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

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Manual 3*	Test methods for bitumen rubber
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Manual 10	Appropriate standards for bituminous surfacings
Manual 11	Labour enhanced construction for bituminous surfacings
Manual 12	Methods and procedures - Labour enhanced construction for bituminous surfacings
Manual 13	LAMBS - The design and use of large aggregate mixes for bases
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* These manuals have been withdrawn and their contents have been incorporated in a technical guideline entitled: *The use of modified binders in road construction* published by the Asphalt Academy

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Preface

This document presents guidelines for the design, manufacture, handling and construction of bitumen rubber asphalt. As it primarily deals with those aspects of hot mix asphalt that are specific to bitumen rubber asphalt, it should be read in conjunction with Sabita Manual 5 - *Manufacture and construction of hot mix asphalt* to obtain a comprehensive perspective of the processes involved.

Extensive reference is made in this manual to standard test methods, particularly those contained in TMH 1: *Standard methods of testing road construction materials* and in the Appendix of TG1: *The use of modified bituminous binders in road construction* (second edition 2007). While it is accepted that these methods will ultimately be incorporated in SABS standards and hence acquire SANS designations, it is expected that this process will not be finalised in the short term. Hence the text adheres to the current nomenclature with a view to revise it once the matter has been finalised.

Test Methods

Unless otherwise stated the test methods referred to in this manual are those to be found in TMH 1: *Standard methods of testing road construction materials*, or TG1: *The use of modified binders in road construction* (second edition, 2007).

Abbreviations

Abbreviations employed in the specification and design method conform to South African Bureau of Standards nomenclature. In addition, the following are used:

Maximum	=	max.
Minimum	=	min.

Scope

These guidelines cover all the work in connection with the construction of bitumen rubber asphalt surfacing, overlays and levelling courses. Wherever reference is made to surfacing, it is also applicable to overlays and levelling courses. They include the procuring and preparation of aggregate and bituminous binder, mixing at a central mixing plant, spreading and compaction of the mix.

In addition, mix design is covered in detail as there are special features of the method used for bitumen rubber asphalt which make it distinct from the method used for conventional binders. Similarly, quality assurance procedures must 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. *Unlike the previous edition this document is written as a best practice guideline and not as a specification document.*

Contents

List of Tables

List of Figures

Chapter 1

Introduction

Introduction

Bitumen rubber asphalt (BRA) has been used successfully in South Africa since its introduction in the early 1980's. The early mixes where produced using the 'dry' blend method whereby the rubber crumb was added as a filler along with the bitumen and 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 properties of the bitumen rubber binder can be properly monitored 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 properties. 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 is aided by the addition of a small quantity of extender oil to help digest the rubber crumbs. 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 as follows
:

- Increased binder softening point and higher binder 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 tyres improves the ultra violet resistance;
- Improved flexibility of the binder due to the presence of the elastomeric polymer in the crumb. This will allow the BRA 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 temperature susceptibility with improved fatigue resistance.

As a result of the above enhanced properties bitumen rubber asphalt has become very popular for overlaying badly cracked pavements, i.e. as a Stress Absorbing Membrane (SAM) and for open graded wearing courses. A good example of the former is the construction of the 40mm continuously graded bitumen rubber asphalt SAM which was placed in 1986 on a 22km section of the distressed jointed concrete pavement on the N2 between Somerset West and Cape Town airport and is still in service today.

Although bitumen rubber asphalt wearing courses are more expensive to construct, they offer extended service life and superior structural strength *vis-à-vis* conventional asphalt overlays. The performance of BRA can be further enhanced for dampening crack reflections if they are used in conjunction with a bitumen rubber seal as a Stress Absorbing Membrane Interlayer (SAMI). The latter will result in a significant reduction in layer thickness when compared to using conventional asphalt overlays.

Bitumen rubber asphalt has an excellent track record in South Africa and offers the engineer improved life cycle benefits over conventional asphalt when used as an overlay for preventing reflective cracking, resisting deformation and providing adequate skid resistance.

Chapter 2

Material and blend requirements

Bitumen rubber

Bitumen

Bitumen complying with the requirements of SABS 307 for 80/100 penetration grade is normally used for the manufacture of bitumen rubber asphalt. Sometimes 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 pulverised 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 TG1: *The use of modified binders in road construction* (2nd edition, 2007), as given in Tables 1 and 2:

Table 1: Sieve Analysis

Passing screen	Mass (%)	Test method
1,180	100	MB 14
0,600	40 - 70	
0,075	0 - 5	

Table 2: Rubber crumb properties

Property	Requirements	Test method
Poly-isoprene content[1] (%) m/m total hydrocarbon	25 minimum	Thermo Gravimetric Analysis
Fibre length (mm)	6 maximum	

Note:

1 *This value pertains to the natural rubber content in the rubber crumb*

Extender Oil

Highly aromatic extender oils which meet the requirements given in Table 3 below, are added to the bitumen prior to the addition of the rubber crumbs:

Table 3: Requirements for extender oil

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

Diluent

The addition of petroleum hydrocarbon distillates as a diluent or cutter is not recommended in bitumen rubber for use in hot mix asphalt.

Bitumen rubber blend

The bitumen rubber blend, containing the necessary extender oil, should comply with the requirements given in Table 4:

Table 4: Guidelines for bitumen rubber blending

Component/criteria	Requirements
SANS 307 penetration grade bitumen[1]	76%m/m minimum
Rubber by mass of the total blend (%)	20 - 24
Extender oil by mass of the total blend (%)	3 maximum
Blending/reaction temperature (°C)	170 - 210
Reaction time (minutes)	45 minimum[2]
Typical shelf life at mixing temperature (hours)	6 maximum[3]

Notes:

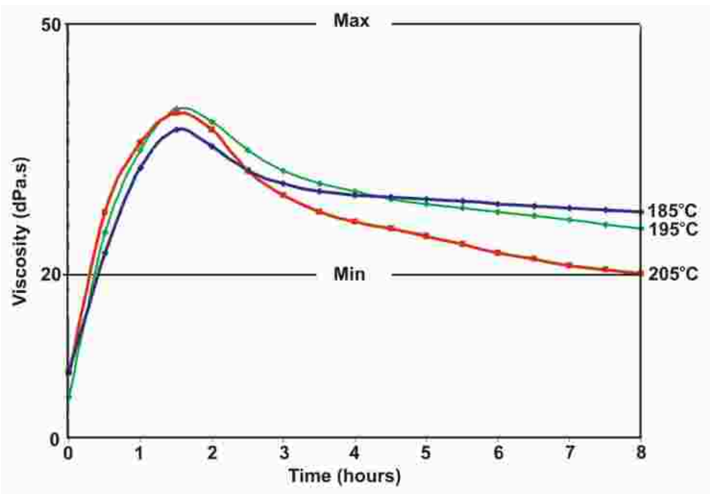
1 *Usually a 80/100 grade bitumen is used but this does not preclude the use of a 60/70 or blend thereof*.

2 *The reaction time commences when all the rubber crumbs have been added to the blend and the blend temperature reaches the asphalt mixing temperature.*

3 *The shelf life for the product is significantly influenced by the composition of the base bitumen and the particle size of the crumb rubber, and may remain acceptable for up to six hours after reaction time.*

Table 4 serves as a guideline only and the onus is on the supplier of the bitumen rubber binder to ensure that the performance properties of the final blended product as stipulated in Table 5 are achieved prior to mixing with the heated aggregate in the asphalt plant. To this end the supplier should have process control systems in place to ensure the end properties are achieved and that records are kept of the material usage. It is recommended that the contractor or supplier of the bitumen rubber binder submit a set of curves of the blended product at temperatures of 185, 195 and 205°C showing the changes in viscosity, softening point and flow properties over time. Figure 1 shows typical changes in viscosity of a bitumen rubber blend at these different temperatures over time.

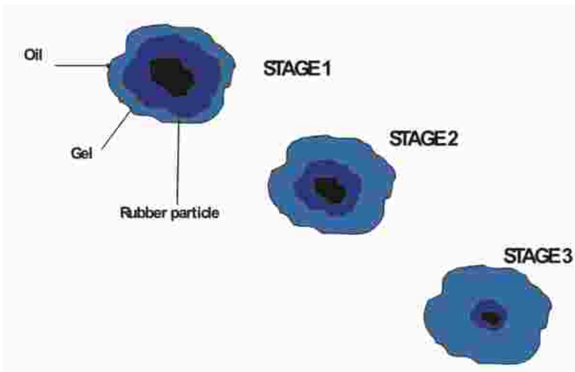
Figure 1: Typical changes in viscosity of bitumen rubber at different temperatures over time



The reaction time commences when all the rubber crumbs have been added to the bitumen and when the reaction between the bitumen and the rubber results in the required binder properties being achieved. 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.

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 are more reactive as they 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.

Figure 2: Reaction stages of rubber in bitumen



It is recommended that the bitumen rubber binder for asphalt wearing courses meet the requirements in Table 5 when sampled within five minutes prior to mixing of the asphalt:

Table 5: Performance related requirements for bitumen rubber in accordance with A-R1 specification[1]

Property	Requirements	Test method[1]
Compression/recovery (%)	5 min: > 80 1 hour: > 70	MB 11
Softening point (R&B) (^{o}C)	55 - 65	MB 17
Resilience at 25^{o}C (%)	13 - 40	MB 10
Flow (mm)	10 - 50	MB 12
Viscosity (dPa.s)[2]	20 - 50	MB 13

Note:

1 *Published in the appendix of TG1*: *The use of modified bituminous binders in road construction.*

2 *Haake or similar hand-held viscometer*.

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 6:

Table 6: Typical temperature/time limits for bitumen rubber

Short term handling		Long term storage		Mixing and laying		
Max temp (°C)	Max holding time (hrs)	Max temp (°C)	Max holding time (hrs)	Max temp (°C)	Min temp (°C)	Max holding time (hrs)
165	<24	150	<72[1]	210	290	Refer to time/viscosity curves

Note:

[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.*

Aggregates

Coarse and fine aggregate should be clean and free from decomposed materials, vegetable matter and other deleterious substances and generally meet the requirements of COLTO 1998: Section 4202(b) unless otherwise indicated in this section.

Resistance to crushing

The crushing value (ACV) of the coarse aggregate, when determined in accordance with TMH1 Method B1: *Aggregate crushing value of coarse aggregates*, should not exceed the following values when used for:

Open and semi-open graded surfacing mixes, % (m/m)	21
Other surfacing mixes, % (m/m)	25

Shape of the aggregate

The weighted average value of the flakiness index (FI) of the coarse aggregate, when determined in accordance with TMH1 Method B3: *The determination of the Flakiness Index of coarse aggregate,* should not exceed 25%.

The FI should be based on the three fractions of the combined aggregate given in Table 7:

Table 7: Aggregate fractions for determining FI

Passing (mm)	Retained (mm)
19,0	13,2
13,2	9,5
9,5	6,7

Polishing

The polished stone value (PSV) of the aggregate, when determined in accordance with SABS 848: *Polished stone value of aggregates* should generally not be less than 50, although values below this limit may be acceptable in certain instances.

Adhesion

When tested in accordance with TMH1 Method C5: *Determination of the immersion index of a bituminous mixture*, the immersion index of a mixture of the binder and aggregate proposed for use should not be less than 75%. The test should be performed on an aggregate blend that complies with the grading limits of the mix under consideration.

The modified Lottman test can be used to assess the potential for stripping in BRA. A tensile strength ratio (TSR) which measures the ITS before and after conditioning by freeze-thaw cycles is recommended. A minimum TSR of 0,8 is recommended for mixes used in high rainfall areas under high traffic applications.

Absorption

When tested in accordance with TMH1 Methods B14 and B15: *Determination of the water absorption of aggregate retained/passing a 4,75mm sieve*, it is recommended that the water absorption of the coarse aggregate should not exceed 1% by mass and that of the fine aggregate 1,5% by mass.

Sand equivalent

The total of fine aggregate used in the mix should have a sand equivalent of at least 50, when tested in accordance with TMH1 method B19: *Determination of the sand equivalent of aggregate* and sand to be blended with the aggregate should have a sand equivalent of at least 30.

Design 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.

Grading

Recommended gradings of the blends of aggregate including any filler as described under Fillers (Page 21) are indicated in Table 8 for the various mixes. The actual grading accepted for the project - designated as the project grading - should form the basis for applying the tolerances given in Table 13 (Page 49).

Table 8: Aggregate gradings for bitumen rubber asphalt

Sieve (mm)	Percentage passing by mass			
	Continuously graded		Open graded	Semi-open graded
	Medium	Coarse		
19,0		100		100
13,2	100	84 - 96	100	70 - 100
9,5	80 - 100	70 - 84	50 - 70	50 - 82
4,75	50 - 70	45 - 63	20 - 30	16 - 38
2,36	32 - 50	29 - 47	5 - 15	8 - 22
1,18	-	19 - 33	-	4 - 15
0,60	13 - 25	13 - 25	3 - 8	3 - 10
0,30	8 - 18	10 - 18	-	3 - 8
0,150	-	6 - 13	-	2 - 6
0,075	4 - 8	4 - 10	2 - 5	1 - 4

Fillers

If the grading of the combined aggregates shows a deficiency in fines, filler may be used to improve the grading. Fillers may either be "active" material, as described below, or inert material such as rock dust suitably graded to bring about the required adjustments to the grading of the aggregate blend. Active fillers may also be used to improve the adhesion properties of the aggregate and durability of the mix. In no instance should more than 2% by mass of active filler be used.

Milled blast furnace slag, hydrated lime, Portland cement, Portland blast furnace cement, fly-ash, or mixtures of any of the above materials are active fillers. All these materials should comply with the requirements of the relevant SABS or other accepted standards for such material.

At least 70% by mass of active filler should pass the 0,075mm sieve and the material should have a bulk density in toluene falling between 0,5 and 0,9 g/mℓ. The voids in dry compacted filler should be between 0,3% and 0,5%, when tested in accordance with British Standard 812: *Sampling and testing mineral aggregates, sands and fillers*, as required in *Standard specifications for roads and bridge works for state road authorities* published by COLTO, 1998.

General

All materials should be handled and stockpiled in a manner that will prevent contamination, segregation, or damage. 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 ensure consistent compliance with the specified requirements.

Chapter 3

Occupational Health, Safety and the Environment

Hazards

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

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

Bitumen rubber is handled below the minimum flash point requirement of 230°C (Pensky-Martens closed cup – ASTM D93) and therefore, if handled correctly, presents a low risk of fire or explosion.

The risk of a fire or explosion is greatly reduced as petroleum hydrocarbon diluents or cutters are not used in the manufacture of bitumen rubber asphalt.

For more details refer to Sabita Manual 8: *Guidelines for the safe and responsible handling of bituminous products.*

Manufacture and handling

It is important that all employees associated with the blending and handling of bitumen rubber binders undergo safety training in order to be made aware of the potential hazards and dangers associated with the blending process and products used.

Rubber crumbs

Care must be taken to ensure that the rubber crumbs are dry as the presence of moisture could lead to a boil-over during blending with the hot bitumen.

Extender oils

Small quantities of extender oils are used in the manufacture of bitumen rubber. Some of these extender oils contain high concentrations of potentially harmful polycyclic aromatic hydrocarbons (PAHs) and every precaution must be taken to reduce the exposure of workers to fume inhalation and/or skin contact. For this reason it is preferable that the extender oil is added into the bitumen and blended offsite under controlled conditions, where there is also less risk of extender oil spillages.

Toluene

Toluene is normally used to extract the binder from the asphalt to determine the binder content of the mix. In the event of using toluene to determine the binder content, the laboratory must be fitted with a fume extraction cupboard to avoid the tester from being exposed to the fumes. The use of an ignition oven is preferred for monitoring the binder contents of the mix produced at the asphalt plant, as it eliminates the exposure of the worker to fumes caused by the use of toluene and also negates the need to dispose of the used toluene.

Chapter 4

The mix design process

Selection of mix type

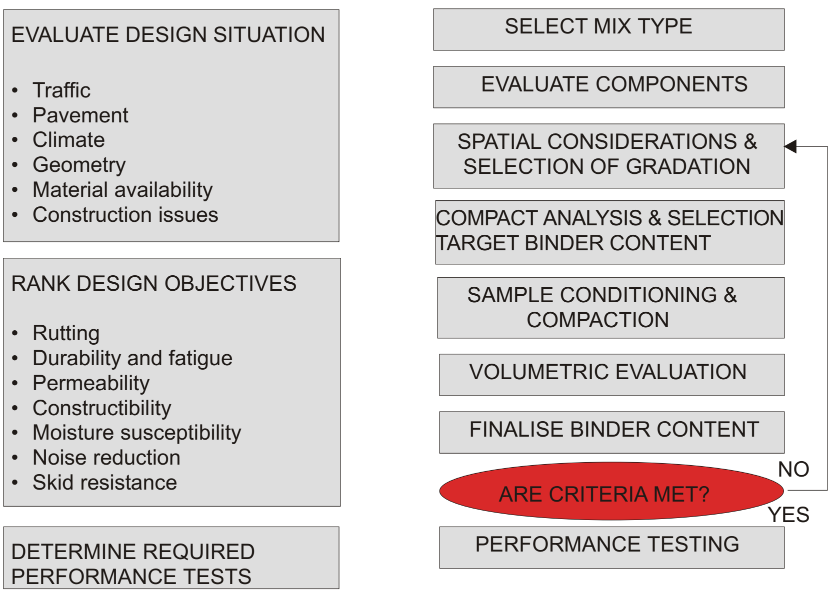
This mix design procedure applies to bitumen rubber hot mix asphalt manufactured using bitumen modified by the addition of rubber crumb prior to mixing with hot aggregate in the mixing plant – the so-called "wet blend" method.

Bitumen rubber asphalt mixes are designed in the same way as mixes using unmodified bitumen, but with variations of standard procedures and the addition of some special tests. Standard procedures are listed for the sake of completeness and references are given for the special features of the design method.

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

The basic steps required for volumetric design and performance testing are shown in Figure 3.

Figure 3: Mix design process



The selection of the mix type can be optimised by considering the design objectives which are influenced by the external environmental considerations. Table 9 lists the performance ratings for the different mix types.

Table 9: Mix types and performance ratings

Type of gradation and binder	Typical applications	Performance ratings (1 = poor, 5 = excellent)						
		Ease of design	Rutting resistance	Durability/fatigue resistance	Skid resistance	Impermeability to water	Noise reduction	Ease of construction
Continuous with bitumen rubber	Flexible surfacing overlay	2	3	4	3	4	3	2
SMA with bitumen rubber	Rut resistant surfacing	3	4	5	4	2	3	4
Open-graded with bitumen rubber	Functional layer	3	4	3	4	1[1]	5	4
Semi-open graded with bitumen rubber	Flexible surfacing layer	3	4	4	3	3	4	3

Note:

[1] *Impermeable support layer or membrane required.*

Component materials preparation

Samples

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

- Coarse aggregate 25 kg;
- Intermediate aggregate 25 kg;
- Fine aggregate 25 kg;
- Active mineral filler (lime, cement etc.) 10 kg;
- Plant extracted filler 10 kg;
- Pre-blended bitumen rubber 15kg.

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 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.

Table 10: Schedule of tests on component material

Material	Test	Reference
Coarse aggregate	Aggregate crushing value	TMH1 - B1
	Flakiness index	TMH1 - B3
	Sieve analysis	TMH1 - B4
	Polished stone value	SABS 848
	Water absorption +4,75mm	TMH1 - B14
Fine aggregates	Sieve analysis	TMH1 - B4
	Water absorption -4,65mm	TMH1 - B15
	Sand equivalent	TMH1 - B15
Bitumen	Penetration value	TMH1 - B19
	Softening point	ASTM D5
	Viscosity	ASTM D36
Rubber crumb	Grading and loose fibre	MB - 14

Bitumen rubber binder

Ideally a bitumen rubber blend should be prepared in the manufacturer's blending plant. It is not recommended that blends are prepared in the laboratory. However in such cases the laboratory procedures must replicate steps in the manufacturer's method statement and therefore it is best left to the bitumen rubber supplier to prepare such blends.

Blended Aggregates

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

Mix design procedure

The general procedures given below are used to establish mix design parameters. However, conditions may have to be varied to conform to the manufacturer's method statement. Once the supper heated aggregates have been mixed with the bitumen rubber binder, store the asphalt mix in the oven at the asphalt mixing temperature for 45 minutes to assimilate age hardening under plant conditions prior to compacting the briquette.

Table 11: Test references

Procedures	Reference
Preparation of asphalt specimens for Marshall testing and voids analysis **Variations:** Mixing and compaction temperatures **Marshall compaction:** Continuously-graded and semi-open graded mixes - 75 blows Open-graded mixes - 50 blows	TMH1 - C2 (appendix)
Determination of bulk relative density of a compacted mixture and calculation of void content	TMH1 - C3
Determination of maximum theoretical density and bitumen absorption	TMH1 - C4
Determination of immersion index	TMH1 - C5
Determination of creep characteristics	TMH1 - C6T
Determination of indirect tensile strength	ASTM D4123

Engineering mix properties

The results obtained from testing the engineering properties of bitumen rubber mixes may render values which are lower than conventional asphalt due to the higher binder film thicknesses of these mixes. The creep characteristics and indirect tensile strength tests are an integral part of the design. Recent research work has shown that dynamic creep does not consistently evaluate the rutting potential of mixes and that other tests such as the wheel tracking test are more suitable. However it can be assumed that the use of modified binder mixes will be confined to solutions of particularly severe problems. It is desirable, therefore, to establish their more fundamental properties. It should be noted that wheel tracking values are more indicative of mix behaviour in service under traffic. Dynamic testing facilities may not be readily available, but their employment is recommended to the prudent designer.

Binder content

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

- Extraction method;
- Nuclear gauge;
- Ignition oven.

The extraction method is still the most commonly used in the mix design procedure. However it is time consuming and poses a potential health risk due to the use of toluene during the extraction process. The nuclear gauge has been found to be accurate and must be calibrated against laboratory prepared samples. The ignition oven 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 the hot mix bitumen rubber asphalt.

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 mix 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 hotplate etc. can have an influence on the test result.
- An extraction is then carried out in accordance with TMH1-C7b.
- A factor (f) is then calculated as follows:

$$f = \frac{\text{mass of bitumen rubber added to aggregate blend}}{\text{mass of bitumen rubber washed away in extraction}}$$

Note:

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 factor has been used or not*.

Design criteria

The suggested nominal mix proportions (% by mass of total mix) 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.

Table 12: Nominal mix proportions and design criteria for bitumen rubber asphalt

Nominal mix proportions (% by mass of total mix)			
Materials	**Continuously graded**	**Open-graded**	**Semi-open graded**
Mixed aggregate	92,0	93,5	91,0
Bitumen rubber binder	7,0	5,5	8,0
Active filler	1,0	1,0	1,0
Design criteria			
Marshall stability (kN)	min. 8	-	min. 6
Marshall flow (mm)	2 - 5	-	2 - 5
Voids in mix (%)	2 - 6	20 - 25	3 - 6
Indirect tensile strength (kPa)	min. 600	-	min. 550
Immersion index (%)	min. 75	min. 75	min. 75
Static creep modulus (MPas)	min. 80	-	-
Dynamic creep	min. 15		min. 15
Film thickness	min. 15	min. 15	min. 18
Gyratory voids @ 300 gyrations	min. 2		min. 3
Modified Lottman	min. 75		min. 75

Note:

The above criteria should be varied to cater for constituent material properties (e.g. aggregate particle shape), structural features (e.g. layer thickness) and purpose (e.g. resistance to reflection cracking, wet weather skid resistance).

Finalisation of the project mix

Following completion of the laboratory designed mix, a mix should be produced in the plant in accordance with this design and tested for compliance with the design requirements. An aggregate blend grading is normally finalised after plant mixing. Proving the design in this way usually results in small deviations from the initial design grading. Following further laboratory testing 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 constructibility and the absence of undesirable handling characteristics.

Chapter 5

Plant and equipment

General

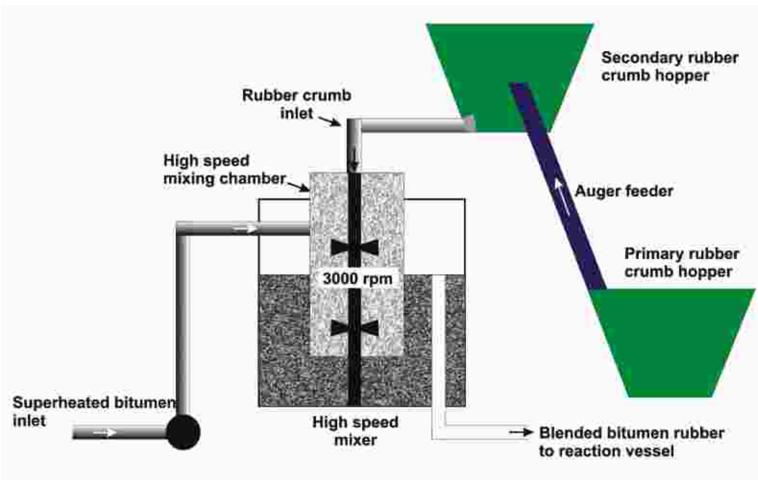
Plant used for the manufacture of bitumen rubber asphalt should be designed and operated in a manner that will ensure the production of a mixture complying with the requirements of the product specifications. The plant and equipment should also be of adequate rated capacity and in good working order.

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 which must be 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 sprayers can also be used for this purpose.

Figure 4: Schematic of a typical high speed bitumen rubber blender



The heating system of the tanks used for storage and super heating of the base bitumen are 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 210°C. The digestion tank should be fitted with augers placed above the heating flues which are able to maintain the binder temperature between 170 and 210°C.

A positive displacement gear pump which is capable of handling a product with a viscosity of up to 5 000 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 adequate 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.

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 then the temperature of the pre-blended bitumen rubber should be reduced immediately to delay the reaction and thus the deterioration of the binder properties. Should the binder properties fall outside the specification limits then a maximum of 25% of the pre-blended binder can be re-blended with fresh materials in order to meet the specification limits. The practice of reconstituting the out-of-specification binder with new material must be kept to a minimum as this can lead to reduced binder shelf life.

Asphalt Mixing Plants

Bitumen rubber asphalt should be mixed in a mixing plant with a proven capability of producing a mixture complying 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, consistency of the mix proportions that meet the specified requirements will require the following equipment control systems:

- 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.

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 the asphalt 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.

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 any petroleum based products should not be permitted.

Vibratory rollers should not be used on bridge decks or over services without prior permission of a responsible party.

Binder Distributors

Where a bituminous tack 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 tight, clean, smooth beds and sides, 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 sheeting to prevent contamination and to inhibit cooling. Hessian is 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.

Chapter 6

General precautions and the storage of mixed materials

Weather conditions

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 all militate against achieving adequate compaction by narrowing the time window available to achieve this.

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 complexity associated with the laying of asphalt in adverse weather conditions, such as rain, wind and low temperatures, it is recommended that the recommendations 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 underlying granular base course layer is equal to or less than 50% of OMC (Optimum Moisture Content).

Surface requirements

The base, or road surface in the case of an overlay, should comply with the requirements of evenness and accuracy of grade, elevation and cross-section and, where necessary, the appropriate 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 surface

Immediately before applying the tack coat, or where there is no tack 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.

Tack coat

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

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

Storage

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

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 Figure 1).

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

Chapter 7

Quality assurance

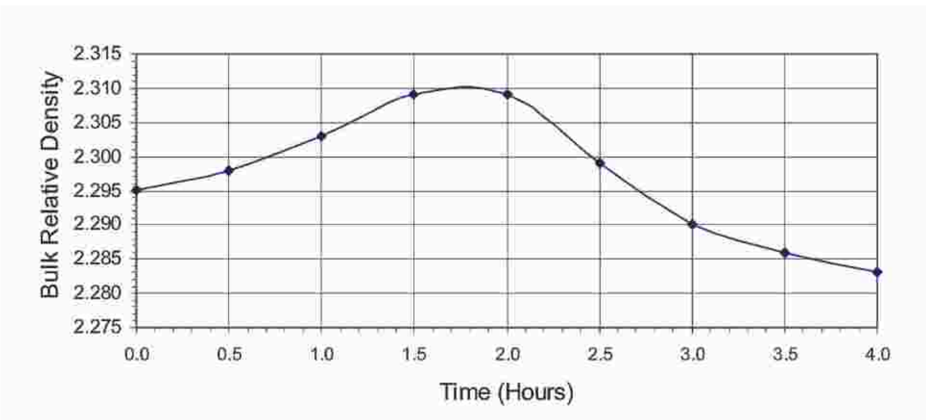
Introduction

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 in particular should be provided by the bitumen rubber binder supplier for producing the asphalt briquettes.

Due to the non-homogeneous nature of the bitumen rubber binder certain challenges will be presented during the monitoring thereof. A pre-site planning meeting should be held with the representatives from the bitumen rubber binder supplier, asphalt manufacturer and paving contractor, and engineer before commencement of the works to decide and agree on the various activities and responsibilities between all the parties. This should include the protocol for taking samples for testing. Agreement must be reached on where and when the bitumen rubber binder sample is to be taken as the properties 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 properties 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 sampling and testing

The 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 1ℓ samples of BR binder;
- Sample frequency i.e. 1 sample every 5th batch;
- 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, flow, sieve analysis;
- Testing frequency e.g. 1 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 3 months.

Note:

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

Asphalt sampling frequency

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
Marshall stability, air voids and flow	100 tons
Texture depth (open graded only)	5 000 m^2
Immersion Index	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 loose inside.

As described in the section binder content in Chapter 4, a sample of the bitumen rubber binder should be taken simultaneously for the preparation of a control mix for the adjustment of binder contents of field samples.

In addition, in order to determine 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 determine 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 (%)
16,0	0
13,2	±5,0
9,5	±5,0
6,7	±5,0
4,75	±5,0
2,36	±4,0
1,18	±4,0
0,6	±4,0
0,3	±4,0
0,15	±3,0
0,075	±1,5
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 Oven method is used)

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