Guidelines for the design, manufacture and construction of bitumen-rubber asphalt wearing courses

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excellence in bituminous products

ACKNOWLEDGEMENTS

The first edition of this manual was published in 1997 and was compiled by the Bituminous Materials Liaison Committee's Technical Committee on Modified Binders.

The third edition followed an investigation sponsored by Sabita into aspects such as rubber crumb particle size, distribution and the reconstitution of overreacted bitumen-rubber binders. The revision was approved by Sabita's Technology Development Focal Point.

The fourth edition, guidance on nominal mix proportions and design criteria was introduced as an interim measure pending the full implementation of a PG specification for bituminous binders and Sabita manual 35 on the design of asphalt mixes.

In this fifth edition the content of the document has been aligned to Sabita Manual 35, such as the definition of mix types in terms of aggregate configuration and design criteria, it incorporates the use of the A-R2 class of bitumen-rubber binder.

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PREFACE

This document presents guide lines for the design, manufacture, handling and construction of bitumen rubber asphalt. As such, it should be read in conjunction with Sabita Manual 5: *Manufacture and construction of hot mix asphalt*, Sabita Manual 22: *Hot mix paving in adverse weather*, Sabita Manual 35/TRH8: *Design and use of Asphalt in Road Pavements* and TG1: *The use of modified binders in road construction,* fourth Edition January 2019 to obtain a comprehensive perspective of the processes involved.

TEST METHODS

Unless otherwise stated the test methods referred to in this manual are those to be found in SANS 3001: *Civil Engineering Test Methods* or TG1: *The use of modified binders in road construction,* fourth Edition January 2019

ABBREVIATIONS

Abbreviations employed in the specification and design method conform to South African Bureau of Standards nomenclature.

SCOPE

These guidelines cover all the work in connection with the construction of bitumen-rubber asphalt layers such as wearing courses, overlays and levelling courses. Aspects covered are the procurement and preparation of aggregate and bituminous binder, mixing at a central mixing plant, spreading and compaction of the mix.

In addition, the section on mix design covers in detail the special features related to bitumen-rubber asphalt, distinct from the methods used for conventional binders. Similarly, quality assurance procedures include special measures to cater for the nature of the rubber modified binder.

Note

1. *The procedures and design method described are applicable to the process in which the rubber is added to and digested by the hot bitumen, i.e. the so-called "wet-blend method". The addition of rubber to the aggregate in the same way as filler, i.e. the so-called "dry-blend method", is not covered in this guideline document.*

2. *As with previous editions, this document is written as a best practice guideline and not as a specification document.*

CONTENTS

1. INTRODUCTION

Bitumen-rubber asphalt (BRA) has been used successfully in South Africa since its introduction in the early 1980's. The early mixes were produced using the 'dry' blend method whereby the rubber crumb was added as filler to the aggregates in the hot mix asphalt manufacturing process. The 'wet' blend method has subsequently evolved whereby the rubber crumbs are pre-blended with the base bitumen before mixing with the heated aggregates and has become the preferred practice for manufacturing bitumen-rubber asphalt. During the 'wet' blend method the proper ties of the bitumen-rubber binder can be properly assessed and controlled to ensure its optimal performance in the asphalt mixture.

Unlike polymer modified bitumen, bitumen-rubber binder is classified as a non-homogeneous binder as the rubber crumb and bitumen remain as distinct detectable phases with their own localised proper ties. The rubber crumbs are obtained from the buffings of recycled pneumatic vehicle tyres. Once the rubber crumb particles are added to the superheated bitumen they start to react with the aromatic components in the bitumen. This reaction process may be aided by the addition of a small quantity of aromatic oil to act as an "extender" to assist with the digestion of the rubber crumbs. Such oils, frequently termed "extender oils", cause the rubber particles to swell and aid their dispersion in the binder.

The reaction continues at elevated temperatures and results in improved binder performance properties compared with those of the base bitumen. The properties associated with bitumen-rubber binders can further enhance the performance of hot mix asphalt in the following ways:

- Raised binder softening point and viscosity can render mixes with greater binder film thicknesses and reduced drain-down of binder especially in open-graded mixes;
- Increased durability and long term performance of the wearing course mixes due to the presence of carbon black in the rubber, which improves resistance to the adverse effects of ultra violet radiation;
- Improved flexibility of the binder due to the presence of the elastomeric polymer in the crumb. This will allow the asphalt to tolerate higher deflections and offer greater resistance to reflective cracking;
- Increased resilience and toughness of the binder will render the mix more resistant to deformation;
- Reduced susceptibility of viscosity to changes in temperature: and
- Improved fatigue resistance

As a result of these enhanced proper ties bitumen-rubber asphalt has become very popular for over laying badly cracked pavements, as part of a Stress Absorbing Membrane (SAM) and for open-graded wearing courses.

The performance of bitumen-rubber asphalt layers also renders them suitable for effectively inhibiting crack reflections if they are used in conjunction with a bitumen-rubber spray seal as a Stress Absorbing Membrane Interlayer (SAMI). While this practice has the benefit of enabling meaningful reductions in layer thickness when compared with conventional asphalt overlays, care should be taken to prevent the entrapment of moisture in such interlayers.

Although bitumen-rubber asphalt wearing courses are more expensive to construct than conventional asphalt, experience in South Africa shows that they offer significantly improved performance in severe conditions. As such, bitumen-rubber asphalt offers the engineer improved life cost benefits, particularly when used as an overlay for preventing reflective cracking, resisting deformation and providing adequate skid resistance.

This document should be read in conjunction with Sabita Manual 35: *Design and Use of Asphalt in Road Pavements, Technical Guideline 1: The Use of Modified Bituminous Binders in Road Construction* and Sabita Manual 5: *Guidelines for the manufacture and construction of hot mix asphalt*.

2. MATERIAL AND BLEND REQUIREMENTS

BITUMEN-RUBBER BINDER

Bitumen

The base bitumen should comply with the requirements of SANS 4001-BT1 for penetration grade bitumen and be suitable for the particular technology used for the production of the bitumen-rubber. The grade normally used for the manufacture of bitumen-rubber asphalt is either 50/70 or 70/100 for hotter and temperate climatic conditions respectively. However, grades may be blended to provide for a product having a particular penetration or viscosity.

It is good practice to record the actual penetration value, softening point and viscosity of the bitumen used in the bitumen-rubber blend.

Rubber

Rubber is obtained by processing and recycling rubber tyres. The ambient grinding process is recommended due to:

- Cost considerations; and
- Irregular shape of particles, with increased surface area.

The rubber should be made up of a blend of car and truck tyres. Whilst radial truck tyres are preferred as they have higher natural rubber content, utilising only radial truck tyres can limit the crumb rubber sources in the South African market. In addition, too high natural rubber content can lead to high initial viscosity - high peak with short shelf life.

The ground rubber should be free from fabric, steel cords and other contaminants except that up to 4% (by mass of rubber) calcium carbonate or talc may be added to prevent rubber particles from sticking together.

The rubber should be free flowing and dry and comply with the requirements of Table 1 in terms of particle size distribution and composition.

Table 1 Requirement's for rubber crumbs

Property	Requirements	Test Method
Sieve analysis (% mass) Passing screen (mm) 1 0.600 0.075	 100 40 – 70 0 - 5	MB-14
Fibre length (mm)	6 max	
Bulk density	300 – 400	MB-16

Extender Oil

If considered appropriate by the manufacturer, these highly aromatic oils, meeting the requirements given in Table 2 below, are added to the bitumen prior to the addition of the rubber crumbs. The need for this component is determined by the process technology in combination with the base binder used in order to meet specification requirements. The use of extender oils should be disclosed in the method statement of the manufacturer and material data sheets of the particular extender oil should be available to the user.

Table 2 Requirements for extender oils

Property	Requirements
Flash point (°C)	180 min
Saturates by mass (%)	25 max
Aromatic unsaturated hydrocarbon (%m/m)	55 min

Diluent

The addition of petroleum hydrocarbon distillates (typically kerosene) as a diluent or cutter is not recommended in bitumen-rubber binders for use in hot mix asphalt.

Bitumen-rubber blend

The bitumen-rubber blend typically complies with the requirements given in Table 3. This table serves as a guideline only, and the onus is on the supplier of the bitumen-rubber binder to ensure compliance of the final blended product with the requirements stipulated in Table 4, prior to mixing the asphalt. To this end the supplier should have process control systems in place to ensure the end proper ties are readily achieved and records are kept of the material usage.

Table 3: Guidelines for bitumen-rubber blending

Component/criteria	Requirements
Penetration grade bitumen complying with SANS 4001-BT1[1]	76% (m/m) min
Rubber by mass of the total blend (%)	18 - 24
Extender oil by mass of the total blend (%)	3 max
Blending/reaction temperature (°C)	170 - 210
Reaction time (minutes)	45 min [2]
Typical shelf life at mixing temperature (hours)	6 max [3]

Notes:

[1] *Usually a single grade of bitumen is used but the use of blends of grade is not precluded, the main objective being to meet end product specifications.*

[2] *The reaction time commences when all the rubber crumbs have been added to the blend, and terminates when the reaction between the bitumen and the rubber results in the required binder proper ties being met.*

[3] *The shelf life for the product is significantly influenced by the composition of the base bitumen and the particle size distribution of the crumb rubber, and the properties may remain acceptable for up to six hours after reaction time if affirmed by the binder supplier's characteristic rheological properties with respect to time and temperature.*

Table 4 Performance related requirements for bitumen-rubber class A-R1 and A-R2

Property	Requirements		Test method[2]
	A-R1[1]	A-R2[1]	
Compression/recovery (%)	5 min: > 80 1 hour: > 70	5 min > 70 1 hour > 70	MB 11
Softening point (R&B) (oC)2	55 - 65	65 - 80	MB 17
Resilience at 25°C (%)	13 - 40	10 - 40	MB 10
Flow at 60°C (mm)	10 - 50	0 - 40	MB 12
Dynamic viscosity (dPa.s)3	20 – 50 at 190°C	10 – 40 at 170°C	MB 13

Notes:

[1] *Classifications as per TG1: The use of modified binders in road construction*

[2] *Published in the appendix of TG1*

It is recommended that the contractor or supplier of the bitumen-rubber binder submits the following information well in advance of the commencement of the operation:

- Percentage rubber;
- Percentage extended oil (where applicable);
- Blending/reaction temperature;
- Reaction time;

- Penetration value and softening point of the base binder;
- A set of curves showing the change in viscosity, softening point and flow properties of the blended product over time at temperatures of 185, 195 and 205˚C. Figure 1 shows typical changes in viscosity of a bitumen-rubber blend at these different temperatures over time.
- A method statement for the manufacture of the binder, without disclosing proprietary products and processes.

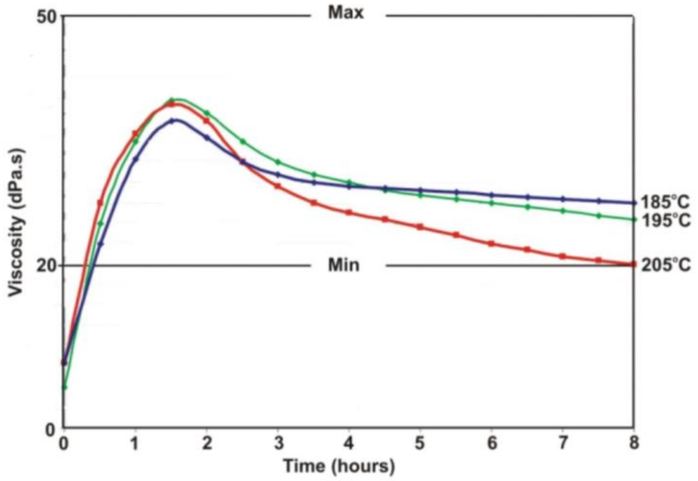

Figure 1 Typical changes in viscosity of bitumen-rubber at different temperatures over time

RUBBER DIGESTION

Digestion of the rubber crumb occurs in stages as the rubber particle is progressively converted from a resilient particle to a gel and finally to an oil. Each of the phases accounts for the performance of the bitumen-rubber in that the elastomeric particle provides resilience while the gel increases the softening point and viscosity. The oil phase improves the durability and increases flexibility (See Figure 2).

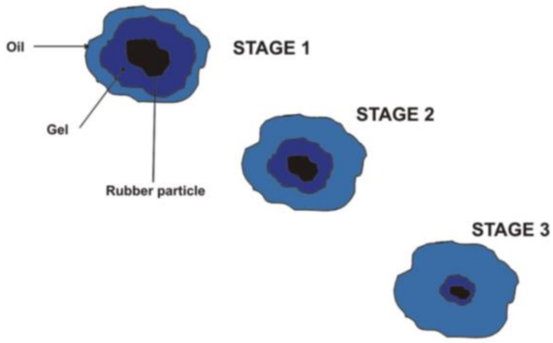

Figure 2 Reaction stages of rubber in bitumen

The source, grading and morphology of the rubber particles will also affect the degree of chemical reaction and therefore the binder performance properties. Rubber from truck tyres is more reactive as these have a higher natural rubber content. Fine particles disperse better within the bitumen whereas large particles tend to remain largely undissolved and float in the bitumen. Buffings which are ground at ambient temperature have a more porous surface compared with those that are cryogenically ground and thus are more absorptive.

It is recommended that the bitumen-rubber binder for asphalt wearing courses meets the requirements set out in Table 4 when sampled within five minutes prior to mixing of the asphalt.

Bitumen-rubber degrades rapidly at temperatures in excess of 200°C. Therefore the blending of the binder generally takes place in close proximity of the asphalt mixing plant. The quantities of bitumen-rubber blended at any time should be limited to amounts that can be mixed and laid prior to degradation of the product.

Proper planning and coordination of activities between the supplier and contractor is essential to avert over-production and product degradation.

After the blending has been completed and the reaction between the bitumen and the rubber has taken place in accordance with the method statement approved for the project (see Chapter 4: *The mix design process*), temperatures and holding times should not exceed the recommended values given in Table 5.

Table 5 Typical temperature / time limits for bitumen-rubber

Binder Class	**Short term handling**		**Storage**		Mixing and laying		
	Max Temp (ºC)	Max holding time	Max temp (ºC)	Max holding time (days)	Max temp (ºC)	Min temp (ºC)	Max holding time(hrs)
A R1	170	24 hours	150	10[1]	210	190[2]	Refer to time/viscosity curves
A-R2	160	> 7days[1]	150	>14[1]	185	170[2]	

Notes:

[1] *If the recommended time period has been exceeded, the binder should be re-sampled and tested to ensure that its properties have not degraded*

[2] *Minimum temperatures for asphalt manufacturing are viscosity-dependent*

RECONSTITUTION OF OVER-REACTED BINDER

Over-reacted bitumen can be classified as homogenised modified binder. While not necessarily complying with the standard requirements for bitumen-rubber, the binder could well be used and need not be disposed of.

In situations where inevitable delays have caused degradation of the binder such that it no longer meets the specified requirements, up to 25% of this over-reacted binder can be blended with new binder and rubber crumbs - with the proviso that the final blend meets the specified criteria. The use of higher proportions of degraded binder can be considered, but will in all likelihood require additional rubber crumb to meet specification requirements.

Any over-reacted bitumen needs to be tested to determine the percentages of it that may be re-introduced into the production of bitumen rubber binder.

PERFORMANCE GRADE SPECIFICATION FOR BITUMINOUS BINDERS

In 2019 SABS published a technical specification, SATS 3208:2019: *Performance Grade (PG) specifications for bitumen in South Africa.* In this specification a framework for grading all bituminous binders is presented based on measures describing stress and strain relationships under field loading, pavement conditions including temperature, traffic speed, traffic volume and pavement structure; and compliance limits derived from fundamental analysis, experience and field performance.

The intention of the specification is not to differentiate between various modifying agents added; all binder should meet the same performance requirements, given the input parameters of climate and traffic. However, for practical purposes, the spindle sizes / gap configuration in tests with the Dynamic Shear Rheometer on non-homogeneous binders, i.e. bitumen-rubber, are specified.

AGGREGATES

Quality

Coarse and fine aggregate should be clean and free from decomposed materials, vegetable matter and other deleterious substances and generally meet the quality requirements as set out in Sabita Manual 35, as given in Table 6 below:

Table 6 Recommended tests and criteria for aggregate selection

Property	Test	Standard	Criteria
Hardness / Toughness	Fines aggregate crushing test: 10% FACT	SANS 3001-AG10	Asphalt surfacings and base: minimum 160 kN Open-graded surfacings and SMA: minimum 210 kN
	Aggregate crushing value (ACV)	SANS 3001-AG10	Fine graded: maximum 25% Coarse graded: maximum 21%
Soundness	Magnesium sulphate soundness	SANS 5839 SANS 3001-AG12	12% to 20% is normally acceptable. Some specifications requires ≤ 12% loss after 5 cycles
Durability	Methylene blue adsorption indicator	SANS 6243	High quality filler: maximum value 5 More than 5: additional testing needed
Particle shape and texture	Flakiness index	SANS 3001- AG4	• 20 mm and 14 mm aggregate: maximum 25[1] • 10 mm and 7.1 mm aggregate: maximum 30
	Polished stone value (PSV)	SANS 3001–AG11	Minimum 50[2]
	Fractured faces	SANS 3001-AG4	• Fine graded: at least 50% of all particles should have three fractured faces • Coarse graded and SMA: at least 95% of the plus 5 mm fractions should have one fractured face
Water absorption	Coarse aggregate (> 5mm)	SANS 3001-AG20	Maximum 1% by mass
	Fine aggregate (< 5mm)	SANS 3001- AG21	Maximum 1.5% by mass
Cleanliness	Sand equivalency test	SANS 3001-AG5	Minimum 50 total fines fraction
	Clay lumps and friable particles	ASTM C142–97	Maximum 1%

Note:

[1] *For certain types of mixes, e.g. open–graded or porous mixes, a maximum flakiness index of 20 is preferred*

[2] *Consideration can be given to adopting a limiting value of 45, with due regard to material availability, traffic, road geometry and climate.*

The design process also requires further tests on aggregates to determine volumetric parameters. These are given in Table 15 of Manual 35 and are given in Table 7 below. Definitions of the volumetric parameters are given in Table 16 of Manual 35.

Table 7 Density parameters used in volumetric analysis

Parameter	Symbol	Definition	Method
Bulk density of aggregate	BD_A	Mass of the aggregate particles divided by the volume of the aggregate particles including the impermeable (internal), and permeable (surface) voids, but excluding the inter-particle voids, expressed in kilograms per cubic metre (kg/m³)	SANS 3001-AG20 (> 5 mm) SANS 3001-AG21 (< 5 mm)
Apparent density of aggregate	AD	Mass of the aggregate particles divided by the volume of the aggregate particles including impermeable (internal) voids but excluding permeable (surface) and inter-particle voids, expressed in kilograms per cubic metre (kg/m³)	SANS 3001-AG20 (> 5 mm) SANS 3001-AG21 (< 5 mm)
Water absorption	W_{ABS}	Difference in mass between the saturated surface-dry condition and the oven-dry condition of a given volume of aggregate	SANS 3001-AG20 (> 5 mm) SANS 3001-AG21 (< 5 mm)
Bulk density of binder	BD_B	The bulk density of the binder, expressed in kilograms per cubic metre (kg/m³)	Method E2 (TMH1)
Bulk density of mix	BD_{MIX}	Mass per unit volume, including the air voids, of a bituminous mixture at a known test temperature, expressed in kilograms per cubic metre (kg/m³)	SANS 3001-AS10

Maximum voidless density of the mix (Rice method)	MVD	Mass per unit volume of a voidless bituminous mixture at a known test temperature	SANS 3001-AS11
Coarse aggregate loose unit weight	LUW	The loose unit weight of an aggregate is the amount of aggregate that fills a unit volume without any compactive effort applied.	AASHTO T-19
Coarse aggregate rodded unit weight	RUW	The rodded unit weight of aggregate is the amount of aggregate that fills a unit volume with compactive effort applied	AASHTO T-19

Aggregate Grading

The SANS 3001-AG1 procedures will be followed in this manual for particle size analysis of aggregates by sieving. To facilitate consistent blending results, aggregate gradings should constantly comply with the requirements of SABS 1083.

FILLERS

The role, function and types of fillers are dealt with in detail in section 4.3.4 of Manual 35. Fillers are classified either as “inert” (such as natural dust or rock-flour) or active” (such as hydrated lime or cement). In asphalt mixes filler normally serves the following purposes:

- Acts as an extender for binder to stiffen the mastic and the mix, thereby improving stability.
- Acts as a void-filling material which can be used to adjust gradings and volumetric properties.
- Some fillers e.g. lime are used to improve the bond between the binder and the aggregate.
- Specific fillers such as fly ash can be used to improve mix compactability.

While adequate amounts of filler ensure adequate cohesion, which is a major contributing factor to the provision of resistance to permanent deformation in certain mix types, excess filler stiffens the mix to the extent that it may be difficult to compact. Insufficient filler will result in low cohesion, and the mix may fall apart.

The types of filler in general use is listed in Table 10 of Manual 35 and is given below in Table 8 below.

Table 8 Filler types and characteristics

Type of filler/origin	Characteristics	Test method / Criteria
Hydrated lime (active filer)	• Improves adhesion between binder and aggregate • Improves mix durability by retarding oxidative hardening of the binder • Low bulk density and high surface area • Relatively high cost • Monitor effect on stiffness to ensure compactability	• Grading (% passing 0.075 mm) (SANS 3001-AG1): minimum 70 • Bulk density in toluene (BS 812): 0.5 – 0.9 g/m/ • Voids in compacted filler (BS 812): 0.3 – 0.5% • Methylene blue test (SANS 6243): maximum value 5
Portland cement (active filler)	• Relatively high cost • Monitor effect on stiffness to ensure compactability	
Baghouse fines	• Variable characteristics require control • Some source types may affect mix durability • Some types may render mixes sensitive to small variations in binder content	N/A
Limestone dust	• Manufactured under controlled conditions and complies with set grading requirements • More cost-effective than active filler • Although it is viewed as an inert filler, the high pH value reduces moisture susceptibility	N/A
Fly ash (non-active filler)	• Low bulk density • Relatively high cost • Variable characteristics require greater control	Same test methods as for active fillers (above)

GENERAL

All materials should be handled and stockpiled in a manner that will prevent contamination, segregation, or dam age. All active fillers, binders and binder modifiers should be used in the sequence in which they have been received, i.e. on a “first in, first out” principle.

Materials should be sampled and tested on a regular basis prior to use to en sure consistent compliance with the specified requirements.

BLEND REQUIREMENTS

All the necessary tests should be conducted on the aggregates in advance to ensure that mix requirements will be met when using the proposed aggregate complying with the required grading limits.

Since water permeability tests are often problematic in that high variability can be experienced given the complexity of flow paths for a particular testing location, air permeability the use of the air permeability test has been introduced to quantify permeability.

3. Occupational health, safety and the environment

The general properties and characteristics of bituminous products that could give rise to adverse health, safety and environ mental effects are well documented in other Sabita publications, and are therefore not repeated in this document. For a more de tailed treatment of bitumen related HSE issues the reader is referred to the following publications:

- Sabita Manual 8: *Guidelines for the safe and responsible handling of bituminous products;*
- Sabita Manual 29: *Guide to the safe handling of solvents in a bituminous products laboratory*;

For HSE discussion purposes bitumen-rubber is grouped under Modified Bituminous Binders and therefore users may also refer to Chapter 2 of TG1: *The use of modified bituminous binders in road construction.*

In the paragraphs that follow, the most important HSE hazards and effects, specific to bitumen-rubber binders, are highlighted and discussed briefly.

Safety hazards

Elevated temperature (160°C - 210°C)

Bitumen-rubber binders are generally applied at higher temperatures than conventional binders to offset the increase in viscosity. The application temperature could be as high as 210°C.

As is the case with conventional binders, the most common potential consequence associated with the handling of bitumen-rubber binders is severe burns resulting from hot liquid or hot processing equipment making contact with unprotected parts of the human body.

Flammable vapour and ignition sources

Bitumen-rubber binders are normally handled at temperatures below the flash point of paving grade bitumen (> 230 °C). However, the addition of extender oils to the bitumen-rubber blend could have the effect of lowering the flashpoint of the blended product. Literature that was consulted indicates the following:

- flashpoints of proprietary rubber extender oils range from 204°C to 220°C;
- flashpoints of bitumen-rubber binders are generally ≥ 220°C.

If handled correctly bitumen-rubber blending and application operations should not present a significant fire or explosion risk. However, it should always be borne in mind that the existence of a flammable mixture in the vapour phase of blending tanks, distributor tanks, etc. can never be completely ruled out. Any high energy ignition source could ignite the mixture resulting in a violent explosion.

Reactive bitumen foaming ('boil over')

Hot bitumen reacts violently with water causing reactive bitumen foaming that could lead to a boil-over during blending with the hot bitumen. Spillage of hot bitumen could result in severe burns to exposed workers.

Recommended controls for safety hazards

- Employees involved with the blending and hand ling of bitumen-rubber binders should undergo specific safety induction/training in order to be informed of the potential hazards and threats associated with the blending process and products used;
- All bitumen-rubber handling plant and equipment that operates at elevated temperatures must have thermal shielding installed;
- Workers must wear appropriate Personal Protective Equipment to protect against contact with hot surfaces or liquid;
- Vapours should be controlled and/or dispersed by venting, particularly when operating temperatures are close to or exceed the flash point of the product;
- Sources of ignition should be eliminated in confined spaces where flammable vapour mixtures may be present. For example, sources of naked flames and practices such as open-flame heat ng of spray bars are not permitted;
- To prevent reactive liquid bitumen foaming and 'boil over' water should not come into contact with

bitumen. To this end, tests should be carried out to ensure that extender oils, and other bitumen-rubber blending additives are not contaminated with water. Also, care must be taken to ensure that the rubber crumbs are dry before adding it to the hot bitumen;

- Care should be taken to ensure that water does not enter into tanks or vessels containing bitumen-rubber at elevated temperatures; pipes, valves, hoses and tanks should be free from water or contaminants.

HEALTH HAZARDS

Blending and paving operations

Small quantities of highly aromatic oils are sometimes used as extenders in the manufacture of bitumen-rubber. These extender oils contain high concentrations of potentially harmful polycyclic aromatic compounds (PACs), also referred to as Polycyclic Aromatic Hydrocarbons (PAHs).

Numerous studies in the USA and Europe have been conducted on the health effects of occupational exposure to 'conventional' bitumen and modified bitumen including bitumen-rubber binders. These studies have found that, at very high temperatures the presence of additives (i.e. extender oils) increases the potential for emission of toxic fumes during blending and paving operations. The studies found however that the measured concentrations of toxic fumes at recommended processing temperatures were very low, and within the prescribed Occupational Exposure Limits. Diligent temperature control during processing of bitumen-rubber is therefore a cardinal rule for quality, health and safety control purposes.

Increased likelihood of exposure to harmful fumes

Of particular interest is a study done in the USA by the National Institute for Occupational Safety and Health (NIOSH). The study is entitled Crumb-rubber modified asphalt paving: occupational exposures and acute health effects, Niosh Health Hazard Evaluation Report: Heta #2001-0536-2864.

The findings of this report also suggest that worker exposures to bitumen-rubber fumes are potentially higher during paving operations, particularly at job stations near the paver or asphalt delivery trucks. Eye, nose, and throat irritation were the symptoms most frequently reported.

The results of this study therefore suggest that worker exposure in close proximity to binder distributors/pavers and delivery trucks should be assessed on site and, if necessary, measures must be implemented to minimise exposure to fumes.

The results of the studies cited above were based on samples taken in the Personal Breathing Zones of operators. See Figure 3.

The breathing zone - a hemisphere of 300mm radius ex tending in front of a person's face measured from the mid-point of an imagi nary straight line joining the ears.

Figure 3 Breathing zone

Handling samples in the laboratory

During processing of bitumen-rubber samples in an asphalt laboratory the test methods may involve heating samples to very high temperatures. Due to the increased potential for emission of toxic fumes under these conditions it goes without saying that good laboratory practice is paramount to ensure laboratory technicians and workers are adequately protected during handling and testing of bitumen-rubber binder samples.

Recommended controls for health hazards

Minimising personal exposure is the only practical way to control the potential ill health effects of bitumen-rubber binder fumes. The following control measures must be given due consideration in blending and application methodology as well as operating procedures:

- Health risk assessments must be conducted to identify specific tasks where workers are at increased risk of exposure;
- Personnel must be made aware of the potential harmful effects of bitumen-rubber fumes;
- A Material Safety Data Sheet (MSDS) for the specific modified bitumen must be available to personnel involved in the testing, handling and application of the binder;
- Personnel must be adequately trained, instructed and super vised to ensure compliance with safe operating procedures;
- Work at the lowest operating temperature commensurate with best practices for handling and application;
- Minimise exposure to “fumes” by ensuring adequate ventilation and safe work practices at the work site (including simple practices e.g. standing upwind of the source of fumes);
- Appropriate respiratory protection must be provided to any personnel working in areas where bitumen rubber fumes are likely to be in their breathing zone (See Figure 3) at concentrations above the Occupational Exposure Limits;
- Strive towards eliminating the exposure of laboratory workers to vapour or fumes caused by the use of toluene. The use of an ignition furnace is preferred for determining binder content.

ENVIRONMENTAL ASPECTS

Generally, bitumen is considered to be a non-ecologically toxic product which does not present any significant danger to plant and aquatic environments.

Bitumen-rubber spills

Notwithstanding the above it should always be remembered that large spillages of hot liquid bitumen, regard less of the binder composition, could have a devastatingly acute local effect on especially plant life. Spill prevention and recovery measures (secondary containment) should always be a top priority in the design and operation of bitumen-rubber blending, transport and paving facilities.

Air emissions

From 1992 onwards a number of studies have been conducted in the USA and Europe specifically to evaluate fume emissions from bitumen-rubber manufacturing and paving sites. Conclusions from these studies suggest that:

- Stack emissions from the production of bitumen-rubber binders are not significantly different than those from the production of conventional asphalt;
- Odour observations did not identify odours emanating from bitumen-rubber binders as being significantly stronger than those from conventional bituminous products. (Noticeable odours were generally confined in close proximity to loaded haul trucks);

Users are urged to en sure that emission controls required in terms of the Air Quality Act, 2004 are properly maintained and carefully monitored to ensure that emission limits are not exceeded.

4. THE MIX DESIGN PROCESS

In preparing this sect ion it is assumed that the design of bitumen-rubber asphalt will be carried out by persons familiar with the design of asphalt as presented in Manual 35. Consequently, the full design procedure I not covered; rather certain aspects particularly pertinent to bitumen-rubber asphalt are highlighted in this sect ion.

SELECTION OF MIX TYPE

In Manual 35, asphalt mixes are primarily classified into two main categories based on aggregate packing i.e. *sand-skeleton* or *stone-skeleton* types. Determining the aggregate packing characteristics of the mix is a critical choice to be made for mix type selection.

In sand-skeleton mixes, the loads on the layer are mainly carried by the finer aggregate fraction, with the larger fractions providing bulk and replacing a proportion of the finer fraction. There is no meaningful contact between the individual larger aggregate particles. Examples include semi-gap graded asphalt, fine gap-graded asphalt, and medium / fine continuously graded asphalt.

In stone skeleton mixes the loads on the layer are carried by an interlocking matrix of the coarser aggregate fraction. For this matrix to be achieved, the spaces between the coarser aggregate fractions are "under-filled" by the finer aggregate fractions, so as not to push the coarser aggregates apart. Contact between the coarser aggregate fractions is thus assured. Examples include coarse continuously graded asphalt, stone mastic asphalt, ultra-thin friction courses, and open graded asphalt (porous) asphalt.

Three classes of mix types are generally used for the manufacture of bitumen-rubber asphalt:

- Continuously graded asphalt
- Bitumen-rubber asphalt gap-graded (BRAGG)
- Bitumen-rubber asphalt open-graded (BRAOG)

Whereas continuously graded asphalt could be either a sand- or stone skeleton mix, generally associated with fine graded and coarse graded respectively, both BRAGG and BRAOG types are stone skeleton mixes. The essential difference in component configuration between the two types is the voids in the mix (VIM). A BRAGG mix would have Marshall VIM of 4 – 6%, whereas a BRAOG mix has VIM of 20 – 25%.

This mix design procedure applies to bitumen-rubber asphalt where rubber-crumbs are added to the bitumen prior to mixing with hot aggregate in the mixing plant – the so-called "wet blend" method.

Bitumen-rubber asphalt mixes are designed in a similar way as mixes using unmodified bitumen, but with variations of standard procedures and the addition of some special tests. These procedures are cove red in this chap ter.

The rates of application and mix proportions of bituminous binder, aggregates and fillers given in this chapter are nominal rates; the actual rates and proportions applied on a project will be dictated by the materials actually used and conditions prevailing during construction.

To assist the select ion of an appropriate mix type in terms of a set of typical de sign objectives, Table 9 lists the performance ratings for the different mix types.

Table 9 Mix classes and performance ratings

Mix class	Typical applications	Performance ratings (1 = poor, 5 = excellent)						
		Ease of design	Rutting resistance	Durability / fatigue resistance	Skid resistance	Impermeability	Noise reduction	Ease of construction
Continuous	Flexible surfacing overlay	2	3	4	3	4	3	2
BRAGG	Flexible surfacing layer	3	4	4	3	3	4	3
BRAOG	Functional layer[1]	3	4	3	4	1[2]	5	4

Note:

[1] *For improved surface texture, surface drainage and noise abatement*

[2] *Impermeable support layer or membrane required*

MIX GRADING

Whereas Sabita Manual 35 requires that the mix packing characteristics should be selected on the basis of the prime function of the asphalt layer, nominal recommended gradings of the blends of aggregate and filler are indicated in Table 10 for the various mix classes. These gradings are guidelines only and the actual mix grading accepted for the project - designated as the project grading - should form the basis for applying the tolerances given in Table 13, which is based on the tolerance limits given in Manual 35..

Table 10 Nominal recommended gradings for mix classes[1]

Sieve (mm)	Percentage passing by mass			
	Continuously graded		BRAGG	BRAOG
	Medium	Coarse		
20		100	100	100
14	100	85 - 100	84 - 100	100
10	80 - 100	70 - 85	68 - 83	55 - 75
5	50 - 75	45 - 65	29 - 43	20 - 30
2	30 - 45	25 - 45	12 - 20	5 - 15
1	-	17 - 30	-	-
0,600	13 - 25	13 - 25	-	-
0,300	8 - 18	10 - 18	-	3 - 8
0,150	-	6 - 13	-	-
0,075	4 - 8	4 - 10	1 - 4	2 - 5

Note:

[1] *Current best practice requires that design procedures, such as the Bailey Method, rather than adherence to grading envelopes, be employed to optimise aggregate packing for enhanced performance. Consequently the gradings indicated are for guidance only and should not be employed to restrict aggregate proportioning*.

COMPONENT MATERIAL SAMPLES

Samples

Prior to the commencement of the deign process all components to be used must be available in sufficient quantities. The following schedule is recommended:

Coarse aggregate	25 kg
Inter mediate aggregate	25 kg
Fine aggregate	25 kg
Filler	10 kg
Pre-blended bitumen-rubber	15 kg

Note*:*

It is recommended that the bitumen-rubber binder supplier provides samples of the pre-blended bitumen-rubber in 1l containers. However, the bitumen-rubber samples should not be reheated more than once, as the properties of the bitumen rubber can be adversely affected.

All samples should be taken in accordance with TMH 5 and TG 1.

It is important that the necessary testing and the necessary precautions are in place to ensure that the mix design is carried out on raw materials complying with the requirements as given in Chapter 2 of this manual.

Bitumen-rubber binder

Ideally a bitumen-rubber blend should be prepared in the manufacturer's blending plant. It is not recommended that blends be made up in the laboratory. However, where this is unavoidable, the laboratory procedures must replicate steps in the manufacturer's method statement.

Blended Aggregates

The various samples of aggregate are blended to produce the desired gradation using a suitable method.

Mix design tests

The general procedures given in Table 11 are used to establish mix design parameters. However, conditions may have to be varied to conform to the manufacturer's method statement. Once the super-heated aggregates have been mixed with the bitumen-rubber binder, the asphalt mix should be stored in an oven at the asphalt mixing temperature for 45 minutes to simulate age hardening under plant conditions before preparing laboratory specimens for testing.

Table 11 Design test references

Procedures	Reference
Preparation of asphalt specimens for Marshall testing and voids analysis **Variations:** Mixing and compaction temperatures **Marshall compaction:** Continuously-graded, BRAGG - 75 blows BRAOG - 50 blows	SANS 3001-AS1: *Making of asphalt briquettes for Mar shall tests and other specialised*
Determination of bulk density of a compacted mixture and calculation of void content	SANS 3001-AS10: *Determination of bulk density and void con tent of compacted asphalt*
Determination of maximum void-less density and bitumen absorption	SANS 3001-AS11: *Determination of the maximum void-less density of asphalt mixes and the quantity of binder absorbed by the aggregate*
Determination of durability (TSR) Modified Lottman Test	ASTM D4867 M *Standard Test For Effect of Moisture on Asphalt Concrete Paving Mixtures*
Determination of dynamic creep	CSIR RMT 004
Determination of indirect tensile strength	ASTM D4123 *Standard Test Method for Indirect Tension Test for Resilient Modulus of Bituminous Mixtures*
Resistance to rutting	AASHTO T 324 *Standard Method of Test for Hamburg Wheel-Track Testing of Compacted Hot Mix Asphalt*
Air permeability	TRH8 (CSRA 1987) Appendix C
Immersion index	TMH1 Method C5 *The determination of the Immersion Index of a bituminous mixture*

BINDER CONTENT

The binder content of the bitumen rubber asphalt can be determined by one of two methods:

- Extraction method;
- Ignition furnace.

Use of the ignition furnace in accordance with SANS 3001-AS21: *Determination of the bitumen content of an asphalt mix by ignition* is the preferred procedure as the extraction method is not only time consuming the determination of the correction factor is a very delicate process.

The ignition furnace burns off the binder at a very high temperature and is thus a very quick and easy quality control measure to monitor the binder content during production of a specific bitumen-rubber asphalt mix to which the furnace method has been calibrated.

During the process of manufacturing bitumen-rubber, the rubber crumb becomes digested by the bitumen. Consequently binder content determinations during manufacture will be subject to a correction factor as some of the undigested rubber is not accounted for during the extraction process. This correction factor must be determined and then used to calculate the true bitumen-rubber binder content of the mix for each sample taken from the plant. The following procedure is recommended:

- An aggregate blend conforming to the design requirements is made up in the laboratory;
- At the same time as the mix is sampled from the plant, a sample of the bitumen-rubber is taken;
- The binder is mixed with the aggregate blend at the design binder content;
- The time of mixing and mixing procedure should be kept the same for the duration of the project as slight changes in aggregate temperature, time of mixing, temperature of hot plate etc. can have an influence on the test result;
- An extraction is then carried out in accordance with SANS 3001-AS20;
- A factor (f) is then calculated as follows:

$$f = \frac{\text{mass of bitumen} - \text{rubber added to aggregate blend}}{\text{mass of soluble bitumen} - \text{rubber binder determined by extraction}}$$

Notes:

1. *When making up this mix, all spatulas, mixing bowls, scoops etc. must be allowed for in the mass determinations;*
2. *No curing of the control hot mix asphalt sample in the oven is recommended as this will lead to poor repeatability in the determination of the factor;*
3. *When reporting the binder content state whether a correction fact or has been used or not;*
4. *To ensure the consistency of specimens, it is good practice to adopt a set time limit for sample preparation;*
5. *The use of a cooling fan is recommended to limit continued digestion during sample preparation.*

DESIGN CRITERIA

The suggested nominal mix proportions and design criteria for bitumen rubber asphalt are listed in Table 12. These proportions constitute a useful starting point for mix design and for tendering purposes. It needs to be emphasised that these criteria may have to be varied to cater for constituent material properties (e.g. aggregate particle shape), structural features (e.g. layer thickness) and layer function (e.g. resistance to reflection cracking or wet weather skid resistance).

Table 12 Nominal mix proportions and design criteria

Nominal mix proportions (% by mass			
Materials	**Continuously graded**	**BRAGG**	**BRAOG[4]**
Blended Aggregate	92	91	93.5
Bitumen-rubber binder[1]	7	8	5.5
Active Filler	1	1	1

Design criteria			
Marshall stability (kN)	8 min.	6 min.	-
Marshall flow (mm)	2 - 5	3 - 6	-
Voids in mix (%)	2 - 6	4 - 6	20 - 25
Indirect tensile strength (kPa)	600 min.	550 min.	-
Dynamic creep (MPa)	15 min.	15 min.	-
Binder film thickness (µm)	15 min	20 min.	15 min.
Modified Lottman (%)	80 min.	80 min.	80 min.
Immersion index[2] (%)	75 min.	80 min.	75 min.
Filler/binder ratio[3]	0.7 - 1.3	0.25 – 0.7	0.5 - 1.3
Wheel Tracking Test	As stipulated in Manual 35[3]		-
Air permeability	$\leq 1 \times 10^{-8}$ cm^2		-

Note:

[1] To accommodate these relatively high binder contents, the VMA requirements may be higher than asphalt with conventional binders

[2] These criteria are given as a guide for field testing only

[3] The proposed permanent deformation criteria for the HWTT are given in Table 31 of Manual 35. It is suggested that, in cases where the rut depth developed after the prescribed minimum number of passes exceeds 6 mm, further investigation be carried out , e.g. MMLS testing

[4] The resistance of open-graded asphalt briquettes to abrasion loss is assessed by means of the Cantabro test as per Sabita Manual 17.

FINALISATION OF THE PROJECT MIX

Following completion of the laboratory design, the mix should be produced in the plant in accordance with this design and tested for compliance with the design requirements. Proving the design in this way usually results in small deviations from the initial design grading, consequently the aggregate blend grading is normally finalised after plant mixing. Following further laboratory test ng and satisfactory results the “project mix” is finalised. It is also good practice to lay this mix on a trial section on site to ensure good constructability and the absence of undesirable handling characteristics.

5. Plant and equipment

General

Plant used for the manufacture of bitumen-rubber asphalt should be designed and operated in a manner that will en sure the production of a mixture complying with the requirements of the product specifications. The plant and equipment should also be of adequate rated capacity and in good working order.

Plant and vehicles used at the laying site should be free from oil, fuel and hydraulic fluid leaks. Freshly laid bitumen-rubber asphalt is very susceptible to such fluids and will result in fatty patches forming should such leaks occur.

Bitumen-rubber blending plants

Bitumen-rubber is usually blended on-site due to its relative short shelf-life. This is done via a high speed mixer whereby the super-heated bitumen and rubber crumb are blended in constant proportions.

Figure 4 shows a schematic of a typical high speed bitumen-rubber blending plant. The bitumen-rubber binder is reacted in a heated digestion tank fitted with mixing augers. These tanks must be self-draining and of optimum capacity to meet the production needs of the asphalt mixing plant given the shelf-life constraints of the blended product. Bitumen-rubber spray tankers can also be used for this purpose.

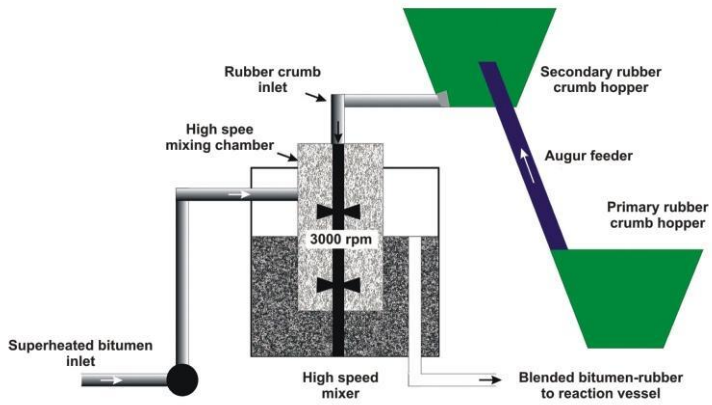

Figure 4 Schematic of typical high-speed bitumen-rubber blending plant

The heating system of the tanks used for storage and super heating of the base bitumen is designed to prevent degradation of the binder during heating. The tank used for super heating the bitumen should be equipped with double flues to heat the bitumen to a temperature of up to 210ºC. The digestion tank should be fitted with augers placed above the heating flues which are able to maintain the binder temperature between 170 and 210ºC.

A positive displacement gear pump which is capable of handling a product with a viscosity of up to 50 dPa.s with adequate capacity should be used to ensure continuous feed and circulation from the digestion tanks to the header tank. From here it is metered on a volumetric basis into the asphalt drum mixer or pugmill during the entire operating period. These pumps have a limited life due to the wear caused by the unrecovered metal in the rubber crumbs and should be replaced timeously. Ideally, the mixing of the bitumen-rubber with the heated aggregate should only take place once the viscosity of the bitumen rubber has reached its peak and is reducing to ensure ad equate coating of the aggregate with the viscous binder.

Binder storage tanks are fitted with thermometers designed to provide a continuous record of the temperature of the binder in the tank. All plant should be provided with a sampling point for the base bitumen and for the bitumen-rubber binder at a point between the digestion tanks and the asphalt mixing plant. To prevent undigested rubber crumb from segregating, means of agitation should be available while in storage.

The planning for the blending of the bitumen-rubber should be done in such a manner that only sufficient quantities of binder are pre-blended to meet the asphalt demand for the current shift. The size of a bitumen-rubber binder batch will vary between 10 and 25 tons. Therefore compartmented tanks or two bitumen rubber distributors of adequate capacity are used in tandem to allow continuous production so as not to cause delays in the manufacture of the asphalt. However should unexpected delays occur which result in a reduction in the demand for asphalt, the temperature of the pre-blended bitumen-rubber should be reduced immediately to retard the reaction and thus the degradation of the binder proper ties.

ASPHALT MIXING PLANTS

Bitumen-rubber asphalt should be mixed in a mixing plant with a proven capability of producing a BRA mixture com plying with all the requirements of the specifications. The rated capacity of the mixing plant should meet production requirements for the project.

Suitable means should be provided for maintaining the specified temperatures of the binder in the pipelines, weigh pots, and other containers or flow lines.

In the case of a drum type mixer, consistent compliance of the mix proportions with the specified requirements, the following equipment control systems should be in place:

- Separate cold feed controls for each of the aggregate fractions and filler;
- Automatic continuous aggregate weighing systems; and
- Integrated controls of aggregate cold feed and binder delivery to the drum.

Regular monitoring of the moisture content of the aggregate fractions is critically important to ensure that the correct amount of binder, based on the dry mass of aggregate, is introduced in the drum.

Contamination of the aggregate in the dryer should be prevented by the correct choice of fuel and control of the burner to ensure complete combustion of the fuel.

To prevent over-reacted bitumen being supplied to the asphalt plant, it is good practice for the viscosity of the binder to be tested immediately prior to manufacture, to ensure that it complies with the minimum specification.

PAVERS

The mixture should be laid with a self-propelled mechanical paver capable of laying to the required widths, thicknesses, profile, camber or cross-fall, without causing segregation, dragging or other surface defects.

All pavers should be fitted with auger sensors and automatic screed controls to maintain the required levels, cambers and cross-falls. Where levelling beams are used they should be at least 7m long.

Due to the high viscous nature of the binder hand work should be kept to a minimum. Similarly all equipment should be thoroughly cleaned at the end of each shift.

ROLLERS

Compaction is normally carried out with static or vibratory steel wheel rollers. The use of pneumatic-tyre rollers are not recommended as they are inclined to cause pick-up of the mix by the tyres. The frequency as well as the amplitude of vibratory rollers should be adjustable so as to be suitable for use on asphalt surfacing mixes.

Notwithstanding the above, when paving on concrete, steel wheel rollers can crushing of the aggregates and in such cases a pneumatic roller may be required for initial compaction, with the steel wheel rollers coming on later to even out the mat.

Where bitumen-rubber asphalt layers are placed on stiff substrates, e.g. concrete pavements, rollers should be selected with due care as regards both mass and type (e.g. vibratory or oscillating) so as to avoid crushing of the aggregates, thereby reducing the voids in the mix which may cause fattiness on the surface.

The rollers should be in good working condition, free from backlash, faulty steering mechanism and worn parts. Drums should be kept clean with adjustable scrapers and with efficient means of keeping the wheels wet to prevent mix from sticking to the rollers. The amount of water used to keep the wheels wet should be just sufficient to prevent adhesion of the mat and not excessive, which would cause untoward cooling of the layer. A soap solution or non-stick additive may be used to prevent adhesion, but petroleum based products should not be permitted.

As with other asphalt applications, vibratory rollers should not be used on bridge decks or over services without prior permission of parties responsible for the structure and/or services.

The layer density achieved must be monitored continuously using a calibrated nuclear density gauge. Over-compaction should be guarded against, since densities of 96% and above could lead to premature bleeding problems. However, it should also be noted that bitumen-rubber characteristically rebound whereby an initial reading of density may be a percentage or two lower than the level at which it would stabilise. As a rule of thumb, the rebound effect for dense graded mixes is around 2% and for open/gap-graded mixes around 1%.

TANKERS

Tankers used for transporting bitumen-rubber should be fitted with heavy-duty recirculation devices of mechanical agitators to prevent segregation of the undigested rubber crumb.

BINDER DISTRIBUTORS

Where a bituminous bond coat is to be sprayed before laying the asphalt, the binder distributors should be certified as fit-for-purpose.

TRUCKS

The aspect of transport of asphalt by truck is covered extensively in Sabita Manual 5: *Guidelines for the manufacture and construction of hot mix asphalt.* A number of important requirements are highlighted here.

Bitumen-rubber asphalt is more sensitive than conventional mixes and therefore special care needs to be taken when transporting such mixes. All trucks delivering asphalt should be in good working order, have clean, smooth beds and sides, should be able to carry and tip loads efficiently, and be issued with a valid roadworthy certificate.

Specific items to be checked are:

- Complete absence of oil leaks;
- Fully functional brakes;
- Good idling and tipping capability, with no hydraulic leaks;
- Tail-gate suitable for tipping into paver hopper; and
- Adequate uphill pull-away capability.

Asphalt in trucks should be covered completely with a tarpaulin or other suitable thermal isolation/insulation sheeting to prevent contamination and to inhibit cooling. Hessian sheets are not acceptable.

To prevent asphalt adhering to the truck body, an approved release agent, e.g. a silicone emulsion, or biodegradable vegetable oil emulsion, should be used. Oil-based materials such as engine oil, paraffin or diesel fuel should not be used

When transporting open-graded asphalt, truck bodies should be cleaned after every delivery.

6. General precautions and the storage of mixed materials

The risk of inadequate compaction of the asphalt layer is considerably increased by unfavourable weather conditions. Rapid cooling due to the loss of heat from the asphalt through the effects of wind, water and low ambient and base temperatures will be counter-productive to the achievement of ad equate compaction since these conditions narrow the time window available to achieve specified compaction.

In addition, water in a granular base being covered with an asphalt layer will introduce weaknesses and offer a poor platform for compaction in addition to rendering the material inferior in strength to carry traffic loading.

Trapped water in the asphalt layer itself could cause loss of durability leading to premature distress.

As most current specifications do not deal comprehensively with the complexities associated with laying asphalt in adverse weather conditions such as rain, wind and low temperatures, it is recommended that the guidelines contained in Sabita Manual 22: *Hot mix paving in adverse weather* be followed to assess the risks involved and to adopt realistic practice when adverse weather conditions are encountered.

Base course moisture content

It is recommended that asphalt should only be placed once the moisture content of the under lying granular base course layer is equal to or less than 50% of OMC (Optimum Moisture Content) of the layer. Some practitioners prefer an upper limit of 20%.

Surface requirements

The surface on which the bitumen-rubber asphalt is placed, should comply with the specified requirements of evenness and accuracy of grade, elevation and cross-section. Where required, corrections should be made prior to paving.

The asphalt used for the correction of the base should be similar to the final layer, except that it may be necessary to adjust the maximum aggregate size in relation to the thickness of the correction layer.

Cleaning of the surface

Immediately before applying the bond coat, or where there is no bond coat, before the application of the asphalt, the surface should be broomed and cleaned of all loose or deleterious material. Damaged prime coat should be repaired by hand brushing or spraying prime material over the damaged portions.

Where the surface to be paved is a newly constructed concrete layer, removal of curing compound and associated layers of laitance would require methods such as sand blasting or water jetting to prepare the surface prior to the application of a bond coat. Allowance in the bill of quantities must be made for this.

Bond coat

In most cases a bond coat would be required to ensure adequate adhesion of the asphalt mat to the under lying layer during compaction.

Generally a diluted bitumen emulsion (anionic or cationic stable mix emulsion, diluted 1:1 with water) is used to attain a complete coverage of a thin residual binder film on the surface. Typically, a residual bitumen coat of approximately 0,15 – 0,25 l/m^2 should be aimed for, depending on the condition of the surface on which the bond coat is sprayed.

Where there are grounds for concern regarding the presence of moisture that may adversely affect the bond between the asphalt wearing course and the substrate, consideration should be given to the use of a modified bitumen emulsion which would yield application rates in terms of residual binder of 0.45 l/m^2.

Storage

Precautions for the storage of mixed asphalt should be covered in the method statement of the manufacturer or sup plier.

Unless provision has been made for storage, the mixing of bitumen-rubber asphalt should take place within four hours prior to paving. Mixed material should be stored in hot storage silos which are capable of maintaining a uniform temperature of the mix throughout. Storage of mixed material for longer than 6 hours should be avoided as deterioration of the material qualities may set in after this period. The exact limitation is dictated by the reaction time and temperature regime of the rubber crumb and the bitumen. (See Chapter 2:

Material and blend requirements).

Open-graded mixes should be laid directly following mixing and not mixed and/or stored too far ahead of paving operations.

7. QUALITY ASSURANCE

INTRODUCTION

Due to the non-homogeneous nature of the bitumen-rubber, special precautions need to be taken during the quality assurance processes.

It is recommended that, before commencement of the works, a planning meeting should be held with representatives of the bitumen-rubber binder supplier, asphalt manufacturer, paving contractor, and engineer to decide and agree on the various procedures, activities and responsibilities of all the parties.

Well in advance of the commencement of operations, it is good practice to establish a detailed method statement setting out details of the binder blending procedure and the preparation of the asphalt mix under full-scale production conditions. Blending and mixing temperatures and times for producing the asphalt briquettes in particular should be provided by the bitumen-rubber binder supplier.

Procedures for taking samples for testing need to be established. Agreement must be reached on where and when the bitumen-rubber binder sample is to be taken as the proper ties will vary with time and temperature due to the ongoing chemical reaction while the binder is at elevated temperature. It is general practice to take the bitumen-rubber binder sample five minutes before the asphalt is manufactured.

The change in the binder proper ties will result in a concomitant change in the volumetrics of the asphalt mix over time. This occurrence is best illustrated in Figure 5.

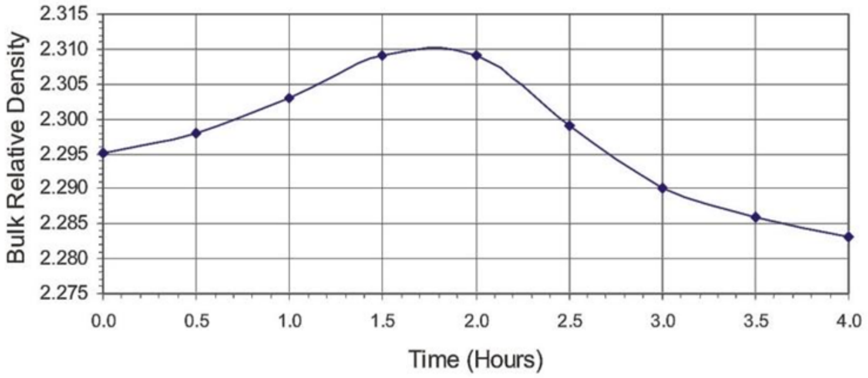

Figure 5: Typical changes in the bulk relative density of the asphalt mix over time

SAMPLING AND TESTING

Binder

The binder sampling plan and testing frequency should be agreed before commencement of the project to ensure adequate samples are taken in the event of any query arising. The sampling plan and testing regimen must include:

- Size of sample required e.g. 4 x 1*l* samples of bitumen-rubber binder;
- Sample frequency i.e. one sample every 5th batch;
- Statement of source e.g. hauler, hopper, digestion tank;
- Type of material e.g. base bitumen, rubber crumb, BR blend;
- Test method e.g. softening point, viscosity;
- Testing frequency e.g. one softening point every 5th batch.

Bitumen-rubber binder samples should be contained in small metal containers with tight lids or covers similarly identified on the outside.

Duplicate samples should be drawn in each case and retained for three months.

Note:

To avoid any disputes it is recommended that correlation testing between the site and central laboratories is carried out before works commence.

Asphalt

It is recommended that samples of bitumen-rubber asphalt be taken at the plant and on site at the following frequencies for the determination of the various properties indicated below:

Aggregate grading	100 tons
Bitumen content	100 tons
Density	500 m^2
Air voids	100 tons
Texture depth (open graded only)	5 000 m^2
Durability	400 tons

Each sample of aggregate and filler should be stored in a bag securely tied and correctly identified by source, contract, sample number and date. Identification should be marked on the outside of the bag, as well as a tag or docket placed inside.

As described in the section *Binder content* in Chapter 4, a sample of the bitumen-rubber binder should be taken at the same time as sampling the mix from the plant for the preparation of a control mix for the adjustment of binder contents of field samples.

In addition, in order to deter mine the mean binder content, a continuous record of quantity of binder used at the mixing plant should be kept. The amount of binder used together with weighbridge certificates of the bitumen-rubber asphalt produced should be used to deter mine the mean percentage of the binder in the mix (excluding possible waste generated during the mixing process).

Compliance limits

To ensure uniformity it is recommended that the mean values of grading and binder content derived from six asphalt samples per lot of the mat sampled in a stratified random sampling procedure should not deviate from the project mix by more than the permissible deviations in Table 13.

Table 13 Tolerance limits for binder content and aggregate grading for the project mix

Passing sieve (mm)	Permissible deviation (%)
20	0,0
14	± 5,0
10	± 5,0
5	±4,0
2	±4,0
1	±4,0
0,600	±4,0
0,300	±3,0
0,150	±2,0
0,075	±1,0
Bitumen-rubber binder content by mass of total mix	±0,4

Note:

It is important to bear in mind that some of the fines (material passing the 0,075mm sieve) are trapped in the rubber crumbs when carrying out the grading analysis after extracting the binder. Up to 1,5% of this fine material can be trapped in the crumbs and could lead to lower-than-actual filler contents being measured after extraction. (This would however not be the case if the Ignition Furnace method is used)

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