A guide to the selection of bituminous binders for road construction

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A guide to the selection of bituminous binders for road construction

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Manual 1	Construction of bitumen rubber seals
Manual 2	Bituminous products for road construction
Manual 3*	Test methods for bitumen rubber
Manual 4*	Specifications for rubber in binders
Manual 5	Manufacture and construction of hot mix asphalt
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Manual 7	SuperSurf: Economic warrants for surfacing unpaved roads
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Manual 27	Guideline for thin layer hot mix asphalt wearing courses on residential streets
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Manual 30	A guide to the selection of bituminous binders for road construction (CD only)

* Withdrawn and their contents have been incorporated in *Technical Guideline 1* (see below)
** Withdrawn and its software incorporated in *TRH12: Flexible pavement rehabilitation investigation and design*
***These manuals have been withdrawn and contents incorporated in *Technical Guideline 2* (see below).

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TG2	Bitumen stabilised materials
TG3	Asphalt reinforcement for road construction

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DVD100	Testing of bituminous products
DVD200	Repair of blacktop roads
DVD300	Hot mix asphalt
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Foreword

During the revision of SANS 307: *South African standard for penetration grade bitumen*, in 2009, the Road Pavements Forum Task Group on Bitumen Specifications recommended that a user guide that will facilitate the correct selection and use of bituminous binders for road construction would be of considerable benefit to practitioners. This manual was produced by Sabita in response to this recommendation.

The reader should note that this document is essentially a concise guide and as such cannot cover all eventualities and applications or replace experience. For this reason, frequent reference is made to other documents in general use, which cover the subject matter in considerably more detail. In this respect the document should prove particularly useful to new entrants in the roads industry sector, faced with choices as to the most appropriate binder for a particular bituminous layer application.

This guideline document covers the role and function of bitumen in road layers or applications, the types and grades available in South Africa, standard specifications and technical requirements, selection criteria for a wide range of applications and a brief description of availability and packaging. While most applications in general use are dealt with in this manual, it should be noted that applications that require specialist knowledge and experience, such as stress-absorbing membranes, geotextile seals and enrichment sprays as preparation to further (re)surfacing, are not covered.

While due care was taken to ensure that this document contains up-to-date information, it is evident that standards pertaining to a number of products and their application are currently under review. Examples are the introduction of a new cutback bitumen grade – MC10 – while other grades MC70 and MC800 will no longer be covered. Also, in the asphalt arena, innovations such as the introduction of warm mix technology and the feasibility of the introduction of hard grades of bitumen for use in high modulus asphalt are underway which will broaden the scope of selection and application of bituminous binders.

Role and function of bitumen

Bitumen is a valuable and versatile road building material used in a broad range of applications, mainly in the construction of road and airport pavements. It is a strong, tough, readily adhesive material, highly waterproof and durable. In road and airfield pavement layers it is used predominantly as a binder – or glue – to bond mineral aggregate material together into a cohesive layer to serve either as a key element of the pavement structure, or as a durable wearing course, offering a safe contact zone between vehicle tyres and the road surface. Other uses in pavements include crack sealing, preparing substrates prior to the application of a bituminous layer and coating of stone aggregates for improved adhesion.

Although solid or semi-solid at ambient temperatures, bitumen is readily liquefied for ease of handling by applying heat, by dissolving it in petroleum solvents, or by emulsifying it in water.

Types and grades of bituminous binders in general use

A number of types and grades of bitumen are available in South Africa for use in a wide range of applications such as:

- Hot and warm mix asphalt;
- Chip seals;
- Prime coats;
- Tack coats;
- Slurry seals;
- Microsurfacing;
- Stone precoating fluids.

Types of bitumen in general use are:

- Penetration grade bitumen;
- Cutback bitumen;
- Modified bitumen;
- Bitumen emulsion.

Below are given short descriptions of these bitumen types; for more details regarding the manufacture, characteristics and behaviour the reader is referred to Sabita Manual 2: *Bituminous products for road construction and maintenance*.

Penetration grade bitumen

Penetration grade bitumen is either used as a primary binder by itself or as base bitumen for the manufacture of cutback bitumen, modified binders or bitumen emulsions. A number of grades are available, ranging from hard to soft. The value associated with a particular grade is the "penetration value" determined in accordance with the testing standard ASTM D5. This test measures the relative hardness or consistency of bitumen at 25°C, representing a typical in-service temperature. The value is used to classify the bitumen into standard penetration ranges in accordance with national standard for penetration grade bitumen, SANS 307.

The following penetration grades are currently available in South Africa:

- 40/50;
- 60/70;
- 80/100;
- 150/200.

NOTE

To align specification limits to testing precision a proposal has been submitted to SABS to amend the penetration grades (and therefore ranges) as follows:

- 35 – 50;
- 50 – 70;
- 70 – 100;
- 150 – 200.

Cutback bitumen

Cutback bitumen is a blend of penetration grade bitumen and a solvent or “flux”. The type of solvent selected determines the rate at which the binder will cure after application. Cutbacks in general use in South Africa are “medium curing” (MC). The viscosity of the cutback bitumen is determined by the proportion of solvent added; the higher the proportion of solvent, the lower the viscosity of the cutback. The grade of cutback is determined by the type of solvent used and the lower limit of the kinematic viscosity at 60°C.

Figure 1: The constituents of cutback bitumen

Once the solvent has evaporated, the binder reverts to the original penetration grade. An advantage of using cutback bitumen is that it can be applied at lower temperatures than penetration grade bitumen because of its lower viscosity, leading to energy savings. This benefit should be offset by the loss, through evaporation, of non-renewable hydrocarbon energy products.

The following grades of (medium curing) cutback bitumen are available in South Africa[1]:

- MC10;
- MC30;
- MC3000.

Modified bitumen

To ensure satisfactory performance of bituminous layers under severe conditions, such as steep gradients, high prevailing temperatures,

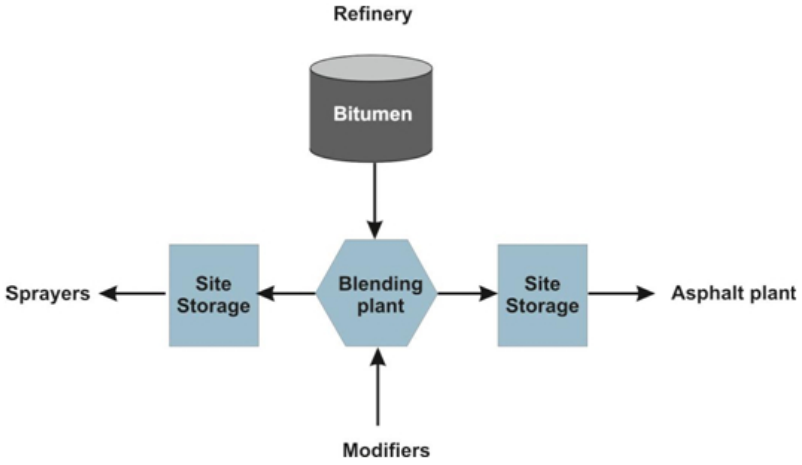


Figure 2: Handling of modified binders

1 The introduction of MC10 is a recent proposal, and has been submitted to SABS for a revision of SANS 308.

highly flexible substrates and severe traffic loadings – especially at low operating speeds – it may be cost effective to modify the consistency and rheological properties of the bituminous binder by the addition of modifying agents. The primary aim of modification is to increase the resistance of layers to permanent deformation at high road temperatures without compromising the properties of these layers over the rest of the prevailing temperature range.

Composition

Modification is achieved by the introduction of polymers, crumb rubber, aliphatic synthetic wax or naturally occurring hydrocarbons. Polymers can be broadly classified into “elastomers” for improving the strength and elastic properties of a binder, and “plastomers” for increasing the viscosity and stiffness of the binder. While these are the primary objectives of binder modification, a wide range of the binder properties can be improved, typically:

- Durability;
- Aggregate retention;
- Cohesion;
- Susceptibility of binder viscosity to changes in temperature.

Users of modified binders should note, though, that modifying the properties of the binder to achieve the aims mentioned above, may compromise other important required properties of the binder such as:

- Loss of early adhesion in spray seal applications;
- Reduction in “self-healing” properties;
- Difficulties in compaction of asphalt; and
- Entrapment of moisture present in the pavement layers at the time of application of the seal or asphalt (due to the denseness of layers constructed with modified binders).

The option to use modified bituminous binders therefore requires careful consideration and understanding of what is to be achieved in

a particular situation as well as an appreciation that workmanship and construction details become even more important when using these binders.

Modifying agents used frequently in South Africa are listed in Table 1. For a more detailed description of modified binders, the reader is referred to Technical Guideline 1: *The use of modified binders in road construction.*

Table 1: Modifying agents

Modifier type	Varieties	
Polymers	Elastomers	Styrene-butadiene-styrene (SBS)
		Styrene-butadiene-rubber (SBR) latex
		Rubber crumb[2]
	Plastomers	Ethylene-vinyl-acetate (EVA)
Aliphatic synthetic wax		Fischer-Tropsch (F-T) wax
Naturally occurring hydrocarbons		Gilsonite
		Durasphalt

Classification

Modified binders are classified in TG1[3] as follows:

1. Type of application

- S – seal;
- A – (premixed) asphalt;
- C – crack sealant.

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

3 TG1: *The use of modified binders in road construction,* 2nd edition November 2007.

2. Type of modifier

- E – homogeneous elastomer;
- R – rubber crumb;
- P – plastomer;
- H – hydrocarbon.

3. Level of modification

A numerical value – 1 or 2 – which generally increases in relation to softening point values, but which is not necessarily indicative of improved overall performance characteristics.

4. Type of binder system

If the product is an emulsion (cold applied) the letter C will follow immediately after the letter indicating the type of application.

Typical modified binders in terms of the above classifications are given in Table 2.

Table 2: Classification of modified bitumen

Modifying agents		Classification
Elastomers	Styrene-butadiene-styrene (SBS)	S-E2, A-E2
	Styrene-butadiene-rubber (SBR) latex	S-E1, A-E1, C-E1
	Bitumen-rubber	S-R1, A-R1, C-R1
Plastomers	EVA	A-P1
Hydrocarbons	Naturally occurring	A-H1
	Aliphatic synthetic wax	A-H2

Bitumen emulsion

Bitumen emulsions are two-phase systems consisting of a dispersion of bitumen droplets in water containing an emulsifier. Emulsification of bitumen is a means of reducing the viscosity of a binder to behave as a fluid during handling and application. The net bitumen content of emulsions vary between 60% and 70%.

Commonly, bitumen emulsions are available in two classes:

- cationic; and
- anionic.

The terms *cationic* and *anionic* derive from the electrical charges on the bitumen globules. In a cationic emulsion the bitumen particles are positively charged; in an anionic emulsion they are negatively charged. The process of "breaking", i.e. the separation of the bitumen and water phases is distinct for cationic and anionic emulsions as follows:

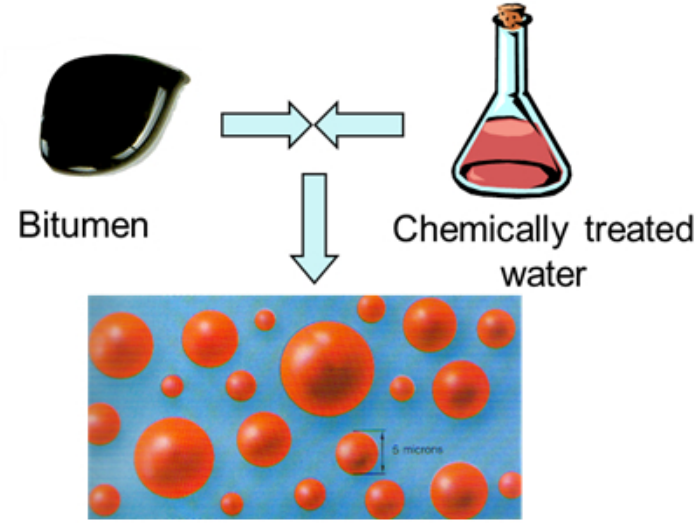


Figure 3: Components for the manufacture of bitumen emulsion

Cationic emulsions

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

Anionic emulsions

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

Compatibility with stone aggregate

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

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

The compatibility of emulsion class and aggregates in general use in bituminous layers is presented in more detail in Table 15: *Compatibility of emulsion type with aggregate type* on page 44. However, the reader should note that, where the aggregates have been precoated with a bituminous precoating fluid, thus preventing direct contact between the emulsion and the aggregate surface, these restrictions generally do not apply.

Invert emulsions

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

Emulsion grades

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

- *Premix grade* – A stable emulsion formulated for mixing with medium or coarse graded aggregate with the percentage aggregate passing the 0,075 mm sieve not exceeding 2%.
- *Quick setting grade* – An emulsion specially formulated for use with microsurfacing seal types, where quick setting of the mixture is desired.
- *Spray grade* – An emulsion formulated for application by mechanical spray equipment in chip seal construction where no mixing with aggregate is required.
- *Stable mix grade* – An emulsion formulated for mixing with very fine aggregates, sand and crusher dust. Mainly used for slow-setting slurry seals, tack coats and fog sprays for surface enrichment.

Modified emulsions are also available for specialised applications. These are three phase cationic emulsion systems where SBR latex is introduced as a third component in the normal bitumen/water two phase system. These binders are not recommended for fog sprays.

In terms of the classification system listed under “modified bitumen” modified bitumen emulsions generally available are shown in Table 3.

Table 3: Classification of modified bitumen emulsions

Modifying agents		Classification
Elastomers	Styrene-butadiene-styrene (SBS)	SC-E2, AC-E2
	Styrene-butadiene-rubber (SBR) latex	SC-E1, AC-E1, CC-E1

Stone precoating fluids

These are low viscosity bitumen-based fluids containing petroleum cutters and a chemical adhesion agent used to:

- coat surfacing aggregates before surfacing to improve the adhesion of the aggregate to the bituminous binder;
- reduce excessive absorption of binder by highly absorptive aggregate.

Precoating fluids should have a low enough viscosity to coat damp or dusty surfacing aggregates and be able to dry in a reasonable period to deposit a non-tacky residual film on the surface of the aggregates. They should also be readily absorbed by porous aggregate to reduce further absorption of binder.

NOTE

The use of bitumen emulsion or diesel has been found in most cases to be unsuitable for use as precoating fluids.

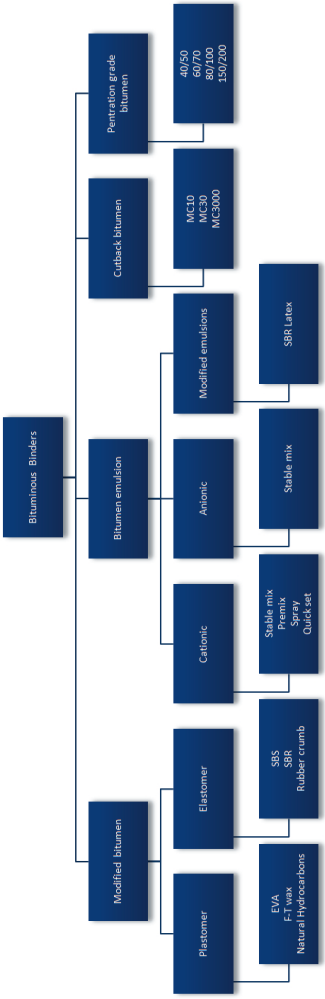
Summary

A summary of the types and grades of bituminous binders currently available in South Africa is given in Table 4 and depicted in Figure 4.

Table 4: Types and grades of bituminous binders

Type	Grade or Class
Penetration grade bitumen	40/50 60/70 80/100 150/200
Cutback bitumen	MC10 MC30 MC3000
Modified bitumen	
Homogeneous polymers SBS SBR EVA	 S-E2, A-E2 S-E1, A-E1, C-E1 A-P1
Non-homogeneous polymers Bitumen rubber	 S-R1, A-R1, C-R1
Hydrocarbons Naturally occurring Aliphatic synthetic wax	 A-H1 A-H2
Bitumen emulsions	cationic spray grade – 60%, 65% and 70% binder content. cationic premix grade – 60% and 65% binder content. cationic and anionic stable mix grade – 60% binder content. Cationic quickset Invert cationic emulsion – 80% binder content (including flux)
Modified bitumen emulsions	SC-E2, AC-E2 SC-E1, AC-E1 CC-E1
Pre-coat fluids	Propriety products – bitumen based fluids with cutters and adhesion agents

Figure 4: Types and grades of bituminous binders



NOTE

The penetration grades listed above are those which were current when this document as published. The new grades awaiting SABS confirmation are:

- 35/50;
- 50/70;
- 70/100;
- 150/200.

Standard specifications and requirements

In view of the complex chemical composition of bituminous binders, it is general practice, worldwide, to make use of performance-related physical properties as the primary means for specifying and selecting bituminous binders.

Specifications for bituminous binders are intended to ensure that:

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

Conventional binders

The specifications for penetration grade bitumen, cutback bitumen and bitumen emulsions published by the South African Bureau of Standards (SABS) are listed in Table 5. For more detail, such as the full range of properties monitored and the limits imposed on them, the relative specification should be consulted.

Table 5: SABS specifications for bituminous binders

Specification number	Title	Grade designations
Bitumen		
SANS 307	Penetration grade bitumen	40/50 60/70 80/100 150/200
SANS 308[4]	Cutback bitumen	MC10 MC30 MC3000
Bitumen emulsions		
SANS 309	Anionic bitumen road emulsions	Spray type Stable mix type
SANS 548	Cationic bitumen road emulsions	Spray type Premix type Stable mix type
SANS 1260	Invert bitumen emulsion Spray type	Prime

4 A proposal has been submitted to SABS to include MC10 into a revision of this specification.

Modified binders

The requirements that have to be met by modified binders when subjected to testing are set out in TG1 (Tables 1 – 11). The tests incorporated in these requirements are intended to ensure that:

- the consistency and rheological properties of the binder are appropriate for a range of in-service conditions of traffic and climate;
- the binder can be safely handled and is stable during storage and handling;
- the performance characteristics are not unduly compromised during hot applications (e.g. hot applied binders in seals and binders used in hot mix asphalt).

Table 6 gives the table number in TG1 setting out the property requirements relevant to the various applications and classes of modified binders.

Table 6: Requirements for various applications

Application	Binder class	Table in TG1
Hot applied polymer modified binders for spray seals	S-E1, S-E2	5
Polymer modified emulsions for spray seals	SC-E1, SC-E2	6
Polymer modified binders for hot mix asphalt	A-E1, A-E2, AP-1	7
Bitumen rubber for spray seals and asphalt	S-R1, A-R1	8
Hydrocarbon modified binders for hot mix asphalt	A-H1, A-H2	9
Modified binder crack sealants	C-E1, CC-E1,C-R1	10
Polymer modified emulsions for machine-applied microsurfacing	AC-E1 (overlays) AC-E2 (rut filling)	11

Stone precoating fluids

In the absence of a national standards specification, based on the successful use of proprietary bitumen-based products, the recommendations shown in Table 7 are presented in Sabita Manual 26[5].

Table 7: Requirements for stone precoating fluids

Property	Requirement	Test method
Density @ 25°C, kg/ℓ	0,85 – 0,95	
Saybolt Furol viscosity @ 50°C, SFs	10 – 30	ASTM D244
Distillation comparison to 360°C, v/v% to 190°C 225°C 260°C 316°C	 0 – 15 10 – 55 45 – 75 70 – 95	ASTM D402
Residue from distillation to 360°C, v/v%	45 – 60	ASTM D402
Dynamic viscosity @ 25°C of residue distilled to 360°C, cps	300 – 500	ASTM D4402
Stripping number	Report[6]	Riedel & Weber

5 Sabita Manual 26: *Interim guidelines for primes and stone precoating fluids*, November 2006.

6 This test should be conducted to assess the effect of aggregate precoating on aggregate adhesion to the project binder by comparison with uncoated aggregate.

Bitumen additives

A number of bitumen additives are employed, particularly in hot mix asphalt. These additives are not intended to modify or improve the rheological properties of bitumen; rather the intention is to improve certain performance characteristics to extend the service life of the asphalt. Table 8 lists additives in common use and their general purpose. Although no specifications for the materials are readily available, examples of generic types are listed to guide the user.

Table 8: Common binder additives used in hot mix asphalt

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

A number of additives to facilitate the production, handling, paving and compaction of asphalt at lower temperatures have also been incorporated in recent full-scale trials. These are best described as "viscosity modifying agents" and could be either minerals, e.g. zeolites, or organic, e.g. waxes and surfactants.

NOTE

Bitumen presents a low order of potential hazard as long as sound and responsible practices are observed during the handling of the product. These practices are covered in detail in Sabita Manual 8: *Guidelines for the safe and responsible handling of bituminous binders*.

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

Figure 5: Safe handling of bitumen on site with the proper personal protection equipment

Selection and application

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

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

There is no substitute for extensive experience and knowledge in this regard and the following comments can only serve as a general guide.

Selection criteria

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

- Chip seals and slurries – TRH3[7], Sabita Manual 10[8], Sabita Manual 28[9];
- Modified binders – TG1;
- Hot mix asphalt – Sabita Manuals 5, 13 and 27;
- Primes and stone precoating fluids – Sabita Manual 26;
- Tack coats – Sabita Manual 5;
- Bitumen stabilised materials – TG2[10].

7 Technical Recommendations for Highways 2007: TRH3 – *Design and construction of surfacing seals.*

8 Sabita Manual 10: *Bituminous surfacings for low volume roads and temporary deviations.*

9 Sabita Manual 28: *Best practice for the design and construction of slurry seals.*

10 TG2: *Bitumen stabilised materials*.

Binders for priming

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

The function of a prime coat is to:

- Provide adhesion between a granular layer and a bituminous layer;
- Inhibit ingress of liquid water while not hampering the evaporation of water in the layer being primed;
- Limit absorption of a sprayed binder application by base;
- Bind finer particles of the upper zone of the layer being primed.

Standard products

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

- MC10 or MC30 cutback bitumen grades complying with SANS 308;
- Invert bitumen emulsion complying with SANS 1260:2004.

The main factors that influence the selection of the type of prime to be used are the type and the absorptive properties of the base and the prevailing weather conditions. Table 9 gives some guidance on the selection of the appropriate priming binder.

Proprietary products

Should primes be used that do not comply with SANS specifications, the supplier should provide specifications against which his product can been tested for compliance. Preferably such products should be certified as being fit-for-purpose by Agrément South Africa.

Bitumen emulsions based primes, known as "Eco-primes", have been developed which claim to be more environmentally friendly than the cutback primes and with solvent contents typically 50% less than those used in MC30. It is suggested that candidate products be subjected to field trials before adoption for a specific project.

Blending

Blending of primes to reduce their viscosities should not be carried out on site, but in a proper blending facility, where proper health and safety precautions can be implemented.

Table 9: Selection guide for prime for various substrate conditions

Type of base	MC10	MC30	Invert emulsion
Graded natural gravel	2	1	1
Crushed stone e.g. un-weathered G1	1	2	1
Lime or cement stabilised	1	1	1
Bitumen stabilised	-	-	2
Calcrete	1	1	1
Containing soluble salts	-	2	-
Absorptive properties of base material			
High moisture content	-	-	-
Low moisture content	1	1	1
High porosity	-	1	1
Low porosity	1	-	2
Plasticity Index >7	1	-	-
Plasticity Index <7	1	1	1
Open graded	-	2	2
Climatic conditions			
High humidity	1	2	-
Wet	-	-	2
Road temperature >25°C	1	1	2
Road temperature <25°C	1	2	1

Key: 1 = first preference; 2 = acceptable; – = not suitable

Binders for tack coats

Tack coats are sprayed bituminous binders applied either to a primed granular substrate or a bituminous layer to promote adhesion between the existing surface and an asphalt layer being placed. Its main purpose is to prevent undue movement of the newly placed asphalt during its compaction and to provide a bond between the asphalt layer and the substrate. This function of tack coats is of critical importance when placing thin (e.g. less than 50 mm thick) layers.

Usually stable mix (anionic or cationic) bitumen emulsion is diluted 1:1 with water to achieve full coverage of the underlying layer with a thin residual bitumen film. The bitumen content of these emulsions is normally 60%, resulting in a net bitumen content of 30% in the tack coat. It is advisable to introduce the water to the emulsion with the two fluids being at the same temperature.

Binders for slurries

A slurry is in fact a cold-prepared homogeneous asphalt mixture used as either a maintenance measure or as a surfacing – or part thereof – in new construction. It is typically composed of:

- fine aggregate;
- a bitumen emulsion;
- water;
- “active” filler (lime or cement).

Slurries are also used in the following applications:

- for texturing and improvements to road finish;
- as a filler in certain types of surfacing and in slurry bound macadam;
- rut filling prior to the application of a reseal.

Although both anionic and cationic stable grade 60% emulsions are suitable for conventional slurries, anionic emulsions are mostly used – mainly for reason of costs. The lack of physical-chemical attraction

between the bitumen particles and a number of aggregate types in general use dictated that curing (breaking) occurs only as a result of normal water evaporation, making the conventional slurry highly suitable for labour intensive surfacing.

The reader should note that since cement or lime is generally used as filler in slurries, the positive charges developed by these fillers may well render anionic emulsions suitable or even superior as a binder due to improved workability. However, as a consequence of the slow setting, conventional slurries are often not appropriate for use in the urban environment where a rapid set is preferred to accommodate pedestrian and vehicular traffic.

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

Binders for crack sealants

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

- Hot applied elastomer modified C-E1;
- Emulsion elastomer modified CC-E1;
- Hot applied bitumen rubber C-R1.

Binders for chip seals

Chip seals consist of ordered applications of one or more bituminous products and aggregates. The function of the bituminous binder in a chip seal is essentially to provide adhesion between the various aggregate particles and between the entire seal and the existing road surface. In addition it should have sufficient cohesive strength to resist brittle fracture.

The binder viscosity should be sufficiently stable over a range of prevailing temperatures to:

- Prevent excessive softening under elevated temperatures so as to retain the aggregates under the action of traffic and to resist excessive flushing of the binder to the surface; and
- Remain flexible at lower temperatures to resist brittle fracture and to accommodate flexure under the action of traffic.

Factors affecting performance

The following binder related factors that influence the performance of spray seals are listed in TRH3:

- Binder type and properties;
- Grade of binder;
- Binder application rates; and
- Viscosity at the time of application.

The reader is advised to refer to section 2.7.2 of the above document for more detail.

Binder selection criteria

A wide range of bituminous binders is used for spray seals, such as:

- 80/100;
- 150/200;
- MC3000;
- SBR/SBS hot modified bitumen – S-E1;
- Cationic spray grade emulsion 65%;
- Cationic spray grade 70%;
- SBR modified emulsion 65% – SC-E1;
- SBS modified emulsion 70% – SC-E2;
- Bitumen rubber – S-R1;
- Cationic spray grade emulsion – 60%.

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

- Traffic ;
- Climate;
- Durability of binder;
- Cost;
- Convenience of application;
- Compatibility with aggregate;
- Road geometry.

Some of these factors are dealt with below.

Traffic and climate

In terms of traffic and climatic criteria, the recommended binders are shown in Table 10 (as per Table 5-1 of TRG3). The reader is cautioned to note the following:

1. In some instances binders other than those listed have been used successfully. Such deviations from the recommendations, however, require specialist knowledge and experience of materials and prevailing conditions.
2. The use of modified hot binders in rainy seasons may be problematic as a result of a lack of early adhesion of aggregate and binder in spray seals applications. Such situations should be approached with extreme caution and may require special formulation of such binders.

Table 10: Recommended binders for various traffic and climatic conditions

Traffic ELV[11]/lane/day	Climatic conditions			
	Winter: dry	Summer: dry	Winter and rain	Summer and rain
<10 000	80/100 pen bitumen + cutter MC3000 Emulsion (80/100 pen base bitumen) Lowveld – 80/100 pen bitumen Modified hot binder or emulsion	80/100 pen bitumen 65% emulsion (80/100 pen base bitumen) Highveld – 80/100 pen bitumen Modified hot binder or emulsion	Cationic emulsion (quick setting) MC3000 Modified hot binder	80/100 pen bitumen + 2% cutter Cationic emulsion Modified hot binder
10 000 – 20 000	80/100 pen bitumen + cutter Modified hot binder or emulsion	80/100 pen bitumen Modified hot binder or emulsion	Modified hot binder or emulsion	80/100 pen bitumen + 2% cutter Cationic emulsion Modified hot binder

11 Equivalent light vehicles.

NOTE

1. The weather-related criteria for using cutters are covered comprehensively in TRH3, Table 5-1: *Recommended binders*
2. Only petroleum based cutters should be used with bitumen.
3. The practice of cutting back hot binders is a hazardous process as the blending temperature of the binder is well in excess of the cutter's flash point. It is recommended that this process should only be undertaken under controlled conditions, such as at a blending plant. If the need to blend a cutter in a sprayer on site is unavoidable, the process should only be carried out in accordance with a method statement prepared by the binder supplier.

>20 000	Modified hot binder	Modified hot binder	Modified hot binder	Modified hot binder

Road geometry

Steep slopes of the road surface, arising from both or either of road gradients and superelevation, could cause binder run-off during construction. Recommended maximum gradients for various types of binder are given in Table 11 as per Table 5-2 of TRH3.

Table 11: Recommended maximum gradients for application of binder types

Binder type	Application viscosity	Maximum slope
Penetration grade:		
80/100	40 – 100 cSt	12%
150/200	40 – 100 cSt	10%
Cutback bitumen:		
MC3000	3000 – 6000 cSt	8%

NOTE

The values of maximum slope given above are guidelines only and are dependent on factors such as road surface temperature, the texture and permeability of the existing surface and the experience and competency of the applicator.

Emulsions:		
60%	20-50 Saybolt Furol secs.	6%
65%	51-200 Saybolt Furol secs.	8%

Aggregate type

Suitable combinations of binders and aggregate type are shown in Table12.

Table 12: Binder-aggregate combinations

Binder type	Aggregate type	
	Siliceous aggregate	Non-siliceous aggregate
Penetration bitumen	No	Yes

NOTE

1. Aggregates with high silica content, such as quartzite, sandstone, granite have poor adhesion with some bituminous products, especially in the presence of moisture. For this reason cationic emulsion should be used with these aggregates or, alternatively, the use of an adhesion agent should be considered if no other aggregate is available.
2. Basic (non-siliceous) aggregates perform satisfactorily with penetration grade bitumen, cutback bitumen, anionic or cationic bitumen emulsions. In view of the minimal difference in cost between cationic and anionic spray grade bitumen emulsions, as well as for practical considerations, cationic emulsion is normally used.
3. In the case of a sand seal, experience has shown that MC3000 cutback bitumen and sand with high silica content perform satisfactorily, especially in drier regions.

MC3000 cutback bitumen	No	Yes

Cationic bitumen emulsion	Yes	Yes

Binders for premixed asphalt

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

In this section guidance will be given for conventional asphalt wearing courses, asphalt bases and “asphalt seals” i.e. asphalt layers of specified thickness of less than 30 mm, used mainly as functional layers in light traffic situations.

Wearing course

The bituminous binder should be selected with due consideration of the aggregate packing (grading) of the mix, in conjunction with traffic and environmental conditions. Bituminous binders and modifiers in general use in wearing course asphalt are set out in Table13.

Table 13: Bituminous binders for wearing course asphalt

Class	Category	Grade/type	Applications
Conventional binders Complying with SANS 308	Penetration grade bitumen	40/50 pen	High traffic situations where high stiffness is required. Generally not appropriate for situations of yielding support layers and low temperatures.
		60/70 pen	Gap, semi-gap, continuously and open-graded asphalt for typical applications in most climatic zones.
		80/100 pen	For improved flexibility of asphalt on yielding pavements. Especially appropriate for very thin layers on residential streets where extending the compaction window under conditions of rapid cooling may be a critical consideration.

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Modified binders Complying with TG1[12]	Elastomer	Styrene-butadiene-rubber (SBR) latex modified A-E1	Improved flexibility and resistance to fracture. Increased stiffness at elevated temperatures and Lower stiffness at low service temperatures.
		Styrene-butadiene-styrene (SBS) modified A-E2	
		Bitumen-rubber modified A-R1	
	Plastomer	Ethyl-vinyl-acetate (EVA) modified A-P1	Improved resistance to permanent deformation.
	Natural hydrocarbons	Gilsonite, Durasphalt modified A-H1	Stiffening of the bitumen and hence the stiffness modulus of the asphalt layer.
	Aliphatic synthetic wax	Fischer-Tropsch (F-T) Wax modified A-H2	Primarily for lowering mixing and laying temperatures. Also has a beneficial effect on resistance to permanent deformation. More resistant to fuel spillage than conventional binders.

12 TG1: *The use of modified binders in road construction.*

Bitumen used in asphalt wearing courses may also contain additives such as listed in Table 8: *Common binder additives used in hot mix asphalt* on page 24.

NOTE

There is a rising tendency to use modified binders in asphalt wearing courses to cope with higher intensity of loading arising from increases in:

- traffic volumes;
- axle loads; and
- tyre pressures.

However, the application of small quantities of asphalt, often in restricted work areas, and requiring hand work normally precludes the use of these binders.

The bituminous binder should be selected with due consideration of the aggregate packing (grading) of the mix, in conjunction with traffic and environmental conditions. *The onus is on the designer to ensure that the use of these more costly binders in conjunction with suitable aggregate packing offer cost-effective solutions.*

Asphalt bases

As is the case in wearing course asphalt, the bituminous binder should be selected with due consideration of the aggregate packing (grading) of the mix, in conjunction with traffic and environmental conditions. Bituminous binders and modifiers in general use in asphalt bases are set out in Table 14.

Table 14: Bituminous binders for asphalt bases

Class	Category	Grade/type	Applications
Conventional binders Complying with SANS 307	Penetration grade road bitumen	40/50 pen	High traffic situations where high stiffness is required. May not be appropriate for low temperature applications.
		60/70 pen	Semi-gap and continuously graded asphalt for typical applications in most climatic zones.
Modified binders Complying with TG1[13]	Elastomer	Styrene-butadiene-styrene (SBS) modified A-E2 Bitumen-rubber modified A-R1	Improved flexibility and resistance to fracture. Increased stiffness at elevated temperatures and Lower stiffness at low service temperatures.
	Plastomer	Ethyl-vinyl-acetate (EVA) modified A-P1	Improved resistance to permanent deformation.
	Natural hydro-carbons	Gilsonite, Durasphalt modified A-H1	Stiffening of the bitumen and hence the stiffness modulus of the asphalt layer.
	Aliphatic synthetic wax	Fischer-Tropsch (F-T) Wax modified A-H2	Primarily for lowering the mixing and laying temperatures. Also has a beneficial effect on the resistance to permanent deformation.

13 TG1: *The use of modified binders in road construction.*

As is the case for asphalt wearing courses, bitumen used in asphalt bases may also contain additives such as listed in Table 8: *Common binder additives used in hot mix asphalt* on page 24.

Asphalt seals (functional layers)

Thin asphalt surfacings, i.e. those of specified thickness less than 30 mm on roads carrying light traffic, typically in residential areas, do not form a significant component of the structure of the pavement. Considerations of stiffness and resistance to rutting should not dominate the selection criteria of bituminous binder grade. The emphasis should rather be on good workability to ensure:

- Durability;
- Low permeability;
- Ease of compaction;
- Flexibility; and
- Surface texture appropriate for low speeds.

In view of the relative narrow time windows available for the compaction of thin asphalt layers, the use of a softer grade of bitumen, e.g. 80/100 penetration should be given due consideration, mindful of climatic conditions. Consideration could also be given to the use of hydrocarbon modifiers such as F-T wax to extend the compaction window, bearing in mind the cost implications.

Bitumen grades in general use for these thin asphalt layers are 60/70 and 80/100 penetration. The reader is referred to Sabita Manual 27[14] for further guidance.

14 Sabita Manual 27: *Guideline for thin layer hot mix asphalt wearing courses on residential streets.*

Binders for stabilisation

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

- an emulsion; or
- foamed bitumen.

The prime purpose of stabilisation is to achieve an increase in material strength and stiffness, at the same time reducing the material's susceptibility to the adverse effects of excess moisture.

In most cases active filler (cement or hydrated lime) is added to:

- aid dispersion of the bitumen among the finer particles;
- in the case of bitumen emulsion, to control the break.

The cement content by mass should neither exceed 1%, nor the percentage of bitumen.

Bitumen emulsion stabilisation

In South Africa cationic or anionic 60% stable mix grade is used almost exclusively. The base bitumen is usually 80/100 penetration grade. The use of stable mix grade enables proper mixing of the binder with dense graded materials with high fines content and extended workability periods for good dispersion.

Compatibility of emulsion and aggregate

The selection of emulsion class for stabilisation is influenced by the type of aggregate to be treated. The guidelines outlined in Table 15 indicate that certain aggregates are not suitable for stabilisation with anionic emulsions. The aggregates listed in this table have silica contents above 65% and alkali contents below 35% i.e. these are acidic rocks. In such cases a cationic emulsion should be used. Once again, as is the case with slurries, where cement and lime is used as filler in the stabilised material, anionic emulsions can be considered for all types of aggregates.

Table 15: Compatibility of emulsion type with aggregate type

Aggregate type	Compatibility	
	Anionic emulsion	Cationic emulsion
Dolerite	✔	✔
Quartzite	✖	✔
Hornfels/Greywacke	✔	✔
Dolomite	✔	✔
Granite	✖	✔
Andesite	✔	✔
Tillite	Variable	✔
Basalt	✔	✔
Sandstone	✖	✔
Rhyolite	✖	✔
Marble/Norite	✔	✔
Syenite	✖	✔
Amphibolite	✔	✔
Felsite	✖	✔

NOTE

On bigger projects emulsion manufacturers may formulate “fit for purpose” emulsions, specifically for the aggregates encountered.

Foam bitumen stabilisation

Foam bitumen is produced by injecting water (and sometimes air) into hot bitumen in an expansion chamber. During this process the water is turned into vapour trapped in tiny bitumen bubbles and the binder volume expands about 15 times. This foaming process is carried on site and the binder is incorporated into the aggregate while still in a foamed state.

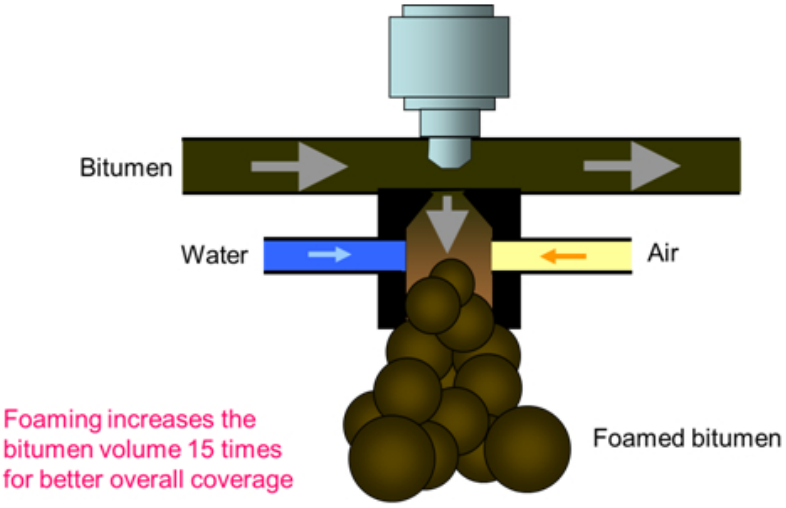

Figure 6: Manufacture of foam bitumen

Binder grade

Binders with penetration values between 80 and 100 are generally selected for bitumen foam stabilised materials. Softer and harder bitumen grades have been used successfully, although harder grade bitumen is generally avoided due to its poor foam quality.

It should be noted that the penetration value alone does not assure suitability of a particular grade of bitumen for use in a foamed bitumen mix. The foaming properties of candidate bitumen grades need to be tested and assessed on the basis of the Expansion Ratio and Half-life as described in TG2.

Availability and packaging

Bituminous binders are usually supplied in bulk road tankers for ease of handling and in the interests of cost-effectiveness. Delivery can be made to:

- storage tanks at asphalt plants;
- emulsion factories ;
- construction sites; or
- into bulk spray distributors, for direct application to the road surface.

Bulk road tankers are generally fitted with liquid petroleum gas or oil heating systems. These heating systems are only used when road tankers are stationary to maintain or increase the bitumen temperature to the level required for pumping, mixing or spraying of the binder.

Bitumen (particularly emulsions) is also supplied in non-returnable drums of 210 litre nominal capacity with the mass of the contents being in the region of 200 kg – the unit in which it is sold.

In specific instances, e.g. when bitumen is exported by sea, it is stored in bulk and transported in purpose-made ISO type containers, generally referred to as “isotainers”, fitted with special heating systems to liquefy the (solid) bitumen for pumping.

Penetration grade and cutback bitumen

The four crude oil refineries in South Africa – one in Cape Town, two in Durban and one in Sasolburg – collectively produce the full SABS range of penetration grade and cutback bitumen used in road building. From time to time, resulting from local demand and available crude sources, it is possible that some refineries may not produce specific grades.

Penetration and cutback grades of bitumen are sold by mass.

Bitumen emulsions

Bitumen emulsions are manufactured in numerous fixed plants in South Africa. All or most of the grades listed in Table 4 are available in bulk or in 200ℓ drums, depending on local demand.

Emulsions are sold by volume.

Modified bituminous binders

Polymer modified

Homogeneous polymers

A number of types of polymer modified bitumen and emulsions are produced by various manufacturing plants in South Africa. The most common modifiers are SBS (Styrene-butadiene-styrene), SBR (Styrene-butadiene-rubber) and EVA (Ethylene-vinyl-aceate).

A number of manufacturers blend their own binder (particularly EVA) at the asphalt batch plant.

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

Non-homogeneous polymers

Bitumen-rubber is usually blended on site in specially designed, high-speed mixing plants, from where it is transferred into a binder distributor for immediate spraying or fed into an asphalt plant for mixing.

Bitumen rubber is, therefore, only available for direct use or where the required volumes are economic to produce.

Hydrocarbons

Blending of binders with hydrocarbons, typically with F-T Wax and natural hydrocarbons generally takes place at hot mix asphalt manufacturing plants.