance of the above, will probably result in sub-optimal performance and possibly premature failure. Also, the selection of modified binders should never be regarded as a substitute for good design and construction practice.

Modified binders have been classified according to the application in which they are expected to perform. Following, are some recommendations as to the most appropriate product for a given primary in-service requirement, substrate condition and/or component availability. Also highlighted are some constraints related to the use of these products.

When the field conditions or demands are such that none of the selection criteria necessarily apply, specialist advice needs to be obtained.

### 7.1 Surfacing Seal Applications

The primary function of a seal is one, or more, of the following:

» Provision (or reinstatement) of a safe riding surface (macro texture).
» Prevention of ingress of moisture into the structural support layers.
» Protecting an aged existing bituminous surfacing.
» Limiting the reflection of fine to medium cracks originating from the substrate as a result of structural fatigue or from the surface as a result of environmental influences through the use of Stress Absorbing Membrane (SAM) or Stress Absorbing Membrane Interface (SAMI).

With the exception of SAM or SAMI layers, it could be argued that the use of conventional bitumen would be appropriate in the majority of surfacing seal applications in South Africa. However, the sustained increase in traffic volumes as well as loading spectrum currently being experienced results in many instances where the historically proven performance range of conventional binders is being exceeded. Thus, in many instances the use of modified binders could extend the range with respect to the appropriateness of surfacing seal applications as a result of:
Table 12: Advantages and disadvantages of modified binders compared with conventional binders

<table>
<thead>
<tr>
<th>Binder type</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetration grade</td>
<td>» Cheapest binder</td>
<td>» Can flush/bleed as a result of high road surface temperatures</td>
</tr>
<tr>
<td>(80/100)</td>
<td>» Permits small quantities to be ordered</td>
<td>» Can flush/bleed as a result of heavy traffic loading</td>
</tr>
<tr>
<td></td>
<td>» Can be hand sprayed</td>
<td>» Can result in a too low application rate in cases of heavy traffic loading</td>
</tr>
<tr>
<td></td>
<td>» Good aggregate wetting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>» Allows trapped water vapour to escape</td>
<td></td>
</tr>
<tr>
<td></td>
<td>» Has “self healing” characteristics</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>» Can flush/bleed as a result of high road surface temperatures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>» Can flush/bleed as a result of heavy traffic loading</td>
<td></td>
</tr>
<tr>
<td></td>
<td>» Can result in a too low application rate in cases of heavy traffic loading</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE-1 (SBR)</td>
<td>» Reduced temperature susceptibility</td>
<td>» Increased binder cost</td>
</tr>
<tr>
<td></td>
<td>» High viscosity at maximum in-service temperature reduces risk of bleeding</td>
<td>» Limited storage life at application temperature</td>
</tr>
<tr>
<td></td>
<td>» Increased cohesive strength</td>
<td>» Can restrict evaporation of trapped moisture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>» Difficult to hand spray</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE-2 (SBS)</td>
<td>» Increased cohesion under heavy traffic loading due to high elastic recovery</td>
<td>» Increased binder cost</td>
</tr>
<tr>
<td></td>
<td>» High softening point reduces risk of bleeding as a result of high road surface temperatures</td>
<td>» Does restrict evaporation of entrapped moisture</td>
</tr>
<tr>
<td></td>
<td>» Lower application temperature than SBR and BR</td>
<td>» Early binder/aggregate adhesion sensitive to cold ambient temperatures and/or moisture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>» Requires aggregate to be pre-coated</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bitumen-rubber</td>
<td>» Can be applied on heavy traffic loading applications</td>
<td>» Highest surfacing cost</td>
</tr>
<tr>
<td></td>
<td>» Increased viscosity at service temperatures reduces risk of bleeding</td>
<td>» Requires special distributors with augers for application</td>
</tr>
<tr>
<td></td>
<td>» Permits higher application rates without risk of bleeding</td>
<td>» Difficult to hand spray</td>
</tr>
<tr>
<td></td>
<td>» Improved aging resistance due to carbon black</td>
<td>» Difficult to produce in small quantities</td>
</tr>
<tr>
<td></td>
<td>» Ideal for sealing a surface with cracks (&lt; 3.0mm)</td>
<td>» Limited storage life at application temperature</td>
</tr>
<tr>
<td></td>
<td>» Suitable for constructing a SAMI</td>
<td>» Does restrict evaporation of entrapped moisture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>» Early binder/aggregate adhesion sensitive to cold temperatures and/or moisture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>» Requires aggregate to be pre-coated</td>
</tr>
</tbody>
</table>
» Increased binder application rate (for early aggregate retention)
» Increased binder application rate (to improve impermeability)
» Increased shear strength (for high stress situations)
» Reduced risk of bleeding (increased binder cohesion) under high in-service temperature conditions (> 60°C)
» Improved shear resistance in high/turning traffic situations
» Reduced sensitivity to daily fluctuations of in-service temperatures
» Limiting, or delaying, reflective or thermal cracking
» Increased durability (increased binder film thickness)

It should however be noted that the binder is only one element of a surfacing seal system and that all aspects such as climate, aggregate, design and construction must be considered prior to selecting the most appropriate binder.

7.1.1 Environmental influences during application

Due to the increased viscosity and cohesive properties of modified binders the climatic conditions required during their application are far more restrictive when compared to those for conventional hot applied binders. An increase in binder cohesion usually results in a concomitant decrease in adhesion (ability to retain aggregate). Due to this reduction in aggregate wetting property, aggregate loss is a real risk if rain or very cold and/or windy conditions are experienced soon after construction. This can be a particular problem on surfacing seals having a relatively low binder application rate as a result of a high traffic loading profile.

The risk of early, and sometimes catastrophic, aggregate loss can be reduced by implementing some of the following measures:

» **Seal type:** single seals are the most vulnerable, especially those with a larger ALD (ie 19 mm versus 6.7 mm stone). The use of double seals significantly reduces the risk of aggregate loss by improving the aggregate interlock.

» **Cover sprays:** the application of a diluted cationic spray grade emulsion with a 30% binder content cover spray can reduce the risk even further. The binder helps glue the aggregates together. The use of conventional binder for the second spray of the double seal could also be considered.

» **Delay in trafficking:** local experience has shown that a significant reduction in early aggregate loss can be achieved if traffic is kept off the newly constructed seal for 24 to 48 hours. Continuous rolling and brooming, especially during the warmer period of the following day, is however necessary in order to achieve this reduction.

» **Adhesion agent:** it is becoming standard practice to add an adhesion agent to the binder to improve its aggregate wetting property. Unless the stability (and thus efficacy) of the product has been adequately proven, the adhesion agent (typically 0.3-0.5% v/v) should only be added and circulated in the spray tanker immediately prior to spraying (up to 30 minutes).

» **Road surface temperature:** the minimum surface temperatures for surface sealing with the respective modified binders are given in Table 13 as a guideline.

» **Cutting back:** while the addition of a cutter may solve, or reduce, a potential adhesion problem in the short term, problems have been experienced with respect to bleeding/flushing of the surface during subsequent hot periods, especially in heavy duty applications. This practice should only be considered when spraying at the end of the summer season before the onset of winter. The use of cut-back modified binders (winter-grades) has however been successful in relatively light duty applications, such as residential streets. Refer to Chapter 3 for information covering the procedures and performance risks associated with this practice.
Table 13: Minimum road surface temperatures for surface sealing

<table>
<thead>
<tr>
<th>Binder Class</th>
<th>Minimum road surface temp (°C) (^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-E1; S-E2</td>
<td>25</td>
</tr>
<tr>
<td>SC-E1; SC-E2</td>
<td>10</td>
</tr>
<tr>
<td>S-R1</td>
<td>25</td>
</tr>
</tbody>
</table>

Notes
1. The supplier’s method statement should also be noted

7.1.2 Aggregate influences

The following aggregate factors should be considered when selecting an appropriate binder:

- **Aggregate quality:** Due to the reduction in the wetting characteristics of modified binders, it is important to use aggregate of good quality that is dry and free from dust. It may therefore be necessary to cover the aggregate stockpiles if rain is expected during the construction period. These conditions apply to all hot applied modified seals, including those applied on lower traffic volume roads. Where the above condition cannot be guaranteed, consideration should be given to utilising cold applied modified binders (emulsions) which are generally more accommodating with respect to aggregate cleanliness and moisture conditions.

- **Pre-coating:** It is recommended that, in all instances of hot applied modified binders, the aggregate should be pre-coated using a bituminous based pre-coating fluid (containing at least 0.5% adhesion agent) to improve both initial and long term retention of the aggregate. Pre-coating the surfacing aggregate will improve binder/aggregate adhesion by reducing the surface tension between the two interfaces (refer to Sabita Manual 26 for more information on best practices for pre-coating aggregates). The application of a final diluted emulsion cover spray may however permit the use of uncoated aggregate in the second application.

- **Aggregate size:** In general, most of the seal types listed in TRH3: Surfacing Seal for Rural and Urban Roads can be constructed utilising modified binders. Cognisance should however always be taken of the minimum spray rates applicable to a specific binder. For example, the minimum recommended spray rate for an S-R1 (bitumen-rubber) binder is 1.8 ℓ/m\(^2\). In order to accommodate this minimum application rate, the minimum nominal aggregate size would be in the order of 13mm (ALD >8,0mm). It may therefore be entirely inappropriate to specify say a 9,5mm single seal utilising an S-R1 binder. Similarly, extreme caution should be exercised if a large nominal aggregate size seal utilising SC-E1 or SC-E2 binders is specified in areas of steep inclines and/or high super elevations. The required application rates may be such that significant run-off of the binder could occur prior to the application of the aggregate.

7.1.3 Substrate influences

The condition of the substrate will greatly influence the performance of the applied surface seal and, as such, it is important to carry out pre-treatment works (to a greater or lesser degree) prior to constructing the seal. The execution of the pre-treatment must be carried out to allow sufficient time for curing to take place prior to resealing.

In some instances, however, there may currently be insufficient funding to implement the most appropriate, though costly, intervention strategy for a long term solution. In such instances the use of
modified binders in seals constructed as a temporary holding action is an option that may be utilised to reduce the rate of deterioration/distress of the pavement and/or its functional properties.

Some of the more common situations encountered are:

- **Aged surfaces**: to ensure good adhesion (both short and long term) to the substrate in situations where the existing surface is still intact but exhibiting signs of ageing or porosity, it may be necessary to apply a light emulsion fog spray to the existing surface prior to application of the modified binder surfacing seal, especially where S-E2 or S-R1 binders are to be used. The rescaling of a very aged, brittle or cracked surface is not recommended unless it is intended as a very short term holding action. The use of a rejuvenator spray can also be considered if the substrate is an open textured seal.

- **Cracked surfaces**: it is important to identify the origin and assess the behaviour of existing cracks on the substrate prior to selecting the most appropriate binder. Surface cracks may be categorised in terms of crack activity (rate of movement) and crack severity (width/depth). The following other issues should be considered when dealing with cracked surfaces:
  - Traffic induced cracking (fatigue) can generally be categorised as rapid crack activity. In these circumstances, a seal design incorporating high binder application rates is recommended and, as such, bitumen-rubber (S-R1) has historically been preferred in such applications. Where the degree of crack activity and structural support conditions are such that significant pumping of fines from the underlying layers is evident, it is unlikely that the application of a modified seal will address the situation other than for a very short period.
  - Cracking as a result of the environment (thermal) or drying shrinkage (stabilisation) can generally be categorised as slow activity cracking. In these instances it would be preferable to use lightly modified (or even unmodified) binders, which have a greater ability to self-heal, than to use highly modified products. If, however, these slow activity cracks also exhibit rapid movement under traffic (ie movement across the crack) then it may be appropriate to utilise a more highly modified binder.
  - For a stress absorbing membrane interface layer (SAMI) a relatively thick layer of binder is required to dissipate any crack induced stresses. In these applications bitumen-rubber (S-R1) has historically been the most common binder used. However, an S-E2 binder may also suffice in certain situations.
  - All cracks in excess of 3.0mm in width must be sealed with a C-E1 or C-R1 binder or, if greater than 5 mm, be repaired prior to rescaling as no modified binder seal can perform satisfactorily in the long term in such situations.

- **Retained moisture**: where the surface to be sealed is cracked or open textured and there is a likelihood of excess moisture within the layer, the use of a highly modified binder in any rescaling application should be viewed with extreme caution. Due to their high cohesion properties, highly modified binders do not permit the escape of any moisture entrapped below the seal, resulting in fairly rapid stripping of the binder from the aggregate in the underlying layer (the so called “pressure cooker” effect). This is especially prevalent where the substrate consists of an asphalt layer. Stripping of the binder has also been observed where the substrate is a surface seal overlying a granular base, but it would appear that the rate of stripping occurs at a slower rate (probably as a result of the thicker binder film prevalent in seals). In such circumstances it would be preferable to only apply the seal after a prolonged dry period. If this is not possible consideration should be given to utilising an unmodified binder which permits the release of moisture and then has the ability to “self heal” during the warmer periods once the pressure of the water vapour has been released.
7.1.4 Project location and programming influences

Hot modified binders degrade or become unstable at a faster rate than conventional binders when heated during storage. In this regard, bitumen rubber (S-R1) has a particularly short application window at application temperatures. While re-constitution of modified binders is possible in some circumstances and under certain conditions, it is always preferable to utilise a “fresh” product, thereby removing any possible doubt with respect to compromised performance.

Therefore, the selection of the most appropriate modified binder type should always take into account the following:

- Distance from blending plant.
- Whether the quantity required is sufficient to justify an on-site blending plant.
- The effect of possible delays in application due to variable weather patterns or construction delays.
- The quantity of binder required to be applied on a daily basis.
- Any other practicalities and logistics that may extend the storage time of the product and possibly compromise its properties.
- Whether hand work is required in the construction of the seal.
- Whether the seal will be constructed in winter.

Where any of the above is probable, consideration should be given to the utilisation of an appropriate modified emulsion binder class.

7.1.5 Traffic influences

The most critical factors generally affecting the performance of a seal are the applied stresses as a result of heavy traffic loading, especially on steep gradients as well as short curve radii. In high traffic situations the maximum conventional binder application rate determined (to prevent bleeding) is often lower than the minimum required for retention of the aggregate. Modified binders permit an increase in the application rate without necessarily increasing the risk of future bleeding. Thus, the introduction of modified binders has permitted the successful application of surface seals for traffic classes well in excess of those traditionally accepted as being the upper limit using conventional binders.

TRH 3: Surfacing Seals for Rural & Urban Roads provides guidance for the selection of the most appropriate binders for given traffic and climatic conditions. The current edition does not however differentiate between the different modified binder classes currently available. Table 4 provides additional guidelines for the selection of the most appropriate binder for a given stress condition.

The definitions of stress conditions are as follows:

- **Highly stressed areas** are one or more of the following:
  - > 30 000 elv/lane/day (TRH3:1998 classification)
  - Curve radii < 50m
  - Gradients > 5%
- **Moderately stressed areas** are one or more of the following:
  - 10 000 to 30 000 elv/lane/day
  - Curve radii < 100m
  - Gradients < 5%
7.1.6 Design influences

Modified binders cannot simply replace the binder application rates determined for conventional binders. Experience and assessment of the performance of modified binder seals over recent years has led to a refinement in the adjustment factors relative to a specific modified binder class. Designers should refer to the latest edition of TRH3: The Design of Surface Seals for Rural and Urban Roads for the appropriate design methodologies.

7.1.7 Selection guide

Table 14 shows possible applications for a given situation to assist in selecting an appropriate modified binder class. The table does not identify the optimum product as this should only be selected by the practitioner after having taken all relevant factors into account.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Modified Binder Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-E1</td>
<td>S-E2</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>Moderately stressed areas</td>
<td>✓</td>
</tr>
<tr>
<td>Highly stressed areas</td>
<td>✓</td>
</tr>
<tr>
<td>Steep gradients</td>
<td>✓</td>
</tr>
<tr>
<td>Active cracking SAM</td>
<td>✓</td>
</tr>
<tr>
<td>Passive cracking SAM</td>
<td>✓</td>
</tr>
<tr>
<td>Active and passive cracking SAM</td>
<td>✓</td>
</tr>
<tr>
<td>Active and/or passive cracking SAMI</td>
<td>✓</td>
</tr>
<tr>
<td>Entrapped moisture</td>
<td>✓(2)</td>
</tr>
<tr>
<td>Very high road surface temperatures (&gt;60°C)</td>
<td>✓</td>
</tr>
<tr>
<td>Low temperature during application (&gt;10°C)</td>
<td>✓(3)</td>
</tr>
</tbody>
</table>

Notes:
1. Suitable for new construction or reseal projects where traffic accommodation is not a problem.
2. Where there is a high risk of moisture entrapment (especially in underlying asphalt layers) the use of an unmodified binder should be considered.
3. Where other factors responsible for possible degradation of the heated product could occur such as a result of long haul distances from the blending plant, disruptions to construction or small areas to be sealed over consecutive days, unmodified binder should also be considered.
7.2 Hot mix asphalt

Not all bituminous binders or hot-mix asphalts require modification. The addition of modifiers and other additives is dictated by technical objectives that need to be met. These could include (Roberts et al, 1996):

- Obtaining stiffer mixes at high service temperatures to minimise rutting;
- Improving fatigue resistance of HMA;
- Improving binder-aggregate bonding to reduce stripping or moisture susceptibility;
- Improving abrasion resistance of HMA to reduce ravelling (particularly in open-graded mixes);
- Minimising tender mix problems during construction;
- Rejuvenating aged binders;
- Permitting higher binder film thicknesses for increased mix durability;
- Preventing binder segregation in discontinuous gradings (e.g. stone-mastic asphalt);
- Reducing flushing and bleeding;
- Improving resistance to ageing or oxidation;
- Reducing structural thickness of pavement layers (with caution!);
- Reducing life-cycle costs of flexible pavements surfaced with HMA;
- Improving overall performance of HMA;
- Improving fuel resistance.

The decision whether to incorporate a modifier or additive in an HMA mixture, and if so, what class, should always be based on the service conditions and/or fundamental engineering requirements such as:

- Predicted traffic loading (rutting);
- Predicted in-service pavement temperatures (high – increased risk for rutting; low – increased risk for premature cracking);
- Stiffness/deflection of support structure (low stiffness or high deflections could increase the potential for premature fatigue failures);
- Degree and extent of existing distresses prior to rehabilitation (presence of existing cracks – durability);
- Type of mix selected (open-graded asphalt, SMA etc.).

The incorporation of modifiers or additives into HMA may improve resistance to permanent deformation, resistance to premature cracking and/or enhance the durability of the mix, which ultimately may result in an extended service life and reduced maintenance. It is, however, important to recognise that the incorporation of a modifier or additive is only part of improving the performance of HMA. Although each modifier or additive may offer certain benefits over conventional HMA, none is a panacea. Sometimes, one property of HMA is improved, but another is compromised. Hence, one must first concentrate on ensuring proper pavement/mix design and construction. Then, and only then, should one turn to engineering the binder or mix with the right type of modifier or additive to solve any specific demand, be it cracking resistance, deformation response or any other property that may need to be enhanced.

Table 15 (based on Roberts et al, 1996) lists some common binder modifiers and additives used in HMA and the general purpose of their use:
## Table 15: Common Binder Modifiers and Additives used in HMA

<table>
<thead>
<tr>
<th>Type</th>
<th>General purpose</th>
<th>Generic examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Filler</strong></td>
<td>Fills voids and therefore reduces optimum binder content;</td>
<td>Mineral filler</td>
</tr>
<tr>
<td></td>
<td>Used to satisfy grading specifications;</td>
<td>» Crushed fines</td>
</tr>
<tr>
<td></td>
<td>Improves stability;</td>
<td>» Portland cement</td>
</tr>
<tr>
<td></td>
<td>Improves binder-aggregate bond (e.g. lime).</td>
<td>» Lime</td>
</tr>
<tr>
<td></td>
<td></td>
<td>» Fly ash</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carbon black</td>
</tr>
<tr>
<td><strong>Extender</strong></td>
<td>Substitutes a portion of bitumen to decrease the amount of bitumen and/or polymer</td>
<td>Sulphur</td>
</tr>
<tr>
<td></td>
<td>required.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Improves the storage stability of SBS modified binders.</td>
<td></td>
</tr>
<tr>
<td><strong>Rubber</strong> (elastomer)</td>
<td>Increases HMA stiffness at high temperatures;</td>
<td>Styrene-butadiene (SBR)</td>
</tr>
<tr>
<td></td>
<td>Produces a more elastic HMA to resist fatigue cracking at intermediate</td>
<td>Rubber latex</td>
</tr>
<tr>
<td></td>
<td>temperatures;</td>
<td>Styrene-butadiene-styrene (SBS)</td>
</tr>
<tr>
<td></td>
<td>Lower stiffness at low service temperatures to resist thermal cracking.</td>
<td>Styrene-isoprene-styrene (SIS)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crumb rubber and bitumen-rubber</td>
</tr>
<tr>
<td><strong>Plastic</strong> (plastomer)</td>
<td>Improves resistance to permanent deformation;</td>
<td>Ethylene-vinyl-acetate (EVA)</td>
</tr>
<tr>
<td></td>
<td>Some grades are known to also improve workability.</td>
<td></td>
</tr>
<tr>
<td><strong>Fibre</strong></td>
<td>Reinforcing and improving the tensile strength and cohesion in HMA;</td>
<td>Natural: Rock wool</td>
</tr>
<tr>
<td></td>
<td>Allows higher binder contents to be used with reduced risk of binder draindown</td>
<td>Polypropylene</td>
</tr>
<tr>
<td></td>
<td>(open graded asphalt and SMA);</td>
<td>Polyester</td>
</tr>
<tr>
<td></td>
<td>Improves durability due to greater binder film thicknesses.</td>
<td>Fibreglass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mineral</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cellulose</td>
</tr>
<tr>
<td><strong>Antioxidant</strong></td>
<td>Increases the durability of HMA by retarding oxidation.</td>
<td>Carbon black</td>
</tr>
<tr>
<td><strong>Rejuvenator</strong></td>
<td>Restoration of aged asphalt</td>
<td>Extender oils</td>
</tr>
<tr>
<td><strong>Hydrocarbon</strong></td>
<td>Increases HMA stiffness and resistance to permanent deformation</td>
<td>Natural occurring asphalts, refinery produced hardening agents (Propane Deasphalted Tar)</td>
</tr>
<tr>
<td><strong>Antistripping agents</strong></td>
<td>Minimises stripping of binder from aggregate</td>
<td>Amines</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lime</td>
</tr>
<tr>
<td><strong>Workability</strong></td>
<td>Reduces mixing and compaction temperature of HMA</td>
<td>FT wax</td>
</tr>
<tr>
<td><strong>Fuel resistance</strong></td>
<td>Improves the resistance of the HMA to fuel spillages</td>
<td>FT wax</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EVA (select grades only)</td>
</tr>
</tbody>
</table>
7.2.1 Resistance to permanent deformation (rutting)

The improvement to rut resistant properties of an HMA mix resulting from the incorporation of a modified binder is well documented and widely accepted. This is especially true for sand-skeletal mixes such as the standard COLTO continuously graded mix types. However, notwithstanding the above, the need to comply fully with all the other fundamental mix design criteria, especially the volumetric properties, cannot be over emphasised.

As implied by the binder classification, binders conforming to the A-P class requirements have been formulated to specifically enhance the rut resistance properties of HMA. The use of this class of binder should however be restricted to layers constructed on a relatively stiff support as their fatigue properties are generally limited (with the possible exception of EVA).

Class A-E binders have to date been the predominant binders used in HMA modification. Notwithstanding the fact that they are classed as “elastomers” their increased stiffness at elevated temperatures can contribute to the rut resistant properties of the mix. In addition, their use is more appropriate on support structures that are more flexible than those for the A-P Class.

Class A-R binders also contribute significantly to deformation resistance and have the added benefit of significantly improving fatigue properties. However, their use is generally restricted to open or semi-open graded mix types, which may not be appropriate on substrate layers that are sensitive to the ingress of moisture (permeable or aged), unless the mix, in the case of a semi-open grading, can be rendered virtually impermeable by the use of a fairly high percentage of A-R binder.

7.2.2 Cracking

Cracking on a pavement surface can be due to one or more of the following:

» Fatigue
» Shrinkage
» Environmental

Fatigue cracking occurs due the cumulative effect of repeated traffic loading resulting from a reduction in stiffness of the supporting pavement structure. Modified binders can be effective in increasing the fatigue resistance of HMA for a given strain level. However, if the strain levels are too high it is doubtful whether any binder class would be effective. In such cases, a surface dressing manufactured with a modified binder (typically an A-R class) could be considered as a holding action.

Shrinkage cracking as a result of seasonal moisture changes and/or cementitious stabilisation can vary greatly with respect to the degree of strain and activity. The use of A-E and A-P class of binders in dense graded (AC) mixes has proven to be generally ineffective in reducing reflection cracking. Mix types that permit relatively high quantities of modified binder such as SMA and semi-open graded mixes have been used successfully in certain instances. In low volume applications the use of mixes incorporating softer standard bitumen as well as higher bitumen contents would also reduce reflection cracking, but resistance to permanent deformation would, as a consequence, be significantly compromised particularly in sand skeletal mixes.

Environmental cracking (top down) occurs as a result of binder ageing and/or temperature changes such as freeze-thaw. The use of modified binders generally permit higher binder film thickness in the mix with a concomitant reduction in the risk of premature ageing. Where an existing asphalt surface
exhibits signs of ageing it may be necessary to pre-treat the surface (e.g. fog spray) to ensure an adequate bond with the new modified HMA overlay.

7.2.3 Mix type

For certain mix types such as SMA and open-grade mixes, the use of a modified binder may be appropriate for purposes other than improvement to rutting or fatigue resistance properties. For example, they could be used to prevent drain down of the binder during transportation and placing. The use of these binders may replace, or be used together with, other products such as cellulose fibre.

7.2.4 Design criteria

The design of asphalt mixes incorporating modified binders should follow the standard procedures contained in the HMA Design Guideline Document. Due to the non-Newtonian behaviour of modified binders, selection of appropriate mixing and compaction temperatures requires careful consideration. Incorrect selection of these criteria will result in erroneous determination of the volumetric properties of the mix which are critical parameters affecting performance. Due to the reduced workability resulting from the addition of certain types of modifiers, for a given binder content, modified binders may cause an increase in Voids in Mix (VIM) of between 0.2 and 0.4% above that obtained for standard bitumen.

7.2.5 Production criteria

All modified binders have a limited shelf life. This is especially true for the A-R class of binder maintained at application temperatures. The logistic issues surrounding the use of modified binders, (eg blending and storing) should always be taken into account prior to their selection. Where only small quantities of HMA are required, or where daily production requirements are relatively low, the appropriateness of their use from a cost premium perspective should be carefully considered. In such instances, modified binders with a high storage stability or modifiers that can be incorporated directly into the mixer’s pugmill or bitumen feed pipe (ie do not require pre-blending with the bitumen) should be considered.
8 CONSTRUCTION

8.1 Surface Seals

The following issues should be considered during the construction of surfacing seals using modified binders:

- **Weather conditions:** modified binders (even if cut back) should not be sprayed if there is a threat of rain or windy conditions. Wind chilling causes a skin to form on the modified binder, especially modified emulsions, and spraying should be deferred until more favourable conditions prevail.

- **Spray lengths:** due to the decrease in adhesion characteristics of modified binders, it is essential that the aggregate spreading and rolling operations be carried out as soon as possible after application of the binder. Hence, it may be necessary to reduce the length of spray runs substantially from those normally acceptable for conventional binders.

- **Shady areas:** where there are overhead bridge structures or localised shady areas, it is considered good practice to commence the spray run at these areas, thereby reducing the time delay of aggregate application and rolling to the minimum. In addition, the binder application rates could be increased by up to 20% in these areas (if approved by the designer).

- **Production rates:** ideally the pavement and ambient temperatures should be at least 5°C and rising prior to application. It may therefore be prudent to limit the production rates by only sealing in the middle part of the day in order to reduce the risk of chip loss.

- **Presence of moisture:** the presence of moisture should be avoided. The substrate should be totally dry prior to commencement of sealing. Where there is a risk of afternoon showers, consideration should be given to postponing the sealing operations, especially if the road is to be opened to traffic the same day.

- **Binders incorporating a cutter:** Where a cutter has been added to the modified binder the following should be noted:
  - No spraying of cutback modified binder should take place after 14h00, however rolling should continue until later in the afternoon.
  - The road should ideally be kept closed to traffic overnight, especially in higher traffic situations, and rolling should continue the next morning. The road should only be opened to traffic when the road temperature has risen above 15°C.
  - The cutting back of a modified binder will result in lowering its viscosity and density. Therefore the application rate and spraying temperature must be adjusted accordingly.

- **Contingency plan:** Even if all best practices have been followed with respect to design and construction of the seal, the fickleness of the weather or other influences such as plant breakdowns and unforeseen delays, could result in unexpected significant early stone loss. It is therefore considered good practice to always have a contingency plan in place should such situations occur. Such plans should include provision for:
  - Emergency closure of the lane at any time (day or night) including appropriate traffic accommodation measures.
  - Longer term lane closures with additional rolling during the warmer part of the day.
  - Application of a fog spray as soon as possible.
8.2 Hot Mix Asphalt

HMA mixes incorporating modified binders are generally constructed in a similar way to that for conventional mixes with the exception that the compaction temperature required can be somewhat higher depending on the type and percentage of modifier utilised. This higher temperature requirement dictates that particular care must be exercised to ensure that:

» There is adequate compaction plant available;
» Appropriate rolling patterns are employed (determined on trial sections);
» There is minimal delay between manufacture and placement of the product;
» There is a continuous supply of mix to limit the number of joints (hand work on modified HMA is difficult);
» Environmental, health and safety obligations are not compromised.

In the case of EVA modified asphalt it is important to ensure that the necessary crystalline structure has formed, otherwise the mat will tend to shove under the rollers if the temperature is too high.

An exception to the above is where the binder is modified with an F-T wax. One of the benefits of these binders is that they have a significantly lower viscosity than conventionally modified binders at equivalent mixing/compaction temperatures. This implies that the appropriate compaction temperatures must therefore be reduced accordingly otherwise there is a high risk that the paved layer will:

» Exhibit excessive movement under the rollers;
» Develop permanent fine shear cracks allowing ingress of moisture;
» Become over-compacted with associated premature flushing/bleeding of the surface.
9 QUALITY ASSURANCE IN STORAGE AND HANDLING

This section deals with the quality related issues arising from the storage and handling of modified binders at a work site as an integral part of the process flow for handling modified binders shown in Figure 9. For information pertaining to quality management in the loading of modified binders into road tankers, the transportation and off-loading thereof refer to Sabita Manual 25 published November 2005.

![Figure 9: Process flow for handling modified binders](image)

9.1 Heating of modified binders

The main difference in the handling of modified binders compared with conventional binders is the need for additional care in ensuring that the effectiveness of the polymer has not been reduced through overheating as modified binders are generally applied at higher temperatures. Special care must also be taken when heating a modified binder during storage and application to ensure that the properties of the modified binder are not adversely affected.

On-site heating of modified binders is done with flame tubes that protrude into the tank space. Diesel burners are mainly used and these types of burners are also rapidly replacing LPG burners as a means of heating on road and spray tankers. The temperature on the outside of the tube which comes into contact with the binder is in excess of 300°C. By nature, bitumen is a poor conductor of heat and heat transfer takes place through convection when the bitumen is in a fluid state. Therefore, it is imperative that during the heating of a hot-applied modified binder that the following steps are
taken to counteract localised overheating of the binder in the vicinity of the flue pipes and possible degradation of the polymer:

- The tank should be designed with an appropriate circulation system to ensure that there is a constant movement of binder over the flues during heating.
- In the event of having to superheat the binder above 180°C it is essential that tanks are fitted with augers or stirrers to prevent localized overheating.
- Store the binder at the minimum pumping temperature and not at the application temperature. The binder should only be heated to the application temperature just prior to use to limit degradation of the polymer.
- Do not allow the binder to solidify in the storage tank as reheating will result in localised overheating around the flues. Rather heat the binder intermittently over an extended period to maintain a constant storage temperature.
- Avoid rapid heating of the binder. As a rule of thumb the rate of heating should not exceed 5°C per hour unless the tank is fitted with an agitation mechanism.
- All tanks are to be fitted with calibrated temperature gauges. In the case of a sprayer a temperature gauge should be fitted on the spray bar as well as the tank to ensure that the binder is sprayed at the correct application temperature.
- All established modified binder storage facilities should strive to install temperature recording devices with automatic temperature controls for heating.
- Obtain a method statement from the supplier on the correct handling and storage temperatures for the modified binder.

The handling criteria will vary depending on the type of modified binder. This will be discussed in more detail later in the section but in the absence of any additional information from the supplier, Tables 6, 7 & 8 provides a guideline for the handling of the various classes and types of modified binders.

### 9.1.1 Hot-applied polymer modified binders

To ensure that the properties of the hot-applied polymer modified binder are not adversely affected during storage only minimal amounts of heating should be applied to ensure that the product remains pumpable. It is important that hot polymer modified binders are circulated during heating as prolonged, intense heating will cause carbonisation of the binder on the flues and degradation of the polymer. The latter will lead to a reduction in the binder’s softening point resulting in the product not meeting the required specification. Carbonisation on the flues will also reduce the efficiency of the heating system and could lead to blocked nozzles on the sprayer. The storage life of the binder at elevated temperatures will vary according to the amount and type of modifier used, compatibility of the base bitumen and the manufacturing process.

Polymer modified binders should not be kept at their application temperatures for longer than necessary and Table 16 should be used as a guideline. If the heated binder is not used at the end of the work shift then the temperature should be reduced and only super heated again prior to reuse. Generally the heating of a polymer modified binder above 180°C will result in a reduction of its storage life. If there is any doubt about the suitability of a product after heating and storage then a sample should be taken and the softening point should be checked against the specification.

Table 16 provides a guideline for heating polymer modified binders for normal storage and application purposes. The suppliers of these binders must be consulted to ascertain the appropriate temperatures which are relevant to their specific type of modified binder. If the recommended time period has been
exceeded samples of the binder should be taken and retested to ensure that the properties of the binder have not degraded.

Table 16: Typical temperature/time limits for polymer modified binders

<table>
<thead>
<tr>
<th>Binder Class</th>
<th>Short Term Handling</th>
<th>Storage</th>
<th>Spraying/Asphalt Mixing/Application</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max Temp (°C)</td>
<td>Max Holding Time (hrs)</td>
<td>Max Temp (°C)</td>
</tr>
<tr>
<td>S-E1 (SBR)</td>
<td>180</td>
<td>24</td>
<td>150</td>
</tr>
<tr>
<td>S-E1 (SBS)</td>
<td>180</td>
<td>24</td>
<td>150</td>
</tr>
<tr>
<td>S-E2</td>
<td>180</td>
<td>24</td>
<td>150</td>
</tr>
<tr>
<td>A-E1 (SBR)</td>
<td>180</td>
<td>24</td>
<td>150</td>
</tr>
<tr>
<td>A-E1 (SBS)</td>
<td>180</td>
<td>24</td>
<td>150</td>
</tr>
<tr>
<td>A-E2</td>
<td>180</td>
<td>24</td>
<td>150</td>
</tr>
<tr>
<td>A-P1</td>
<td>160</td>
<td>24</td>
<td>140</td>
</tr>
</tbody>
</table>

Notes
1. If the recommended maximum holding time has been exceeded then resample and test the binder to ensure compliance with the specification.
2. In the event of non-polymer modified binders being used, refer to the supplier for guidelines on handling and application temperatures.

9.1.2 Polymer modified emulsions

No polymer degradation should occur with modified emulsions during the normal temperature range encountered in handling and storage and shown in Table 17. Unlike their hot-applied counterparts, emulsions should not be heated during storage but only heated prior to application. If polymer modified emulsions are kept in storage for any length of time it is advisable to gently agitate the emulsion from time to time. Polymer modified emulsions are shear sensitive so pumping must be limited and should preferably be carried out by vane pumps or under compressed air. Prolonged storage can lead to an increase in the ‘residue of sieving’ and lower the viscosity values due to coagulation and settlement of the bitumen and latex droplets in the tank.

Polymer modified emulsions should be passed through a strainer when loading and discharging from a tank or sprayer in order to remove the lumps which form due to skinning. During storage, a skin forms on the surface of the product due to evaporation of the water phase and pieces of skin may break off over time causing blockages in the nozzles on the sprayers. It is important that the strainers are checked and cleaned regularly to prevent a build up of material.
Table 17: Typical temperature/time limits for polymer modified emulsions

<table>
<thead>
<tr>
<th>Binder Class</th>
<th>Short Term Handling</th>
<th>Storage</th>
<th>Spraying/Application</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max Temp (°C)</td>
<td>Max Holding Time (hrs)</td>
<td>Max Temp (°C)</td>
</tr>
<tr>
<td>SC-E1/E2¹</td>
<td>60</td>
<td>24</td>
<td>Ambient</td>
</tr>
<tr>
<td>SC-E1/E2²</td>
<td>70</td>
<td>24</td>
<td>Ambient</td>
</tr>
<tr>
<td>CC-E1</td>
<td>Ambient</td>
<td>240+</td>
<td>Ambient</td>
</tr>
</tbody>
</table>

Notes
1. This applies to modified emulsions with a binder content of approximately 65% m/m.
2. This applies to modified emulsions with a binder content of approximately 70% m/m.
3. The modified emulsion should be gently circulated at regular intervals to avoid sedimentation over time.
4. If the recommended maximum holding time has been exceeded, the binder should be resampled and tested to ensure compliance to the specification.

9.1.3 Bitumen rubber

Bitumen rubber degrades rapidly at application temperatures which are in excess of 200°C. Therefore the blending of bitumen rubber generally takes place in close proximity to the spray site or asphalt mixing plant. On completion of the digestion period, the product generally has a further usable life at the application temperature of approximately 4 hours. The rate of degradation will vary depending mainly on the application temperature and can be monitored on-site with a hand held Haake viscometer. The manufacturer of the bitumen rubber should supply temperature curves showing the changes in the properties over time. Figure 10 shows typical changes in the viscosity properties of a bitumen rubber at different temperatures over time.

Figure 10: Typical changes in viscosity values for bitumen rubber at different temperatures over time
In order to heat the bitumen rubber to the required elevated temperature a dual set of heating flues are required in the storage and spray tanks. An auger or stirring mechanism is also required to be installed in the vicinity of the heating flues to prevent localised over heating and carbonisation of the binder. A positive displacement gear pump capable of pumping a liquid with a viscosity of up to 7 000 cSt is required to transfer and spray the bitumen rubber binder. Only sufficient quantities of bitumen rubber should be blended at any time in accordance with what can be sprayed or mixed within the application viscosity window of the product. Allowance must be made for changing weather conditions and construction delays. Proper planning and close cooperation between the supplier and contractor is essential to limit the over production of bitumen rubber which may result in unnecessary degradation of the bitumen rubber over prolonged periods of heating. Product must not be superheated if it is not going to be used. This will enable the product to be superheated at a later stage for reuse if it is still within specification. If it is out of specification then up to 25% can be reblended with new bitumen and rubber crumb.

Table 18 shows the recommended temperatures and time limits for the short-term handling, storing, spraying, mixing and application binders modified with bitumen rubber.

<table>
<thead>
<tr>
<th>Binder Class</th>
<th>Short Term Handling</th>
<th>Storage</th>
<th>Spraying/Asphalt mixing/ Application</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max Temp (ºC)</td>
<td>Max Temp (ºC)</td>
<td>Max Holding Time (hrs)</td>
</tr>
<tr>
<td>S-R</td>
<td>165</td>
<td>150</td>
<td>240&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>A-R</td>
<td>165</td>
<td>150</td>
<td>240&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>C-R</td>
<td>165</td>
<td></td>
<td>190</td>
</tr>
</tbody>
</table>

**Notes**
1. If the recommended time period been exceeded the binder should be resampled and tested to ensure that the properties of the binder have not degraded.

### 9.2 Contamination

Contamination of modified binders with other bituminous binders or petroleum products can adversely affect their performance properties. The largest risk of contamination occurs during the transporting and storage of the product. Prior to loading by a haulier, or transferring product into site storage tanks or a sprayer, it is essential that the tank is clean and contains no other product, unless it is a dedicated tank. In the latter case, it is essential to ensure that the existing product in the tank is still in specification. Some modified binders (eg bitumen rubber and hot modified SBR binders) have limited storage lives and are more prone to degradation during prolonged heating. Should this material be mixed with new product, the final product could be out of specification.
When changing products, proper flushing procedures must be followed to avoid any possibility of contamination between incompatible products that could adversely affect the product quality or possibly result in a boil-over in the case of an emulsion. More details are provided in section 3.8 in Sabita Manual related to the changing of product and flushing procedures.

9.3 Quality assurance

Due to the specialist nature and time required to complete some of the prescribed tests, it is not feasible to conduct the full spectrum of tests at the point of manufacture prior to dispatch or on-site prior to application of the binder. The main objective of the quality assurance process is to ensure that product supplied meets the required specification and that the quality of the binder be maintained until it is applied. From the time the product is dispatched from the blending plant it is exposed to the risk of contamination and degradation unless the binder is handled in the correct way. This could occur mainly through over heating and shearing at the different stages of handling from loading, transporting, offloading and storage, until it is mixed with aggregate or sprayed.

To ensure that the properties of the applied modified binder have not changed significantly from that of the original product dispatched from the blending plant, the following quality control measures are recommended:

» The supplier must conduct the necessary tests on the product to ensure that it meets the specification requirements before dispatching the product. The supplier must keep retention samples for each batch for a period of 12 months following the completion of the project. In the case of modified emulsions this period can be reduced to 6 months from date of manufacture.
» The supplier should supply a laboratory certificate for each batch stating the binder properties. This might not include all the test requirements but should contain the indicative tests like softening point. The batch certificate should be faxed to the site or delivered with the haulier driver.
» Samples should be taken from the haulier while discharging the product on-site and retained for further testing in the case of a dispute.
» Samples should be taken from the site storage tank on a daily basis and tested prior to application. In the case of a sprayer samples should be taken for every load sprayed.
» Product not applied can be returned to storage and retested for compliance prior to further use.
» All samples must be clearly labelled with all relevant details for ease of identification and traceability.
» To limit the potential for a dispute between the manufacturer’s and the site laboratory’s test results, it is recommended that correlation testing be done between the laboratories before commencement of the binder supply to identify any discrepancies.

Prior to the commencement of a contract, the full spectrum of tests should be conducted on the first batch of the product to demonstrate the supplier’s ability to comply with the specification. Thereafter, the respective tests are to be conducted at an agreed frequency unless there is a change in the source of raw material (base bitumen or polymer grade). In the case of bitumen rubber, the supplier must also provide a set of curves showing the changes in the flow, softening point and viscosity properties with time for the blend to be used.

Table 19, 20 and 21 provide an indication of the frequency level for all the tests required at the different stages.
### Table 19: Test frequencies for hot polymer modified binders

<table>
<thead>
<tr>
<th>Property</th>
<th>Manufacturer</th>
<th>Haulier</th>
<th>Site storage</th>
<th>Sprayer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Before ageing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Softening Point</td>
<td>Every batch</td>
<td>Every load</td>
<td>Every day</td>
<td>Every load</td>
</tr>
<tr>
<td>Elastic recovery @ 15°C</td>
<td>Every batch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynamic Viscosity @ 165°C</td>
<td>Every batch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage stability @ 160°C¹</td>
<td>Every 10th batch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flash Point</td>
<td>Once, at start of project</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>After ageing (RTFOT)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass change</td>
<td>Every 10th batch</td>
<td></td>
<td></td>
<td>Every 10th load</td>
</tr>
<tr>
<td>Difference in Softening Point</td>
<td>Every 10th batch</td>
<td></td>
<td></td>
<td>Every 10th load</td>
</tr>
<tr>
<td>Elastic recovery @ 15°C</td>
<td>Every 10th batch</td>
<td></td>
<td></td>
<td>Every 10th load</td>
</tr>
<tr>
<td>Dynamic Viscosity @ 165°C²</td>
<td>Every 10th batch</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes**
1. This test should be performed on a frequency basis or whenever there is a change in the source of base bitumen or bitumen crude type.
2. Only required if the binder is used for HMA.
### Table 20: Test frequencies for polymer modified emulsions

<table>
<thead>
<tr>
<th>Property</th>
<th>Manufacturer</th>
<th>Haulier</th>
<th>Site storage</th>
<th>Sprayer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binder content (m/m)</td>
<td>Every batch</td>
<td>Sample only</td>
<td>Every day</td>
<td>Every load</td>
</tr>
<tr>
<td>Saybolt Furol viscosity @ 50°C</td>
<td>Every batch</td>
<td></td>
<td></td>
<td>Every 5th batch</td>
</tr>
<tr>
<td>Residue on sieving (/100 ml)</td>
<td>Every batch</td>
<td></td>
<td></td>
<td>Every 5th batch</td>
</tr>
<tr>
<td>Particle charge</td>
<td></td>
<td></td>
<td></td>
<td>Every 5th batch</td>
</tr>
<tr>
<td>Sedimentation after 60 rotations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Recovered binder residue**

<table>
<thead>
<tr>
<th>Property</th>
<th></th>
<th></th>
<th></th>
<th>Every load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Softening point</td>
<td>Every 5th batch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elastic recovery @ 15°C</td>
<td>Every 5th batch</td>
<td></td>
<td></td>
<td>Every 5th batch</td>
</tr>
</tbody>
</table>

### Table 21: Testing frequency for bitumen rubber

<table>
<thead>
<tr>
<th>Property</th>
<th>Spray tanker</th>
<th>HMA storage tank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Softening point¹</td>
<td>Every load</td>
<td>Every batch</td>
</tr>
<tr>
<td>Dynamic viscosity @ 190°C</td>
<td>At the start of every load</td>
<td>At the start of every batch</td>
</tr>
<tr>
<td>Compression recovery: 5 minutes</td>
<td>Every 5th batch</td>
<td>Every 5th batch</td>
</tr>
<tr>
<td>1 hour 4 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resilience</td>
<td>Every load</td>
<td>Every batch</td>
</tr>
<tr>
<td>Flow</td>
<td>Every load</td>
<td>Every batch</td>
</tr>
</tbody>
</table>
9.4 Site quality control plan

Prior to the commencement of a contract where substantial quantities of modified binders are to be applied, it is recommended that a pre-supply meeting is convened between the modified binder supplier, the contractor and the engineer. The following items should be discussed:

» Quality control issues including:
  • Binder test requirements and testing frequencies;
  • Sampling plan and who is responsible for taking of samples;
  • Responsibility for the provision of laboratory certificates for the base bitumen and the modified binder;
  • Supplier’s method statement regarding the handling and storage temperatures, and time constraints for the various binders;

» The contractor’s production programme and the binder quantities required on a daily basis including:
  • Procedures for ordering product including minimum lead times;
  • On-site binder storage requirements to meet the demand, including heating and pumping requirements;
  • Protocol for re-blending off-specification product;

» Environment management plan for the storage, spillage and waste disposal of binders and flushings.

The above items should be recorded in writing and form part of the quality management plan for compliance by all participants.
10 SAMPLING AND TESTING

The sampling and testing of modified binders are more susceptible to problems than conventional binders due to the fact that they are multiphase systems which are very sensitive to heat and shearing. Hence the thermo-mechanical history of a modified binder could have a major influence on its properties. Therefore, they must be handled in a standard way during the taking and the preparation of samples prior to testing, otherwise the test results could vary substantially beyond the normal precision limits.

10.1 Sampling

All modified binders should be sampled in accordance with the procedures provided in Method MB-1: Sampling of modified binders. MB-1 covers sampling from bulk storage, during loading, from sprayers and drums. It is also important that the samples are truly representative of the batch being tested. Hence, it is imperative that the binder is thoroughly mixed in the tank before sampling to ensure that the binder is homogenous.

10.1.1 Safety precautions

Strict precautions must be adhered to when taking samples of hot modified binders to avoid injury. The procedures set out in section 3.6.1 of Sabita manual 25 titled ‘Quality management in the handling and transport of bituminous binders’ must be adhered to.

All storage tanks and spray tankers should be fitted with sampling valves and the use of a thief sampling device should be avoided. If the spray-bar has nozzles which can be opened individually then a sample can be taken from the spray nozzle. At no stage must an open tin be used to take a sample from the top of a tank. The sampling valve should be located on a circulation line with a permanent support on which to rest the container during filling. Road tankers (haulers) should not be fitted with sampling valves as they have no means of circulating the product. Therefore samples must be taken in-line at the binder plant when loading or when the product is offloaded at the site storage tank.

Appropriate sample containers must be used which are new, clean and can be properly sealed. All sampling should be undertaken by properly trained personnel. Remember that at the end of the day the test result is only as good as the sample taken.

10.1.2 Monitoring of product during handling

As part of every project, sampling and testing protocols should be established from the point of manufacture to application in order to monitor the properties of the binder. Table 22 shows the recommended sampling points in the supply chain:
Table 22: Sample monitoring during handling

<table>
<thead>
<tr>
<th>Sample point</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - From the finished product storage tank prior to releasing the product;</td>
<td>Supplier</td>
</tr>
<tr>
<td>2 - In-line during discharge from the finished product storage tank and the</td>
<td>Supplier</td>
</tr>
<tr>
<td>loading of the road tanker;</td>
<td></td>
</tr>
<tr>
<td>3 - n-line during off loading from the road tanker into the on-site storage</td>
<td>HMA manufacturer/Applicator</td>
</tr>
<tr>
<td>tank or sprayer;</td>
<td></td>
</tr>
<tr>
<td>4 - From the on-site storage tank prior to mixing in a HMA plant or from the</td>
<td>Consultant</td>
</tr>
<tr>
<td>sprayer’s sampling valve prior to spraying</td>
<td></td>
</tr>
</tbody>
</table>

The manufacturer must take a sample from the finished product tank (1) and test the product against the specification prior to releasing the product. The reason thereafter for taking samples at the various points in the supply chain (2, 3 & 4) is for quality assurance purposes. It is important to ensure that the quantity of the sample is sufficient to conduct the necessary tests. The samples taken prior to application (4) should be split into three containers for reference purposes in the case of a dispute in the test results and for further testing.

These samples must be properly labeled with all the relevant information pertaining to the sample taken to provide for adequate traceability in the event of a dispute. The testing frequency must be agreed in the quality management plan and in the absence of such Table 9, 20 and 21 in Chapter 9 can be used as a guideline.

10.1.3 Storage of samples

The above samples are not necessarily tested but retained for the duration of the contract’s defects liability period which is normally a 12 month period after completion of the contract. To ensure that the properties of the sample taken do not change during storage, the samples must be stored:
  » In airtight containers
  » At an ambient temperature of 25°C ± 5°C

Avoid storing the samples in metal shipping containers or outdoors in the direct sun. Any deviation from the above can affect the properties of the sample. In the case of a modified emulsion, the quality of the emulsion will start deteriorating after 3 months thus limiting the duration to a maximum period of 6 months before sedimentation takes place.

10.1.4 Sample preparation

Modified binders are heat sensitive and can undergo significant changes in their properties if exposed to high temperatures for extended periods as this could lead to degradation and/or separation of the polymer from the base bitumen. Hence, improper heating of the samples can affect the properties of the binders and provide a non-representative result of the actual modified binder supplied. To avoid a disparity in test results it is important that the modified binder samples undergo a minimum and controlled amount of heating. Method MB-2: Sample preparation provides a procedure for preparing polymer modified binders and bitumen rubber prior to testing.
A convection oven must be used to reheat samples from room temperature until the binder is liquid enough to handle. The use of a hot plate must be avoided for this purpose as the source of heat cannot be accurately controlled and measured, and will increase the risk of localized over heating. Once the sample is liquid a low shear mechanical stirrer with variable speed should be used to ensure a homogenous sample which is representative of the original binder.

To ensure that the test results are repeatable and reproducible between laboratories, the supplier and engineer should agree on a protocol for reheating the sample in the site laboratory. This should include standardisation in terms of method MB-2 on:

- Type of equipment used to heat the sample.
- Rate and period of heating.
- Type of stirring mechanism to be used.

### 10.2 Testing of modified binders

The samples should be tested in accordance with the methods given in this manual (Appendix 1) to ensure that the results comply with the product requirements. The intention in the longer term is that these methods should be written up into SANS format and will not form part of this guideline in the future. At the time of publishing, discussions were underway with SABS to embark on this process and the reader is urged to monitor these developments.

It is important that split samples of the modified binder are sent to all the participating laboratories (e.g. supplier, site and control laboratories) and tested before commencement of a project to ensure that the results are within the reproducible limits as prescribed by the test methods.

### 10.3 Asphalt mix design

The properties of the modified binder used in hot mix asphalt will influence the engineering properties of the resultant mix. The substitution of a modified binder for conventional bitumen in an asphalt mix can result in higher air voids due to reduced workability of the higher viscosity modified binders. However, the traditional method of determining the binder’s optimum mixing and compaction temperatures based on given viscosities of 170 and 280 Pa.s respectively is not applicable to modified binders. In the latter case, unrealistically high temperatures are obtained when determining equivalent mixing and compaction temperatures for polymer modified binders using this approach. This is due to the phenomenon of ‘shear thinning’ because of the non Newtonian behaviour of these binders.

The recommended approach is to conduct the asphalt mix design using conventional bitumen to determine the mix volumetrics. Once the design target values have been achieved it is recommended that the conventional bitumen is substituted with the modified binder, briquettes are compacted at different temperatures and the resultant air voids of the mix measured. The temperature which equates to the design air voids is then used as the compaction temperature. The changes in the theoretical mix relative densities must also be taken into account. The mixing temperature of the modified asphalt should be approximately 5 to 10°C higher than that of conventional bitumen. As a rule of thumb the compaction temperature should be increased by 3°C per % of SBS modifier used. However, the supplier of the modified binder should be consulted to provide guidelines on mixing and compaction temperatures for this purpose.
11 PROTOCOL FOR INTRODUCING A NEW MODIFIED BINDER

The intention of TG1 is that the recommended limits for modified binders generally remain polymer blind and are based on end property parameters. Therefore, the onus rests on the supplier to source the appropriate type and quantity of polymer to modify the base bitumen in order to meet the end property requirements in line with the specification.

To date the most commonly utilised modifiers have been SBR, SBS, rubber crumbs and, to a lesser degree, EVA. A performance history of these modifiers has been accumulated over the last two decades with the current regime of tests methods prescribed in this document, and the subsequent limits specified, serving mainly the purpose of controlling quality, and consistency of manufacture. Due to the current lack of true performance-based properties and specifications, the recommendations do not necessarily guarantee the binder’s fitness-for-purpose for all the various applications and environmental conditions likely to be encountered during the binder’s service life.

A modified binder is but one component material within a system and factors such as, inter alia; aggregate properties, construction techniques, traffic, temperature as well as mix/seal design methodology will have an influence on its long term performance. The purpose of this section is to develop a protocol for introducing new modified binders in order to encourage innovation in a controlled and responsible manner. This is best achieved through a combination of conducting laboratory tests on the binder (with and without aggregates) and evaluating the binder’s performance during field trials.

11.1 Laboratory testing

Prior to a new modified binder being used in the field it is recommended that the following laboratory tests, where appropriate, should be conducted:

- A full set of tests as specified in accordance with TG1.
- In the case of the binder being used in hotmix asphalt the following comparative tests should be conducted to obtain an indication of the binder’s relative contribution to the desired performance properties of the mix, vis-à-vis against that of a known binder using a standard mix:
  - Rutting test @ 60°C (wheel tracking)
  - MMLS (wet and dry)
  - Fatigue test @ 25°C – ITS, Nottingham tester
  - Moduli – Resilient and Dynamic Creep
  - Adhesion – Riedel & Weber
  - Abrasion – Cantabro test
  - Viscosity parameters to determine mixing and compaction temperatures
  - Binder ageing - RTFOT
  - Compatibility with available base bitumens - Storage stability (changes in properties over time)
  - Special tests – Fuel resistance, Drain down test

- In the case of the binder being used in a seal the following tests should be performed, if relevant, against conventional bitumen and known modified binders:
11.2 Field trials
Field trials should be conducted to evaluate the performance of the new modified binder under varying traffic and climatic conditions over time. The construction of the trial section should allow for the substitution of a known binder in the surfacing seal/hot mix asphalt with the new binder in such a way that the new binder is subjected to the same service conditions as the “control” section. It should however always be borne in mind that it is not always possible to “simply” substitute one particular binder with another (mass/mass or volume/volume) as particular properties could dictate that some adjustments may be necessary to the specific seal or mix design. If at all possible (from the associated risk of poor/non-performance perspective) it is always desirable to construct the trial at varying binder content/application rates in order to fully assess the sensitivity of the product to variations in design. For the construction of hot mix asphalt trial sections, a minimum quantity of 100 tons of asphalt is required to achieve a representative mix. The chainages of the start and end points of the trial sections are to be recorded and marked on site for future assessments. During the construction of the trial section the following aspects need to be recorded:

General
» Section identification
» Date and time of construction
» Weather conditions
» Air and pavement temperatures
» Substrate conditions
» Vertical and horizontal alignment of pavement
» Drainage conditions
» Traffic conditions

Material and construction details
» Component material properties
» Asphalt mix properties
» Modified binder application temperatures
» Application rates
» Type and number of roller passes

Post construction assessment
On completion and at agreed intervals, ideally every 6 months before and after winter, and/or the rainy season, a visual inspection should be carried out of the trial sections along with an appropriate testing protocol. The visual inspection should evaluate, where appropriate, the following functional properties:
» Surfacing texture
» Aggregate loss
» Binder appearance and condition
» Crack extent and activity
» Any signs of surfacing distress
The following measurements and tests should be conducted:

» Rut measurements in wheel tracks
» Surface texture
» Skid resistance
» In situ performance based tests e.g. MMLS (wet or dry)
» Cores or slabs should be taken to determine:
  • Binder properties
  • Asphalt mix volumetrics and engineering properties

The trial sections should be monitored over a period of time to allow for a proper evaluation. However, experience has shown that if problems are likely to be encountered with the performance of a new binder, they will generally be manifested, or give an indication of potential problems, after the first summer and winter cycle.

If funds are available then use should be made of accelerated pavement testing (APT) on the test sections to help predict long term performance of the candidate materials.

It is always desirable to have any performance assessments of “new product” trial sections carried out by knowledgeable and independent practitioners. Information gained from the laboratory tests and field trials must be recorded and made available to road authorities/specifiers so that they will be in a position to make meaningful assessments as to the suitability of the new binder for the required application.
APPENDIX
Sampling and Testing

METHOD MB-1: Sampling of modified binders

1. SCOPe
This test method sets out the procedures for the sampling of polymer modified binders and rubber bitumen blends.

2. DEnITION
The object of sampling to prescribed protocols is to ensure that correct sampling procedures are followed and that results provide the required information on a composite sample that is representative of the whole.

3. APPARATUS
3.1 One-litre open top metal tins fitted with a triple-seal-friction lid for the storing of binders.
3.2 A sampling thief
3.3 A thermometer measuring 0 to 200°C in 1.0°C divisions.
3.4 Heat resistant gloves for handling of hot equipment.
3.5 Safety glasses or face shields for protection whilst sampling.

4. METHOD
4.1 Sampling from bulk storage
Samples should be taken from a bulk tank by means of a sampling “thief” or via a sampling valve. The sample valve may be attached to the side of the tank or built into the discharge line. The sample should be drawn when at least one third and not more that two thirds of the contents of the tank has been discharged.

4.1.1 The contents of the bulk tank should be thoroughly mixed by pump circulation or stirring for at least 30 minutes.
4.1.2 Withdraw approximately 4 litres from the sampling valve and discard by returning to the bulk product in the tank. Draw four one-litre samples for testing purposes. Seal containers immediately after sampling.

4.2 Sampling from Sprayers
4.2.1 Circulate the contents of the sprayer at least 15 minutes before sampling. If the sprayer is fitted with an agitating mechanism such as an auger, the sample can be taken sooner.
4.2.2 The sample can be taken from the spray bar, a sampling valve or through the manhole of the tank, using a sampling thief.

4.3 Sampling from drums
4.3.1 Select the number of drums at random. Sample one drum from each batch and test against specification. If the sample does not comply with the specification, then several containers must be sampled. As a guide, the number should be the cube root of the total number of drums in the batch.
4.3.2 Mix the contents of the drums to be sampled thoroughly by rolling, turning end over end and stirring if necessary.
4.3.3 If emulsion is being sampled, place a suitable rod through the bung and establish whether excessive sediment and/or separation is present at the bottom of the drum. As the rod is withdrawn, examine closely for signs of lumps or extraneous matter.
4.3.4 Pour four one-litre samples for testing purposes. Seal containers immediately after sampling.

4.4 Labelling
Ensure that samples are securely packed for transport to the testing laboratory. The sample must be clearly identified by marking on the lid and the container. The following information should appear on the label.
» Client
» Project Number
» Type of material
» Batch number
Technical Guideline:  
The use of Modified Bituminous Binders in Road Construction

» Date and time
» Sampling temperature

4.5 Storing of samples

Store the samples in a cool place (below 30°C) until they are tested. Bitumen emulsion samples should be tested not later than 10 days after sampling.

5. NOTES

5.1 Safety Precautions

Strict precautions shall be taken at all times to avoid injury or the risk of fire, when handling hot polymer modified binders. The following are some of the precautions to be taken in the handling of these binders:

5.1.1 Safety glasses or face shields must be worn whilst sampling.

5.1.2 Heat resistant gloves, with close fitting cuffs and other suitable protective clothing should be worn during sampling.

5.1.3 Sample containers should be held with tongs or supported on a suitable tray whilst the sample is being taken.

5.1.4 Smoking should not be allowed during sampling.

5.1.5 Sampling personnel should stand away from the sampling valve and on the windward side.

5.1.6 The sample valve should be opened very slowly to prevent a sudden outflow of hot material.

5.1.7 See also SABITA Manual

5.2 Sampling precautions

5.2.1 Samples shall be taken in clean one-litre containers free from any contamination by solvents and other bituminous binders.

5.2.2 Seal the sample tightly immediately after sampling. Wipe any spilled material on the outside of the tin with a clean dry cloth immediately after sampling. Do not use solvent soaked cloths

Reference:
Austroads Modified Binder Test MBT 01.200
METHOD MB-2: Sample preparation

1. **SCOPE**

   This method describes how samples of homogenous polymer modified bitumen and non-homogenous bitumen-rubber bitumen is prepared prior to testing.

2. **APPARATUS**

2.1 An oven capable of temperatures of 200°C for heating bituminous materials with an accuracy of ±5°C

2.2 Spatula suitable for stirring the samples

2.3 Thermometer to read up to 200°C in 1°C divisions.

2.4 Controllable hot plates or Bunsen burner

3. **METHOD**

Sample reduction from bulk (samples larger than 2 litres). This method is not applicable to modified bitumen emulsions. The procedure shall be as follows:

Maintain the oven at 160°C

(a) Heat the bulk sample to a temperature of 160°C, allowing sufficient time to reach this temperature.

(b) Remove the sample from the oven and thoroughly stir it for 30 seconds with a spatula without entraining air.

(c) Divide the bulk sample into sub-samples using smaller containers of 1 litre capacity.

3.1 Bitumen emulsion

Open the sample container and examine the sample for signs of settlement. Stir the sample until homogenous before testing. If unable to reconstitute the sample due to irreversible settlement, mark the sample "Unable to test due to settlement".

3.2 Bitumen-rubber

3.2.1 It is assumed that the samples are cold when received.

3.2.2 Two one litre samples are required. One sample for the viscosity test and the second sample for the remainder of the tests.

3.2.3 Open the sample containers. If unable to remove the lids, make a small hole in the lids to allow for air to escape.

3.2.4 Place the samples in an oven maintained at 180°C.

3.2.5 After two hours in the oven, the temperature of the samples should be approximately 180°C and the binder should be sufficiently fluid. Do not keep in the oven for longer than 3 hours.

3.2.6 Remove the sample required for the viscosity test from the oven. Heat to the final test temperature of 190°C over a suitable heat source, whilst stirring continuously with a spatula, before performing the viscosity test.

3.2.7 Homogenise the second sample by stirring for approximately 1 minute with a spatula after removal from the oven. Gentle heating over a controllable heat source will be required to maintain the temperature at approximately 160–170°C.

3.2.8 Immediately pour into the test moulds.

**Note:** If hot sub-samples are received, samples can be split as per 3.2.2 above. The samples must then be allowed to cool down completely before proceeding to step 3.2.3.

3.3 Polymer modified binders of the type A-P1, A-H1 & A-H2

3.3.1 It is assumed that the sample is cold when received.

3.3.2 Open the sample container. If unable to remove the lid, make a small hole in the lid to allow for air to escape.

3.3.3 Place the sample in an oven maintained at a temperature of 180 ± 5°C.

3.3.4 After two hours the samples should be sufficiently fluid. Do not keep in the oven for longer than 3 hours.

3.3.5 Homogenise the sample by stirring for approximately 5 minutes with a spatula whilst heating over a controllable heat source. Do not heat to a temperature higher than 180°C.

3.3.6 Immediately pour into the test moulds.

**Note:** If hot sub-samples are received, the samples must be allowed to cool down completely before proceeding to step 3.3.2.

3.4 Polymer modified binders of the type S-E1, A-E1, S-E2 and A-E2
3.4.1 It is assumed that the sample is cold when received.
3.4.2 Open the sample container. If unable to remove the lid, make a small hole in the lid to allow for air to escape.
3.4.3 Place the sample in an oven maintained at a temperature of 180 ± 5°C.
3.4.4 After two hours the sample should be sufficiently fluid to pour. Do not keep in the oven for longer than 3 hours.
3.4.5 Homogenise the sample by stirring for 30 minutes with a variable speed electric stirrer fitted with a paddle mixer, whilst controlling the temperature at 170 to 180°C. The speed of the stirrer should be carefully controlled to minimise the risk of entraining air into the sample.
3.4.6 Immediately pour into the test moulds.

**Note:** If hot sub-samples are received, the samples must be allowed to cool down completely before proceeding to step 3.4.2.

4. **GENERAL**

4.1 Polymer modified binders are complex mixtures of polymers, bitumen and other petroleum additives. Due to the higher than normal handling temperatures, the risk of burning with polymer-modified bitumens is higher than with standard bitumens. Notices describing the action to be taken in case of burns should be prominently displayed in the laboratory. The safety precautions mentioned under "Method MB-1 of sampling polymer modified binders" should be taken.

4.2 As the properties of polymer modified binders are affected by the handling of the sample in the preparation of test specimens, it is necessary to strictly adhere to the preparation procedures described above.

4.3 Polymer modified bitumen is characterized by the formation of a structure on cooling after blending of the constituents. The sample must thus be heated to a temperature at which this structure will be broken down before testing and moulding test specimens. The rate of cooling influences the structure formation and, therefore, conditions under which specimens are cooled prior to testing must be controlled.

4.4 Polymer modified binders are heat sensitive materials and may undergo significant changes in their properties if exposed to high temperatures for extended periods. Improper heating can therefore, result in sample test results that may not truly represent the characteristics of the material.
METHOD MB-3: Modified rolling thin film oven test

1. SCOPE

This test method sets out the procedure to measure the effect of heat and air on a moving film of semi-solid polymer modified bitumen material. In order to address the complex flow characteristics that occur in the RTFO bottles an alternative test method has been developed to reduce this problem. This method has a larger quantity of binder and a metal treatment bottle with an internal roller to assist the flow of the binder through treatment.

2. DEFINITION

The test simulates the effect of the manufacturing process where bitumen is hot mixed with aggregate for asphalt production. The oxidation effects at mixing temperatures (typically in the range of 150°C to 170°C on the thin binder films that occur during asphalt manufacture, transportation and placement are simulated by the RTFO test conducted at an oven temperature of 163°C over a period of 90 minutes. This test therefore indicates approximate change in properties of bitumen, which is indicated by viscosity measurements, ductility measurements, penetration and elastic recovery testing undertaken on the binder residue that remains after the RTFO test is completed.

3. APPARATUS

The following apparatus is required in addition to that listed in ASTM: D 2872 – 88 (see note 5.1)

3.1 A suitable balance of 1 kg capacity to 0,001g

3.2 Metal treatment bottles and rollers in accordance with the description in Figure 1.

4. METHOD

4.1 Sample Preparation

PMB samples for testing shall be prepared in accordance with method MB-1 and method MB-2

Heat the sample in its container with a loosely fitted cover in an oven not exceeding the treatment temperature for the minimum time necessary to ensure that the sample is completely fluid. Manually stir the sample but avoid incorporating air bubbles. Select the required number of sample bottles to produce sufficient material for characterizing tests, which are to be performed on the residue. Allow the treatment bottles (with rollers) to cool to approximately room temperature (18 – 25°C)

4.2 Sample Treatment

With the oven at the treatment temperature for at least 2 hours, insert the treatment bottles and rollers into the carriage in a balanced arrangement and fill any remaining spaces with empty bottles.

Leave the samples for 30 minutes without rotating the carriage or any air flowing.

Start the rotation of the carriage and the air flow with the flow meter indicating 4± 0.5 L/min

Maintain the samples in the oven for 60 min (± 10s), and then switch off the carriage and airflow.

4.3 Treatment Sample

Leave the samples to settle in the oven for 1 – 2 minutes. To aid sample collection, the lid can be removed and the roller suspended above the treated material.

Taking out one bottle at a time, pour the contents from each bottle into a suitable container for testing. Drain each bottle until the treated material stops running freely (just dripping)

Stir the material in the container briefly to ensure that the contents from all bottles are mixed to yield a representative sample.

Testing on the treated samples should be completed within 24 hours.

5. REPORT

A comment on the sample behaviour during the test, in terms of its flow characteristics.

If sample flow is restricted at any stage during the test, oxidation of the binder, or loss of volatiles will be reduced and the test will not truly reflect the real effects of asphalt plant mixing and transportation.
6. **NOTES**

When testing binders with the roller method a wire hook (paper clip) can be used to support the roller over the open treatment bottle. This encourages complete drainage of the binder back into the bottle.

6.1 The preparation of the oven shall be in accordance with ASTM: D2872-88 but adapted using the apparatus shown in Figure 1.

6.2 When the quantitative value of the loss in mass is required use two separate treatment bottles for the determination. Cool the containers for the test to room temperature and weigh each treatment separately to the nearest 0,001g. Proceed as per 3.2. At the conclusion of the testing period remove the treatment bottles from the oven. Cool the treatment bottles to room temperature in a desiccator. Weigh to the nearest 0,001g and calculate the loss on the basis of the binder in the bottle. Discard the residue.

**References:**

ASTM: D2072 – 88
Austroads MBT 03: 2000

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**Technical Guideline:**

**The use of Modified Bituminous Binders in Road Construction**

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**A** Brass tube (length
Closed at base with 1.6 mm brass plate
External thread to match cap at top

**B** Nominal (2.5 inch Φ) 1.6 mm wall

**C** Air hole in screw cap (diameter)

**C1** Internal recess approximately 3 mm deep

**D** 20 mm Φ standard brass threaded tube

**E** Length of roller including ends
With 90 degree left hand twist from end of roller

**F** Length of 1.6 mm brass end pieces

140 ± 1mm

63 ± 1 mm

12 ± 0.5 mm

30 ± 1 mm

120 ± 1 mm

138 (+) – 1 mm

40 ± 2mm
METHOD MB-4: Elastic recovery of polymer modified binders by ductilometer

1. SCOPE

This test method is used for the characterization of the elastic properties of a polymer modified bituminous binder.

Duplicate samples are extended under pre-determined conditions for a distance of 200 mm and the elongated thread is cut. After a recovery period of one hour the extent of the recovery of the thread is determined.

2. APPARATUS

2.1 Specimen Composite Moulds
Two composite moulds as specified in figure 1 shall be used to form the specimens. The moulds consists of a base plate made of a non-corrosive metal, fitted with a clamping device, and of four frame pieces made of a copper-zinc alloy (brass), as shown in figure 2. The four frame pieces consist of two side-pieces and of two end-pieces, known as clips, in each of which a hole is bored for attachment to the stay bolt plates of the testing machine. The bores in the clips shall be so designed that they fit easily, but without play, onto the stay bolts.

2.2 Ductilometer
The Ductilometer consists of a trough as specified in sub-clause 2.2.1 in conjunction with a testing machine as specified in sub-clause 2.2.2, and a measuring instrument as specified in sub-clause 2.2.3. The ductilometer shall be designed so as to ensure vibration-free testing.

2.2.1 Trough
The trough shall permit an elongation of the briquette specimens to a length of at least 100 cm. Its dimensions shall be such that at least two specimens may be tested side by side. The clearance between the moulds containing the briquette specimens and the sidewalls of the trough shall be not less than 10 mm. When the trough is two-thirds full, the bath liquid shall cover the moulds, attached to the testing machine, both above and below by at least 25 mm. An opal glass sheet shall be placed over the bottom of the trough.

Maintenance of the temperature limits specified in sub clause 3.3 shall be ensured by circulating the bath liquid through the connected thermostat (see sub clause 2.3), and if necessary by the provision of additional insulation.

While the specimens are being pulled apart, the circulation of the bath shall not be switched off, but its rate of flow shall be reduced to such an extent that the threads are not visibly affected by the flow of the liquid. When a moving deflector is fitted at the water inlet point, experience has shown that a rate of water circulation of up to 1.5 litres per minute may be permitted.

2.2.2 Testing machine
The testing machine shall be capable of pulling apart two specimens simultaneously. The specimens shall be held by two plates made of non-corrosive metal fitted with stay bolts (see figure 3). At least one of these plates shall be movable in the direction of pull. The diameter of the stay bolts shall be (8 ± 0.1) mm. The drive of the testing machine shall be so designed that the stay bolts may be pulled apart at a uniform speed of 50 mm/min ± 2.5 mm/min throughout the test. The specified speed shall, in particular, be maintained even when high deformation resistance has to be overcome at the start of the test. Periodic checks shall be made, under load, to establish whether the testing machine can maintain the specified pulling speed.

Note: It will be found useful to use mechanical step-down gearing to permit the selection of other, lower speeds, such as 20, 10 or 5 mm/min.

A stop shall be provided to ensure that in the initial position of the testing machine the distance between the bores in the clips exactly corresponds to that between the stay bolts.

2.2.3 Measuring instrument
The scale interval of the measuring instrument for determining the distance of elongation shall not be greater than 5 mm.

2.3 Thermostat
The thermostat controlling the temperature in the trough of the ductilometer and in the water bath (see sub-clause 2.5) must be capable of keeping temperatures constant within ± 0.2°C.

2.4 Thermometer
DIN 12775 – E 0,1/0/50 thermometer.

2.5 Water Bath
The water bath, for preheating the briquette specimens, shall have a capacity of not less than 10 litres capacity, and a filling height of not less than 70 mm. It shall contain a perforated shelf, supported in a position 25
mm above the bottom of the bath. The water bath shall be so dimensioned that, when the briquette specimens, locked to their base plates, are placed on the perforated shelf, they shall be at least 10 mm apart and at a distance of at least 10 mm from the side walls of the bath. The water bath shall be filled to a level where the surface of the briquette specimen is covered by bath liquid to a depth of at least 25 mm. The trough (see sub-clause 2.2.1) may also be used for preheating the specimens.

2.6 Knife
The knife shall have a straight cutting edge of at least 40 mm in length, or a planing blade.

2.7 Mould Release Agent
For example, a mixture of equal parts of glycerin and dextrin.

2.8 Bath Liquid
Bath liquid for filling the water bath as specified in sub-clause 2.5 and the trough as specified in sub-clause 2.2.1. The water shall be free of surface-active additives.

If differences between the specific gravity of the water and the density of the specimen material disturbs the formation of the thread, causing it either to rise to the surface or sink to the bottom of the bath, then the specific gravity of the bath liquid in the trough shall be adjusted to the density of the specimen material by the addition of either methyl alcohol or sodium chloride.

3. TEST SPECIMEN PREPARATION

The samples, taken according to the method given in MB-1 and MB-2, shall be prepared as described in DIN 52003. The test shall be carried out using two specimens, each weighing approximately 20 g.

3.1 Preparation of the composite moulds
The base plate and the wedge-shaped surfaces of the sidepieces of each mould shall be lightly coated with a mould release agent, such as that specified in sub-clause 2.7. Then the frame pieces of the mould shall be assembled on the base plate as shown in figure 2, the clamping device being used to lock the frame pieces rigidly to the base plate, forming a tight seal at all points of contact. A check shall be made that the distance between the sidepieces of the adjacent moulds is \((10 \pm 0,1)\) mm.

3.2 Filling the two composite moulds
The two moulds, slightly heated if necessary, shall be filled, care being taken to avoid the formation of bubbles, by pouring the molten sample until the meniscus rises noticeably above the level of each mould. Particular attention shall be paid when filling the moulds that the right-angled edges between base plate and frame pieces are entirely filled, the same applying to the undercuts in the clips.

3.3 Heat treatment of briquette specimens
After filling, the moulds shall initially be left, protected against dust, for 30 minutes to cool to room temperature, then transferred to the water bath maintained at the test temperature to within ± 0,2°C. The clearances between the briquette specimens and to the sidewalls, as specified in sub-clause 2.5, shall be checked, as well as the depth of immersion of the specimens in the bath fluid.

The moulds containing the briquette specimens shall first be kept for 30 minutes in the water bath. Then the excess binder shall be cut off level with the mould frame with the aid of a warmed knife. The moulds shall then be returned immediately to the water bath, maintained at the test temperature, and kept there for a further 85 - 95 minutes.

Between filling the moulds and starting the elongation operation in the ductilometer, \((150 \pm 10)\) minutes shall have elapsed.

4. TEST PROCEDURE

After the specified heat treatment, the briquette specimens shall be lifted off the base plate and transferred to the ductilometer trough, where the clips shall be mounted on the stay bolts of the testing machine which has been brought into the initial position for the test. The scale of the testing machine shall previously have been adjusted to the zero setting. Then the sidepieces shall be carefully removed. Circulation of the bath liquid shall now be reduced, being set either at or below the maximum permissible rate of flow specified. Throughout the test, the temperature shall not vary from the initial temperature by more than 0,3°C.

The testing machine specified in sub-clause 2.2.2 shall now be actuated. The threads formed by the two briquette specimens, as they are pulled apart shall be observed and the appearance of clumps (pearling) shall be reported.

Threads shall be suspended at a level about halfway between the surface of the liquid and the bottom of the trough. If the threads rise to the surface to sink to the bottom, the specific gravity of the bath liquid shall be corrected as described in sub-clause 2.8, and the test repeated.
The samples shall be elongated to a distance of 200 mm. After the elongation distance of 200 mm has been reached, stop the ductilometer and hold the sample in its elongated position for five minutes. After five minutes clip the sample approximately in half by means of a scissors or other suitable cutting device. Let the sample remain undisturbed in the ductilometer for a one-hour recovery period. At the end of this time, retract the half sample specimen until the two broken ends touch. At this point note the elongation in mm.

5. **CALCULATIONS AND REPORT**

Calculate the percent recovery by the following formula:

\[
\text{% Recovery} = \frac{(200-E)}{200}
\]

Where E represents the observed elongation after rejoining of the sample

Report the percent recovery to the nearest whole percentage point. Repeat the test if the duplicate test results differ by more than two percentage points.

---

**Figure 1:** Example of a composite mould for forming the briquette specimens

**Figure 2:** Frame pieces of the composite mould

**Figure 3:** Stay bolt plates of the testing machine with two briquette specimens in the initial position
METHOD MB-5: Torsional recovery of polymer modified binders

1. SCOPE

This test method sets out the procedure for the determination of torsional recovery of polymer modified binders using a sample bolt and cup assembly.

2. DEFINITION

A simple means of determining the elastic properties of a polymer-modified binder is to measure its Torsional recovery.

3. APPARATUS

3.1 A cylindrical headed aluminium bolt assembly, as illustrated in Figure 4 with a total mass of 45 ± 5g. The bolt has a cylindrical head with a diameter of 28.6 mm and a thickness of 9.52mm. The threaded shank of the bolt is 44.5 mm long. A metal “spider”, with three radial pins and two nuts, can be used to centre the assembly. A pointer is required for angle measurements in the absence of the spider. See Figure 1 for details of this assembly and the optional components.

3.2 A sample tin, cylindrical, flat bottomed and 55mm in diameter.

3.3 An angle-measuring device and sample clamp assembly, or an alternative means of clamping the sample/bolt assembly and determining the initial and recovered angle. The recommended device provides a scale, of 80 mm radius and graduated in degrees around at least half its circumference, and a clamp capable of holding the sample cup within 3 mm of its centre and without deforming the cup by more than 3 mm in any direction.

3.4 A water bath capable of operating at 25± 0.5°C, fitted with an appropriate thermometer.

3.5 A drying oven, thermostatically controlled and capable of maintaining a temperature of 60°C to 200°C, with a set point accuracy of ± 5°C.

3.6 A stop watch

3.7 A spanner to suit the bolt assembly

4. METHOD

The torsional recovery apparatus operates by manually rotating an aluminium bolt, previously embedded in a cup of modified binder, through an angel of 180 degrees and measuring the extent of recovery of the original applied rotation. The initial 180-degree twist is applied with a spanner over a 10 second period. The recovery after 30 seconds is reported.

4.1 Prepare the sample as described in Method MB-2

Assemble the bolt; spider and nuts to position the surface of the bolt head 8 ± 2 mm below the top of the sample cup. Preheat the assembly and cup to 180°C and pour the modified binder into the tin assembly, until it begins to form meniscus on the top surface of the bolt.

4.2 Testing

Allow the assembly to cool for one hour by leaving it to stand at room temperature (25 ± 3°C). Adjust the assembly height to keep the top surface of the bolt flush with the sample surface. Place the assembly into the 25°C water bath and allow it to stabilize for one hour (see Note 6.1) Adjust the spider to a position 7 ± 2mm above the rim and return the assembly to the bath. Place the sample assembly on the base-plate and fit the pointer to the 180-degree position without disturbing the sample. Using the spanner, turn the bolt moving the pointer from the 180-degree position to the zero position using a steady motion for 10 seconds (see Note 6.2). Release the bolt when the pointer reaches the zero position and commence timing (see Note 6.3). Record the recovered angel after 30 seconds as A.

5. CALCULATION

The torsional recovery is given by the following equation:

\[
\text{Torsional recovery, } \% = \frac{A}{180} \times 100
\]

Where A = recovered angle in degrees

When the scale presented in figure 2 is used, the torsional recovery is read directly.
6. **NOTES**

6.1 The test should be conducted in an air-conditioned laboratory at 25 ±3°C. Alternatively the test can be conducted within the water bath.

6.2 The rate at which the torque is applied to the sample is critical for reproducible results. The objective is to apply 180 degrees of rotation in 10 seconds. Figure 2 presents a practical scale marked from zero (0 degrees) to 10 (180 degrees) to help with this task.

6.3 The spider assembly should not come into contact with the rim of the cup at any time during the recovery phase.

6.4 The following precautions should be taken when handling all bitumens:
   a) Eye protection, such as safety glasses and/or face shields, shall be worn when handling hot bitumen.
   b) Heat resistant gloves, with close fitting cuffs, and other suitable protective clothing shall be worn when handling hot bitumen.
   c) There shall be no smoking while handling hot bitumen.
   d) While the material is still cold, loosen the lid of the sample container (invert the can and warm the lid, if necessary), or punch a hole in the lid.

7. **ACCEPTABILITY OF RESULTS**

The following criteria could be used for judging acceptability of results.

<table>
<thead>
<tr>
<th>Property</th>
<th>Units of Precision</th>
<th>Repeatability (r)</th>
<th>Reproducibility (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torsional Recovery</td>
<td>Units of measurement (*)</td>
<td>0.09 ( \sqrt{\text{m (100 - m)}} )</td>
<td>0.30 ( \sqrt{\text{m (100 - m)}} )</td>
</tr>
</tbody>
</table>

Where \( m \) is the mean test result

(*) While actual result for these properties are calculated in percent, the generic term “units of measurement” is preferred to avoid any confusion between the absolute value (percent) or percentage of the actual value.

**Reference:** Austroads MBT22: 2000
Figure 2  Practical scale marked from 0 to 10 seconds (0 to 100 percent recovery)
METHOD MB-6: Storage stability of polymer modified binders

1. SCOPE

This test method sets out the procedures for the determination of the stability of a modified binder. The Softening Points (ring & ball) are determined of the upper and lower sections of a sample stored vertically for three days.

2. DEFINITIONS

Stability is the resistance to segregation between the modifying agent and the base bitumen when the modified binder is stored hot.

3. APPARATUS

3.1 An open ended 300mm long glass tube with a diameter of 12.5mm
3.2 Silicon Rubber stoppers (capable of withstanding temps of 175°C) to cork a 12.5mm diameter tube.
3.3 An oven, thermostatically controlled to maintain a temperature of 160°C ± 2°C
3.4 A stand with a clamp that will hold the glass tube vertically in the oven
3.5 A glass cutter
3.6 Ring and ball apparatus according to method ASTM D36

4. METHOD

4.1 Preparation of test sample

A sample of approximately 100ml of modified binder is heated in an oven set at 160°C ±2°C for not longer than 60 minutes

Pour the melted sample into the glass tube (after corking the base) to about 10mm from the top. Cork the top of the glass tube. Ensure that the cork has a v-notch cut along its length to act as a breather. Place the glass tube in the oven (set at 160°C ± 2°C) in a vertical position (using the standard clamp). The sample must remain in the oven for three days at 160°C ±2°C. After three days remove the glass tube and allow it to cool to room temperature. The sample must then be cooled to about 0°C. At this temperature cut the tube with a glasscutter transversely into three equal sections.

Prepare the top and bottom section in accordance with method ASTM D36 (ring & ball) to determine the softening points of the top and bottom respectively.

5. CALCULATIONS

Calculate the difference in softening point between the top and bottom section and record in °C.
METHOD MB-7: Modified Vialit adhesion test

1. SCOPE
This test method describes the procedure for determining the adhesive and cohesive properties of modified binders to aggregate at 5°C and 25°C.

2. APPARATUS
The apparatus is illustrated in Figure 1.

Testing Plate:
The testing plate shall be of mild steel, 2 mm thick, and measure 200mm by 200mm. The surfacing of the plate shall be grooved to a 250 μm CLA specification and the entire plate shall be rust proofed by electrolysis nickel plating.

Vialit Apparatus:
The apparatus shall consist of a metal base, horizontally regulated by three adjusting screws and two levels. The test plate is located within four right-angled vertical guides and supported horizontally at a height of 100–150 mm above the base of the apparatus. A steel shaft is attached to the base with a cylindrical ball guide attached to the shaft and positioned such that when the ball is released, it falls through a distance of 500mm before striking the centre of the testing plate.

Ball:
The ball shall consist of stainless steel, 50mm in diameter and weigh 510g +/- 5g.

Roller:
Consisting of a steel cylinder nominally 210 mm diameter x 250 mm, covered with a 13mm thick rubber coating and fitted with a 1,1m steel handle. The roller assembly is ballasted with water to a total mass of 25 +/- 1 kg.

Ring:
A brass ring of OD 154mm +/- 5 mm, 10 mm height

3. METHOD
By means of the brass ring form a circular well with putty or other suitable sealant (e.g. Prestik) positioned approximately in the middle of the testing plate. Remove the ring leaving the sealant ring behind.

Pre-heat the plate and modified binder to be tested in an oven to a temperature of 160°C. Remove the plate and binder, and apply 22,4 g (equivalent to 1,2 l/m²) of the binder evenly within the sealant well. Equilibrate the test plate on a hot plate to 65°C.

For specification control purposes, apply dry, dust-free quartz aggregate of nominal size 9,5 mm to the binder in such a way that a shoulder to shoulder mosaic is achieved, with the aggregate orientated so that it lies along the direction of its ALD. Do not apply downward pressure when placing the aggregate.

The aggregate must be applied within three minutes of removing the binder and plates from the oven.

After the aggregate placement remove the test plate from the hot plate and roll the aggregate with the roller with three single traverses perpendicular to one side. Rotate the plate by 90° and apply another three passé with the roller. The rolling operation must be complete within one minute of removing the test plate from the hot plate.

Count the number of aggregate chips applied (Z)

Condition the test plate at the test temperature (5°C or 25°C) for one hour.

After conditioning, the plate is turned upside down within the Vialit apparatus and the ball is dropped onto the plate. The time from the removal of the plate from the conditioning cabinet to the dropping of the ball should not exceed 25 seconds.

Note:
The procedure as written is for specification compliance. It may be modified to specific site conditions as follows:
» Pre-coating may be applied to the aggregate
» The binder application rate may be adjusted to site conditions
» The aggregate should be altered to that used on site.
» The temperature at which the aggregate is applied may be adjusted to the average site temperature of the binder at aggregate application.
4. REPORTING

Count the number of chips lost (L) after impact. The degree of retention, R is calculated as follows:

\[ R = \frac{(Z-L)}{Z} \times 100 \]

Where Z = the total number of chips applied.

Also report any deviations from the specification test method, w.r.t. application rates, temperature and aggregate size.

*Figure 1: The Modified Vialit Adhesion Testing Equipment*
METHOD MB-8: Pull out test method for surfacing aggregate

1. SCOPE

This method sets out the procedure for the determination of the pull out test for surfacing aggregates.

2. DEFINITION

The pull out load test is the load required to dislodge a stone chip from a bituminous seal on the road to assess when the surface treatment can be opened to traffic.

3. APPARATUS

3.1 A spring balance with a capacity of 1000g and graduated every 10g.
3.2 Crocodile clips or small spring loaded battery clamps with attached nylon or string approximately 0.6m long.
3.3 Large headed nails, 200mm x 25mm long, which have been bent to form hooks.
3.4 A 1m long strip of neoprene sponge rubber, 20mm wide and 3mm thick.
3.5 One tube of high strength flexible “Pratley wonder-fix”.
3.6 One tube of “Pattex” super gel.
3.7 One pair of scissors.
3.8 A contact thermometer reading 80°C in 0.1°C divisions.

4. PREPARATION OF APPARATUS

Method A describes the preparation using glued hooks. Glued hooks should only be used for aggregate that has not been pre-coated. Method B describes the preparation using crocodile clips and can be used for uncoated or coated aggregate.

4.1 Method A (Preparation of hooks)

Soak the nail hooks in boiling water and detergent for five minutes to remove all traces of oil. Remove from the water and allow to dry. Cut the neoprene rubber strip into small squares with sides between 7mm and 8mm long. Glue the rubber pads to the heads of each hook using high strength flexible Pratley wonder fix. Allow the glue to dry for 24 hours.

Attachment of hooks to stones

Apply a thin layer of Pattex super gel to the rubber pad and immediately place on top of one of the stones so that the hook is standing vertically. Hold firmly in place for 10 seconds. Repeat until all the hooks are attached. Allow at least five minutes before applying a load to any of the hooks. Attach a spring clip to the spring balance using a suitable length of nylon line. Attach a typical stone and hook to the ring clip and zero the spring balance. Complete the test as per section 4.0.

4.2 Method B (using crocodile clips)

Attach crocodile clips to each end of a suitable length of nylon line. Attach one end to the spring balance. The length of line should be such that the zero point of the scale is at eye level. Place an average sized stone into the crocodile clip and zero spring balance. Complete this test method as per section 4.0.

5. TEST METHOD

Select an area of the road surface in either the left or right wheel path of the surfacing. Measure and record the surface temperature to the nearest 0.5°C using the contact thermometer. The thermometer should be placed against several stones in the vicinity of the test and an average taken. Record the start times of the test and temperatures. Select a stone and attach the crocodile clip or attach the hook glued to the stone. Slowly raise the upper portion of the scale and apply a pull out rate of 20g/second. Monitor the scale carefully and continue the load increments until the stone becomes detached. Record the maximum reading on the pullout test data sheet (fig 1). Remove the stone from the clip and repeat the test a further nine times at this position. If the stone twists during the test and results in a significantly reduced pull out force, the result should be ignored.

6. CALCULATIONS

Apply a temperature correction factor to the data to give pull out loads at 40°C or such other temperature in the range of 15°C to 50°C as may be expected on the road. The following formula and preliminary constants for various binders should be used:

\[ f_2 = f_1 \times 10^{(a \times (T_2 - T_1))} \]

Where:
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\[ f_2 = \text{pull out force (gram @ temp } T_2 \text{ (°C)} \]
\[ f_1 = \text{pull out force (gram @ temp } T_1 \text{ (°C)} \]
\[ m = \text{constant} = 0.050 \text{ for conventional binders} = 0.033 \text{ for polymer modified binders} = 0.025 \text{ for bitumen - rubber} \]

At temperatures below 15°C the binder becomes more brittle and the above corrections no longer apply.

Calculate the mean and standard deviation of the temperature corrected data. The mean value of 1 standard deviation approximates the 10th percentile value. Depending on the traffic volumes and speeds, and the consequences of stripping, the 15th percentile value or 10th percentile value should be used to assess whether the road could be opened to traffic.

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<thead>
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<td>Location: Date:</td>
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<tr>
<td>Seal Placed: Date: Time: Application:</td>
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<tr>
<td>Binder Type: Stone Size: ALD:</td>
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<td>Comments on stone loss:</td>
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<table>
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<th>TEST NUMBER</th>
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<tr>
<td>End</td>
<td></td>
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<table>
<thead>
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<th>Stone Number</th>
<th>Pull-out load (g)</th>
<th>Stone dimensions (mm)</th>
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<td></td>
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<td>10</td>
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<td>Average</td>
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<tr>
<td>Std dev</td>
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</tbody>
</table>
7. CRITERIA

Preliminary criteria for opening to traffic are tabulated in the table below.

<table>
<thead>
<tr>
<th>Geometry</th>
<th>Traffic volume (vpd)</th>
<th>Minimum likely pull out force taking temperature changes into account</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer: temperatures generally &gt; 15°C</td>
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<td></td>
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<tr>
<td>Straight</td>
<td>&lt; 4 000</td>
<td>100</td>
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<tr>
<td>Curves</td>
<td>&gt; 4 000</td>
<td>150</td>
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<tr>
<td>200 800m</td>
<td>&lt; 4 000</td>
<td>200</td>
</tr>
<tr>
<td>Sharp Curves and intersections</td>
<td>&gt;4 000</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td></td>
<td>300</td>
</tr>
<tr>
<td>Winter: Temperatures can drop to &lt;5°C</td>
<td></td>
<td></td>
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<tr>
<td>Straight</td>
<td>&lt; 4 000</td>
<td>200</td>
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<td>Curves</td>
<td>&gt; 4 000</td>
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<tr>
<td>200 800m</td>
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<td>Sharp Curves and intersections</td>
<td>&gt;4 000</td>
<td>300</td>
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<td></td>
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<td>350</td>
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</tbody>
</table>

**References:** Sabita Manual 3

Data table for pull-out test for surfacing aggregate
METHOD MB-9: Pliers test for assessment of adhesion properties

1. PURPOSE

The main and overriding criterion at the time of construction of the seal is to achieve adhesion between the binder and the aggregate. The pliers test can be used to quickly check the effective wetting and adhesion binder characteristics for the prevailing conditions. This test can also be performed in the laboratory to simulate site conditions.

2. TEST LOCATION ON SITE

The most important consideration is the time interval between spraying the binder and spreading the last of the aggregate. The test should be conducted at least at two points, say midway along the sprayer run, and towards the end of the run.

3. METHOD

» After spraying the binder, but immediately before spreading the aggregate:

» Drop several pieces of precoated aggregate onto the binder from a height of about 25-30 mm.

» Let them remain there for a minute

» Then pick them up cleanly.

» Note: Do not throw, press or push the aggregate to try and assist the adhesion process, but drop and pick up the aggregate pieces cleanly.

4. VISUAL ASSESSMENT

Visually examine the pieces of aggregate and assess the binder characteristics from the binder film adhering on the surface of the aggregate pieces.

» Correct adhesion – a thick and black film of the binder will have coated and adhered to the face of the aggregate pieces, and there may be short tails formed to indicate the setting up of the binder is taking place.

» Poor adhesion – the binder will not have adhered, and there is nil or only minimal coating on the face of aggregate pieces.

» Binder viscosity too low – there will be wetting and adhesion, but the binder film will most likely be very thin and may be brownish, rather than black, in colour. The binder may also be flowing or dripping from the aggregate depending on the rate of application of the binder and the condition and influence of the aggregate pre-coating.

5. QUALITY CONTROL ON SITE

As part of the normal operations along the job, aggregate particles should be removed at various stages after spreading and rolling to assess the effectiveness of the adhesion to the binder. If adequate wetting and adhesion is not achieved, the seal will probably be a failure regardless of the accuracy of the design and actual rates of application achieved.
Plate I: Example of good adhesion properties

Plate 2: Example of too little cutter
No wetting or adhesion with aggregate particle

Plate 3: Binder very soft or too much cutter and may have problem in retaining aggregate particles
METHOD MB-10: Ball penetration and resilience of bitumen-rubber blends

1. **SCOPE**

   This test method sets out the procedures for the determination of the penetration of a standard ball into non-aged and oven-aged bitumen rubber as well as the rebound recovery.

2. **DEFINITION**

   The penetration of bitumen is defined as the distance in tenths of a millimetre that a standard needle will penetrate into the bitumen under fixed conditions of loading, time and temperature. This test measures the relative hardness or consistency of bitumen rubber blends.

3. **APPARATUS**

   3.1 A standard bitumen penetrometer with a plunger assembly which can be tared to weigh 75 ± 0.01 when the ball penetration tool is attached

   3.2 A ball penetration tool with a ball of 17 ± 0.1 mm in diameter attached to a shaft, which fits into the penetrometer. The tool should weigh 27.5 ± 0.1 g (see fig 1)

   3.3 Glass beakers, diameter of approximately 70mm and at least 70mm deep or flat bottom metal tins with the same dimensions.

   3.4 A forced draft-drying oven capable of maintaining a temperature of 60 ± 1°C.

   3.5 A water bath, thermostatically controlled, capable of maintaining a temperature of 25 ± 2°C

   3.6 A penetration transfer dish of glass or heavy plastic with a diameter of at least 130mm and at least 120mm high.

4. **METHOD**

   4.1 Preparation of test specimen

   Take samples of bitumen rubber (MB-1) and prepare them as described in method MB-2. Fill the test container in paragraph 2,3 to a height of approximately 60mm with the bitumen rubber. Prepare one specimen from each sample.

   4.2 Ageing of samples

   After pouring the specimen, allow to cool for 30 minutes. The specimen is then allowed to age by placing it uncovered in a force draft oven at 60 ± 1°C for 24 ± 1 hour. After ageing, condition the specimen in a water bath at 25 ± 2°C for at least two hours before testing.

   4.3 Testing

   Coat the penetration ball, fitted to the penetrometer, very lightly with silicone grease. Place the container with sample in the transfer dish filled with water from the water bath to cover the surface of the sample to a depth of at least 20mm.

   Place the ball in contact with the surface of the material to be tested, not less than 10mm from the side of the container. Set the indicator dial of the penetrometer to zero. Release the penetration assembly and allow it to penetrate the specimen for five seconds. Record the reading as ball penetration “P” in tenths of a mm.

   Without returning the dial pointer to zero, press the ball down an additional 100 units at a rate of 10 units per second.

   Re-engage the clutch to hold the tool down for an additional five seconds. During this time set the dial pointer on zero for non-spring load spindles. Release the clutch, allow the specimens to recover for 20 seconds, engage the clutch and record the reading as F. (see 4)

   Determine the penetration and resilience, if possible, at three points equally spaced from each other and at least 10mm away from the side of the container. Between each test, determine the temperature of the water in the transfer dish. If the temperature has dropped by more than 1°C, replace the water from the water bath.

5. **CALCULATIONS**

   Calculate the resilience for each test to the nearest one percent as follows:

   Resilience (%) = P + 100 – F

   Where:

   P = Ball penetration value (0,1 mm)

   F = reading after recovery (0,1 mm)

   Report the average ball penetration value and average resilience for the conditional and unconditional samples to the nearest one percent conditioned.
6. **NOTES**

6.1 If the mass of the ball penetration tool is 27.5 g, it should only be necessary to remove the 50 g weight from the penetration shaft used for the normal bitumen penetration test in order for the assembly to have a total mass of 75 g.

6.2 Where metal tins are used as sample containers, the rims of the tins should not be much above the level of the sample for the material at the start of the test. If the container is seamed around its bottom rim, a suitable spacer should be placed under it to ensure a solid base. A plaster of Paris spacer, made as follows, has been found to work well. Mix plaster of Paris to a pasty consistency. Flatten the paste with a straight edge to approximately 5 mm thick. Coat the bottom of a metal container lightly with silicone grease and press it slowly into the plaster of Paris (to assist in the removal of air under the tin.) Cut the excess plaster of Paris at the sides of the tin to form a neat base. Leave the plaster of Paris at the sides of the tin to form a neat base. Leave the plaster of Paris to set and remove the tin. This base can remain in the transfer dish. Tins are placed on it for testing.

6.3 The clutch of the penetrometer may slip slightly during the rest period when testing material with a fairly high resilience. Holding the measuring plunger down and monitoring any slippage on the dial may prevent this. Slippage can be corrected or prevented by slight downward pressure on the plunger.

**References:**
- SABITA method BR2T
- ASTM Designation D3407 and D3408
- ASTM D5

---

**Figure 1: Ball Penetration Tool**

<table>
<thead>
<tr>
<th>Material Steel Mass of Ball Penetration Tool: 27.5 ± 0.1 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Mass of Ball and Penetrometer Shaft: 75 ± 0.1 g</td>
</tr>
</tbody>
</table>

**NOTE:**

ONLY THE FOLLOWING DIMENSIONS ARE CRITICAL:
- Top Diameter of Shaft: 3.2 ± 0.1 mm
- Diameter of Ball: 17 ± 0.1 mm
- Mass of Tool: 27.5 ± 0.1 g
METHOD MB-11: Compression recovery of bitumen rubber binders

1. **SCOPE**

The elastic recovery of a bitumen-rubber cylinder is measured after it has been compressed to half its original height.

2. **DEFINITION**

Compression recovery of bitumen-rubber blends indicates a measure of the contribution made by the rubber crumbs.

3. **APPARATUS**

3.1 A compression frame capable of reducing the height of the bitumen-rubber specimen from 25.4 mm to 12.7 mm (fixed). The frame shall have a removable metal base plate on which the specimen(s) can be formed (see Fig 1).

3.2 Moulds of silicone rubber or other suitable material capable of withstanding a temperature of 175°C with inside dimensions: height 25.4 mm; diameter 19.0 mm. The moulds should be made in such a way that they can be easily removed (see 4.1).

3.3 A water bath or air cabinet capable of maintaining a temperature of 25±0.2°C.

3.4 Releasing agent such as a 1:1 mixture of glycerine and dextrin or silicone grease.

3.5 A height-measuring device such as a T gauge to measure to an accuracy of at least 0.5 mm.

3.6 Self-releasing or plastic coated paper cracks of 20 mm diameter (see 5.2).

3.7 A stop watch

4. **METHOD**

4.1 Preparation of test cylinders

Prepare the bitumen-rubber as described in Method BR1T. Place two cylindrical moulds on the clean base plate, each approximately halfway between the centre of the base plate and the guide holes. If moulds other than silicone rubber are used they should be treated with the releasing agent. Fill the moulds to excess with the bitumen-rubber. Allow cooling to room temperature and removing the excess material with a hot spatula.

4.2 Testing

Immerse the test specimens together with the base plate in the water bath or air cabinet at 25±2°C for at least one hour. Remove it from the water bath or air cabinet and carefully remove the moulds from the cylinders. Place the base plate in the test rig. Place a round of paper on top of each bitumen-rubber cylinder. Place the compression plate on top and, by means of the lever, compress the bitumen-rubber cylinders with a smooth quick action until the spacer rings touch the compression plate.

Immediately remove the compression plate and the releasing paper rounds and note the time accurate to five seconds. If a stopwatch or other timing device is used, set it in operation.

Measure the height of each of the cylinders after five minutes plus five seconds, one hour plus five minutes, four hours plus 15 minutes, 24 hours plus 30 minutes and four days plus one hour recovery. During this time samples should be left where it could not be damaged and will be free from vibrations and shock.

5. **CALCULATIONS**

Calculate and report the percentage recovery as a percentage of the original height to the nearest one percent after five minutes, one hour, four hours and four days recovery:

\[
\% \text{ Recovery} = \frac{h}{25.4} \times 100
\]

Where: \( h \) = height of recovered specimen in mm.

Report the results accurate to 0.1% for five minutes, one hour, four hours and four days recovery.

6. **NOTES**

Silicone rubber moulds may be made using a self-curing or two-part silicone rubber compound or similar material. Metal moulds can be used to make the silicone rubber moulds. The silicone rubber mould is cut vertically on one side to facilitate removal of the bitumen-rubber cylinder. It is held together with an elastic band when in use.

The backing paper used for self-stick labels or film has been found to work well.
If an air cabinet is not available the samples may be kept in a room where the temperature is controlled at 25 ± 2°C. This fact should be mentioned in the test report.

**Reference:** Sabita Method BR3T

*Figure 1: Apparatus for compression recovery test*
METHOD MB-12: Flow test for bitumen-rubber binders

1. SCOPE

This test measures the flow properties of bitumen-rubber blends at high temperatures.

2. APPARATUS

2.1 Moulds consisting of a brass or copper plate 3.2 mm thick with a rectangle 20 x 60 mm cut out of it. Multiple specimen moulds can also be used with the cut-outs not less than 20 mm apart.

2.2 Smooth, flat, tinned oven trays or similar stiff metal plates at least 200 x 200 mm (see 5.1)

2.3 A force draft drying oven capable of maintaining a temperature of 25 ± 1°C, free from vibration (see 5.2)

2.4 A water bath or air cabinet capable of maintaining a temperature of 25 ± 1°C and big enough to accommodate the tray in 2.2.

2.5 A firm frame or support to keep the tray (2.2) at an angle of 35 ± two degrees in the oven.

2.6 A scale or other measuring instrument to measure accurately to 1 mm

2.7 A spatula with a 25 mm wide blade.

2.8 Water-soluble releasing agent such as a 1:1 mixture of dextrin and glycerine or silicone grease

3. METHOD

3.1 Preparation of test specimen

Prepare the bitumen rubber as described in method MB-2. Prepare at least two moulds for each sample to be tested by coating it thoroughly with the releasing agent. Place the moulds not less than 20 mm apart with one short side approximately 10 mm from one side of the tray. (Multiple specimen moulds can also be used – see 2.1) This will be the topside of the specimens. Fill the moulds with an excess of bitumen rubber.

When cool, trim the top surface level with the sides of the moulds using a hot spatula. Holding the flat side of the blade of the spatula at an angle to the specimen level off the excess material. It should not be scraped off with the sharp edge of the blade. The slight bulge that is formed behind the spatula is acceptable.

Remove the moulds carefully from the specimens after cooling and wash clean the test specimens and plate clean of releasing agent. Make a mark opposite and in line with the bottom end of each of the specimens on the bottom of the tray with an indelible heat resistant pen or soft pencil. Place the tray with specimens in a water bath or air cabinet at 25 ± 1°C for 30 ± five minutes prior to testing.

3.2 Testing

Remove the tray from the water bath or air cabinet and dry it and the specimens with an absorbent cloth or paper towel. Place the tray in the oven at 60°C ± 1°C at an angle of 35 ± two degrees with the topside facing up. The oven should not vibrate as this may influence the results. Leave the specimens in the oven for four hours ± five minutes, remove and allow to cool to room temperature. Make a mark opposite the lower end of the specimen below the previous mark. Measure the distance between the two marks as the flow distance accurately to 1 mm.

4. CALCULATIONS

Report the flow distance in mm accurately to 1 mm for the average of the two samples. Also indicate in the report if any separation of bitumen from the bitumen-rubber is noticed.

5. NOTES

5.1 Research indicates that the metal the tray is made of does not influence the results. The only important prerequisite is that the surface should be smooth and free from scratches. When cleaning the tray it is very important not to scratch it.

5.2 It may be impossible to find a force draft oven without any internal vibration. Every effort should be made to reduce and minimise vibration in the oven as far as possible because it may influence the results.

Reference: Sabita Method BR 5 T
METHOD MB-13: Dynamic viscosity of bitumen-rubber binders

1. SCOPE

This method describes the determination of the dynamic viscosity of bitumen-rubber blends using a hand held, battery operated, and rotary viscometer.

2. APPARATUS

2.1 A hand-held rotary viscometer with a rotor-cup to measure dynamic viscosity in the range 0,5 to 10 Pa.s. For laboratory use the instrument should be mountable on a stand (see also 5.2)

2.2 A purpose-made stand or retort stand and clamps to hold the viscometer rigidly for viscosity determinations in the laboratory.

2.3 An oven thermostatically controlled and capable of maintaining temperatures of 150°C to 300°C accurate to ± 5°C

2.4 A 300°C thermometer accurate to ± 1°C

2.5 Asbestos gloves

2.6 A stirring rod or spatula capable of mixing and stirring of the viscous bitumen material.

2.7 Metal tins or glass beakers with capacities of approximately one litre and with a diameter of at least 100mm allowing a sample depth of at least 80mm. If the tins are also used as sample containers they should have tightly fitting lids.

3. METHOD

3.1 In the field

Take a representative sample of bitumen-rubber blend as described in Method MB-2 using the sample containers in 2.7 above. Directly after taking the sample, stir it well with a suitable stirring rod. Measure and record the temperature (see 5.1)

Attach the correct viscosity cup-rotor to the viscometer such that viscosity measurements will be between 0,5 and 10Pa.s (see 5.2). Ensure that the vent hole on top of the rotor is open. Place the sampling tin or beaker on a firm non-heat absorbing base and immerse the viscometer rotor in the centre of the sample up to the depth mark on the stem. After approximately 30 seconds start the rotation of the rotor while holding the instrument absolutely horizontal (see 5.3). If possible, a stand should be used. Take and record the viscosity reading to an accuracy of 0,1 Pa.s approximately ten seconds after the rotor is set in motion. Remove and clean the rotor (see 5.6)

3.2 In the laboratory

Take a representative sample of the bitumen-rubber blend as described in Method MB-1

Heat the sample as quickly as possible in an oven to the recommended spray temperature (see 5.5). If the sample is in a container as specified in 2.7 above, the viscosity can be determined directly. Otherwise, transfer the sample to a container as specified in 2.7. Stir the sample with a suitable stirrer while the temperature is monitored. When the required test temperature is reached (see 5.4), remove the stirrer and thermometer and determine the viscosity as described in 3.1. The viscometer should be fixed onto a stand to hold it firm and horizontal. Remove and clean the rotor (see 5.6)

4. CALCULATIONS

The viscosity readings should be taken and recorded accurately to 0,1 Pa.s. Report the results to the same accuracy together with the date, time, sampling and binder temperature (see 5.6)

5. NOTES

5.1 In seal work it is necessary to measure the viscosity of the bitumen-rubber blend before, during and after spraying to determine its spray ability. To make the results meaningful the viscosity and temperature should be determined as soon as possible after sampling to prevent heat loss.

5.2 The metric standard for expressing dynamic viscosity is Pa.s. Most viscometers are, however, calibrated in either centipoise (cP) or dPa.s with 1 cP = 1 dPa.s x 10² = 1 Pa.s x 10⁻³. Therefore 1,5 Pa.s = 15 dPa.s = 1500 cP

5.3 To prevent damage to the instrument some manufacturers stipulate that the viscometer is set in motion before the cup is immersed. In order to comply with this requirements, while still allowing for the cup to heat up to the temperature of the bitumen-rubber, it is suggested that the cup is immersed for 30 seconds, pulled more than halfway
out of the binder, the motion started and the cup immersed to the mark. The viscosity reading should then be taken approximately 10 seconds after this second immersion.

5.4 The viscosity should be measured at the spraying temperature.

5.5 The bitumen-rubber sample should be heated and tested in the shortest time possible as the properties of the blend may change considerably with prolonged heating. Material should be discarded if it has remained at this high temperature for more than one hour, unless time dependent tests are required.

5.6 Clean the rotor-cup as soon as possible after the test, while it is still hot, by first wiping excess material off with a dry cloth or paper and then cleaning it in a suitable organic solvent such as toluene.

Reference: Sabita Method BRST
METHOD MB-14: Particle size distribution and loose fibre content of rubber crumbs

1. SCOPE

This method describes the procedure for a dry sieve analysis for rubber crumbs intended for use in bitumen-rubber blends. The loose fibres are collected during the sieving operation as a rough indicator of fibre content.

2. APPARATUS

2.1 The following test sieves, 200mm diameter, complying with SABS 197: 2,36 mm; 1,18mm; 0,600mm; 0,300mm; 0,150 mm; 0,075 mm with a lid and receiver

2.2 A suitable nylon or bristle sieve brush

2.3 A balance accurate to 0,01 g to weigh up to at least 200g

3. METHOD

Obtain a representative sample of approximately 500g of rubber crumbs either from randomly selected individual bags as delivered on site or from the rubber crumbs container at the blending or mixing plant at random intervals.

Mix the sample thoroughly and break down any lumps that it may contain (see notes 5.3) Scoop out duplicate test samples of more or less 50g each and test each sample as follows:

Nest the sieves on the receiver in descending order of size and transfer the sample to the top sieve. Place the lid in position and hand sieve the sample for approximately two minutes by rocking and tapping the sieves. Mechanical sieving can be used for this initial operation especially when the presence of fibres is suspected, but the final sieving should be done by hand.

Remove the lid and gently rub the rubber crumbs in the uppermost sieve. Hand sieve the material until nothing more passes that specific sieve. If fibre is present it can be clearly seen in the sample as short light coloured hairs. These will form a ball during the sieving operation. Collect the fibre balls carefully and place them in a clean receptacle. Remove the sieve and repeat the operation for each sieve in the series, For the 1,18mm and other finer sieves the fibres collected on a specific sieve are placed back on the next coarser sieve and re-sieved to remove rubber particles sticking to the fibres. The fibres are then carefully collected and placed in the fibre receptacle (see notes 5.2)

Weigh the material retained on each sieve accurately to 0,01 g. Also determine the mass of the fibres collected from the sieves. A sieve analysis reporting form such as form B4/1 in TMH 1 method B4 can be used for reporting the results.

4. CALCULATIONS

Calculate the percentages passing the sieves as described in TMH1 method B4 and report the results to the nearest 0,1%.

Calculate the fibre content as a percentage of the total sample by mass and report together with the grading results.

In the report the following should be noted:
» The batch number and sampling date if available
» The condition of the bags in which the rubber was stored
» The height of the rubber bag stockpile
» The presence of foreign materials in the rubber such as steel wire, string etc.
» If the rubber crumbs are loose or lumpy
» If fibre particles are visible or not.

5. NOTES

5.1 Although the fibre particles in rubber crumbs are fairly short they tend to form a ball during the sieving operation. The same happens during the blending and/or mixing operation and their presence creates construction problems and may leas to an unacceptable end product.

It is impossible to separate or collect all the fibres in the crumbs but usually the specifications state that no fibre or a very small percentage is allowable. This method will therefore be sufficient in most instances where fibre could be a problem.

5.2 The sieving operation and collection of fibres is a tedious process and care should be taken that the operator does not hurry the test.

5.3 Rubber crumbs should be dry when sampled. If damp, they should be dried in a force drying oven at 60°C for one hour prior to testing. Higher temperatures and prolonged heating may change the characteristics of the rubber and should be avoided.

Reference: Sabita Method BR6T
METHOD MB-15: Resilience of rubber crumbs

1. **SCOPE**

This method determines the resilience of the rubber crumbs to characterize the performance of the rubber when used in bitumen-rubber blends.

2. **APPARATUS**

2.1 An oven capable of maintaining a temperature of 160 ± 5°C for at least one hour.

2.2 Bitumen penetration apparatus and a ball penetration tool as described in Method MB-10

2.3 A standard bitumen penetration cup with a diameter of 55 mm and a depth of 35 mm.

2.4 An aluminium disc with a diameter of 55 mm and a thickness of 8 mm to fit loosely inside the penetration cup to be used. A slight hollow is made in the centre of the disc to a depth bringing the mass of the disc 50 ± 0.1 g.

2.5 A tin pan, 250 ± 5 mm square and at least 20 mm high.

2.6 A stopwatch or timing device to measure periods of 10 seconds accurately to 0.1 second.

3. **METHOD**

3.1 Keep the rubber sample to be tested in the laboratory in a closed container to obtain a temperature of 25 ± 2°C (see 5.1). Fill the penetration cup loosely with the rubber by pouring it into the cup until it overflows. Give the cup a light shake sideways to remove most of the surplus rubber. Level the surface of the rubber by scraping it off with a straight edge or side of a spatula. Do not compact the rubber at all. (See 5.2)

3.2 Carefully place the aluminium disc on top of the rubber and position the cup under the penetration apparatus with the ball penetration tool fitted to it. Centre it to allow the ball to fit in the hollow without any sideways movement. Zero the gauge with the ball just touching the disc. Release the clutch of the penetrometer. Depress the ball evenly to read 100 (10 mm) on the dial in three seconds. Hold the dial spindle and ball there for three seconds. Release the spindle and ball and let the rubber recover for 10 seconds and then engage the clutch. During this time the dial pointer should be returned to zero if it is not spring loaded. After the recovery period, record the readings as Y.

Heating of second sample:

Pour some rubber crumbs from the sample container into the square pan to an even depth of 20 mm.

Place the pan with rubber in an oven at 160°C for one hour ± one minute. Remove it from the oven and cover the pan with a suitable cover such as a bigger pan or glass plate while it is allowed to cool to ± 25 2°C. Repeat the test as described above on the baked rubber and record the result as X.

4. **CALCULATIONS**

Calculate the resilience of the original rubber as follows:

Resilience (Raw): \(100 - Y\)

Calculate the resilience of the rubber after heating to 160°C for one hour as follows:

Resilience (baked) : \(100 - X\)

Calculate the loss in resilience of the rubber as:

\[
\text{Res (Raw)} - \text{Res (Baked)} \times 100\% \\
\text{Res (Raw)}
\]

Report the results to the nearest whole number together with the following information:

Sample number
Date
Rubber batch number/Date
Manufacturer

5. **Notes**

1) If the environmental temperature of the laboratory is outside these limits, the rubber should be placed in a hot box or brought to the test temperatures by any means other than by direct heating.

2) To classify rubber crumbs it is also necessary to know their bulk density. For referee purposes method MB-16 should be used. For classification purposes however
the following method has been found to be accurate enough. Weigh the penetration cup (2.3) accurately to 0.1 g as $Ce$. Fill it as described in 3.1 with rubber prepared according to method MB-16. Weigh it again with rubber as $Cr$. After the test has been completed determine the volume of the cup by filling it with distilled water $25 \pm 0.2^\circ C$, putting a small glass plate on top, removing all air bubbles, drying and weighing it as $Mf$. Also determine the mass of the cup and glass plate as $Mc$. The volume of the cup is calculated as follows:

$$\text{Volume of cup } V_c = \frac{M_f - M_c}{0.99707} \text{ cm}^3$$

The bulk density of the rubber is calculated as follows:

$$\text{Bulk density of rubber} = \frac{Cr - Ce}{V_c} \times 1000 \text{ kg/m}^3$$

**Reference:** Sabita Method BR7T
METHOD MB-16: Bulk density of rubber crumbs

1. SCOPE
This test determines the bulk density in water of rubber crumbs in the particle size range 0,600 to 0,300 mm used in bitumen rubber manufacture. The method in MB-15 (5.2) can be used as a quick test but this method will be regarded as the referee method.

2. APPARATUS
2.1 The following test sieves, 200 mm in diameter, complying with the requirement of SABS 197: 0,300 mm and 0,600 mm and a receiver.
2.2 A balance to weigh up to at least 50 g accurate to 0,01 g
2.3 A glass-measuring cylinder, at least class B, of 100ml capacity with 1 ml graduations.
2.4 A glass beaker with a capacity of 250ml with graduations not greater than 50ml apart.
2.5 Glass stirring rods of lengths suitable for use in the glass beaker and measuring cylinder
2.6 A wash bottle with jet.
2.7 A hotplate, thermostatically controlled, capable of gently boiling a beaker of water
2.8 An anionic wetting solution such as a 10% Teepol solution.

3. METHOD
3.1 Preparation of samples
Obtain a bulk sample of the rubber at least 1 kg mass by taking small sub-samples from at least 10 randomly selected bags of rubber crumbs. Thoroughly mix the crumbs and pour out into a large pan or similar container. Using a small scoop, such as a teaspoon, scoop out small quantities of rubber crumbs randomly to obtain a test sample of 20-25 g. If the sample is wet, air-dry it. Prepare at least two samples.

3.2 Sieving of material
Clean and dry the test sieves to be used. Stack the two sieves on a receiving pan. Add the test sample to the 0,600mm sieve and hand sieve it for approximately two minutes by rocking and tapping the sieves. Check whether the mass of material retained on the 0,300 mm sieve exceeds 20 g. If it does, divide the material in two and receive one half for at least another two minutes on the 0,300 mm sieve. If there is less than 7,5g of material on the 0,300 mm sieve prepare and sieve a second lot of material as described above. After sieving mix the two lots thoroughly. Treat the duplicate sample similarly.

3.3 Determination of the bulk density
Transfer 7,5 ± 0,1g of the material retained on the 0,300 mm sieve to a clean dry 250 ml beaker. Add 70 ml of distilled or de-ionised water and bring it to boil on the hotplate. Allow boiling for 30 minutes while stirring occasionally with a stirring rod. Wash particles deposited on the wall of the beaker down with water from the wash bottle. Keep the total volume of material in the beaker between 60 and 70 ml.

After the 30-minute period, transfer the contents of the beaker to a 100 ml measuring cylinder using the wash bottle to wash it in. Make the volume in the measuring cylinder up to 100 ml.

Add 10 ml of the prepared wetting agent and thoroughly agitate the contents by stirring rapidly in a circular motion. Reverse the direction of stirring to stop rotation of the suspension and allow it to remain undisturbed for 15 minutes.

After the 15 minutes, measure the settled volume of the rubber particles to the nearest 0,5 ml, neglecting any floating particles. Similarly test the duplicate sample.

4. CALCULATIONS
Calculate the bulk density of each test sample as follows:

\[
\text{Bulk density (kg/m)} = \frac{7,5 \times 1000}{V}
\]

Where \( V \) = settled volume of the rubber particles (ml)

Calculate the average bulk density for the two samples. If the results differ by more than four percent (repeatability) another sample should be tested and the result, differing by more than four percent from any one of the others, rejected.

REFERENCES:
OLIVER J.W.H. A bulk density test to characterize the morphology of rubber particles. ARRB Internal Report, AIR 286-3 Australian Road Research Board, April 1981
Sabita Method BR8T
METHOD MB-17: Softening point of modified bitumen by ring and ball method

1. DEFINITION

The softening point is the temperature at which the modified bitumen attains a particular degree of softness under the specified conditions of the test.

Reference: ASTM D36 (using shouldered ring)

METHOD MB-18: Dynamic (Apparent) viscosity of polymer modified binders

1. SCOPE

This test method outlines the procedure for measuring the apparent viscosity of a bitumen binder at the specified test conditions using the Brookfield Thermosel system and SC 4 spindles

2. DEFINITION

The co-efficient of viscosity is the ratio between applied shear stress and rate of shear. This co-efficient measured in Pa.s, of the resistance to flow of a liquid and commonly termed viscosity.

Reference: ASTM B4402

METHOD MB-19: Low temperature ductility of polymer modified binders

1. DEFINITION

The ductility of modified bitumen is expressed as the distance in centimetres by which a standard briquette can be elongated before the thread breaks under the conditions specified.

Reference: DIN: 52013
METHOD MB-20: Recovery of residue of modified bitumen emulsion

a) The recovery of modified bitumen residue from emulsion using a rotary evaporator (Method A)
b) The recovery of modified bitumen residue from emulsion using a Bunsen burner (Method B)

1. SCOPE

This method describes the recovery of Modified bitumen residue from a modified bitumen emulsion containing some fluxing oil. The residue recovered represents the modified binder on the road after a period in which the fluxing oils are allowed to evaporate.

METHOD A

2. APPARATUS

2.1 A rotary evaporator, including holding and receiving flasks designed to be subjected to at least one atmosphere of vacuum (about 63cm Hg), according to DIN 1996 (Buchi or similar)
2.2 A vacuum pump and manometer (Hg)
2.3 An oil bath and heating facility
2.4 A thermometer measuring 0 to 200°C

3. SAMPLE PREPARATION

Polymer Modified Binder samples for testing shall be prepared in accordance with method MB 1 and method MB 2.

3.1 Add 300g ± 1 g modified emulsion to the one litre holding flask of the rotary evaporator (500 g ± 2 g in two litre flask) Attach firmly to the apparatus and lower the flask into the oil bath at 60°C ± 5°C. (See figure 1). The oil should come up to the level of emulsion in the flask. Start rotation of the flask at 50 rpm and subject to a vacuum of 30cm Hg ± 5cm. Start the flow of cold water through the condenser of the apparatus. Leave for 60 minutes ± 5 minutes. Raise the temperature gradually to 150°C, ensuring that the emulsion does not boil over onto the condenser (vacuum as before). This may take up to 30 minutes. Leave at 150°C ± 5°C for 60 minutes ± 5 minutes.

While the vacuum is maintained during recovery, a small flow of air should be introduced into the holding flask (via the valve at the top of the condenser) to assist in driving off the volatiles (water and flux). Remove the holding flask containing recovered modified bitumen and pour out for further testing.

METHOD B

4. Apparatus

4.1 A Bunsen burner
4.2 A one litre squat glass or metal beaker
4.3 A glass thermometer measuring 0°C to 200°C

5. SAMPLE PREPARATION AS PER 3.1

5.1 Add approximately 160g of modified emulsion to the beaker. Place on the heating facility. (See figure 2). Stir the sample with the thermometer at approximately two revolutions per second. Continue stirring until the temperature of the residue is 170°C. Maintain the temperature of the residue at between 170 and 180°C for a further 15 minutes, whilst stirring continuously. The heating rate should be such that the preparation is completed within 45 minutes.
METHOD MB-21: Viscosity of modified bitumen emulsions by means of the Saybolt -Furol viscometer

1. SCOPE

The Saybolt Furol viscosity is determined by measuring the efflux time, in seconds, of 60ml of sample flowing through a calibrated Furol orifice under the specified conditions of the test.

Reference: SABS 548 which refers to ASTM: D244

METHOD MB-22: Water content of modified bitumen emulsions

1. SCOPE

This method describes the procedure for determination of the water content of a bitumen emulsion by distillation and using a carrier liquid.

Reference: ASTM: D244

METHOD MB-23: Residue on sieving of a modified bitumen emulsions

1. SCOPE

This method determines the quantity of modified binder present in an emulsion in particles of such size as to be retained on a gauge of specified mesh opening.

2. METHOD

SABS 548, which refers to IP 91, with the following amendments
The sieve should be a 0.150 mm sieve, 50mm high and approximately 80mm in diameter
The reagent (soap solution) shall be a 0.1N hydrochloric acid solution containing 1% cetyltrimethyl - ammonium bromide (centrimide)

References: Cationic: SABS 548 which refers to IP 91
Anionic: SABS 309 which refers to IP 91
METHOD MB-24: Particle charge of modified bitumen emulsions

1. SCOPE

This test determines the mass of binder deposited on a cathode after being subjected to the particle change test for 30 minutes.

2. METHOD

The ASTM D 44 method is followed with the following amendment
The thickness of the electrode shall be 0.71 mm.

Reference: SABS 548 - 1972 which refers to ASTM D 244