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

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Technical guidelines

TG1  The use of modified binders in road construction
TG2  Bitumen stabilised materials
TG3  Asphalt reinforcement for road construction
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  • Bitumen emulsion tests
  • Hot mix asphalt tests
  • Bitumen rubber tests

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DVD450  BitSafe - Safe loading and off-loading of bitumen
Acknowledgements

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We acknowledge the contributions made by the members of the sub-committee and the final editing done by RH Kingdon.

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The third edition was edited by Piet Myburgh following 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.

In this fourth edition, guidance on nominal mix proportions and design criteria have been reintroduced 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.

DISCLAIMER

Considerable effort has been made to ensure the accuracy and reliability of the information contained in this publication. However, neither Sabita nor any of their members can accept any liability whatsoever for any loss, damage or injury resulting from the use of this information. The contents of this publication do not necessarily represent the views of all members of Sabita.
Preface

This document presents guidelines 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*, and Sabita Manual 35/TRH8: *Design and use of Asphalt in Road Pavements* 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* (third edition, 2015).

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, which make it distinct from the method 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
Acknowledgements 5
Preface 6
Scope 7

1. Introduction 10

2. Material and blend requirements 12
   Bitumen-rubber binder 12
   Bitumen 12
   Rubber 12
   Extender oil 12
   Diluent 13
   Bitumen-rubber blend 13
   Rubber digestion 15
   Reconstitution of over-reacted binder 17

Aggregates 17
   Resistance to crushing 17
   Shape of the aggregate 18
   Resistance to polishing 18
   Adhesion 18
   Absorption 18
   Sand equivalent 19
   Blend requirements 19
   Grading 19

Fillers 19

General 20

3. Occupational health, safety and the environment 21

Safety hazards 21
   Elevated temperature (160°C - 210°C) 21
   Flammable vapour and ignition sources 21
   Reactive bitumen foaming ("boil-over") 21
   Recommended controls for safety hazards 21

Health hazards 22
   Blending and paving operations 22
   Increased likelihood of exposure to harmful fumes 23
   Handling samples in the laboratory 23
   Recommended controls for health hazards 24

Environmental aspects 24
   Bitumen-rubber spills 24
   Air emissions 25
4. The mix design process
   Selection of mix type 26
   Component materials preparation 27
      Samples 27
      Bitumen-rubber binder 28
      Blended aggregates 29
      Mix design procedure 29
   Binder content 31
   Design criteria 32
   Finalisation of the project mix 33

5. Plant and equipment 34
   General 34
      Bitumen-rubber blending plants 34
      Asphalt mixing plants 35
      Pavers 36
      Rollers 36
      Binder distributors 37
      Trucks 37

6. General precautions and the storage of mixed materials 39
   Weather conditions 39
   Base course moisture content 39
   Surface requirements 39
      Cleaning the surface 40
      Tack coat 40
   Storage 40

7. Quality assurance 41
   Introduction 41
   Sampling and testing 42
      Binder 42
      Asphalt 42
   Compliance limits 43

References 44
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 properties 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 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 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 properties bitumen-rubber asphalt has become very popular for overlaying 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.
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. The grade normally used for the manufacture of bitumen-rubber asphalt is 70/100. 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 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 Table 2 as regards composition.

Table 1: Sieve Analysis

<table>
<thead>
<tr>
<th>Screen size (mm)</th>
<th>Percentage passing (m/m)</th>
<th>Test method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>MB 14</td>
</tr>
<tr>
<td>0,600</td>
<td>40 - 70</td>
<td></td>
</tr>
<tr>
<td>0,075</td>
<td>0 - 5</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Rubber crumb properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Requirements</th>
<th>Test method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibre length (mm)</td>
<td>6 maximum</td>
<td></td>
</tr>
<tr>
<td>Bulk density (g/cm³)</td>
<td>1,10 - 1,25</td>
<td>MB 16</td>
</tr>
</tbody>
</table>

Extender Oil

If considered necessary, these highly aromatic oils, meeting 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

<table>
<thead>
<tr>
<th>Property</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flash point (°C)</td>
<td>180 minimum</td>
</tr>
<tr>
<td>Saturates by mass (%)</td>
<td>25 maximum</td>
</tr>
<tr>
<td>Aromatic unsaturated hydrocarbon (%m/m)</td>
<td>55 minimum</td>
</tr>
</tbody>
</table>

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 4. 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 5, prior to mixing the asphalt. To this end the supplier should have process control systems in place to ensure the end properties are readily achieved and records are kept of the material usage.

Table 4: Guidelines for bitumen-rubber blending

<table>
<thead>
<tr>
<th>Component/criteria</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetration grade bitumen complying with SANS 4001-BT1</td>
<td>76% (m/m) minimum</td>
</tr>
<tr>
<td>Rubber by mass of the total blend (%)</td>
<td>18 - 24</td>
</tr>
<tr>
<td>Extender oil by mass of the total blend (%)</td>
<td>3 maximum</td>
</tr>
<tr>
<td>Blending/reaction temperature (°C)</td>
<td>170 - 210</td>
</tr>
<tr>
<td>Reaction time (minutes)</td>
<td>45 minimum²</td>
</tr>
<tr>
<td>Typical shelf life at mixing temperature (hours)</td>
<td>6 maximum³</td>
</tr>
</tbody>
</table>

Notes:

1. Usually a 70/100 penetration grade bitumen is used but this does not preclude the use of blends of grades, the main objective being to meet end product specifications.
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 properties being met.

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.

Table 5: Performance related requirements for bitumen-rubber (Class A-R1 as per TG1)

<table>
<thead>
<tr>
<th>Property</th>
<th>Requirements</th>
<th>Test method¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression/recovery (%)</td>
<td>5 min: &gt; 80</td>
<td>MB 11</td>
</tr>
<tr>
<td></td>
<td>1 hour: &gt; 70</td>
<td></td>
</tr>
<tr>
<td></td>
<td>24 hours &gt; 40</td>
<td></td>
</tr>
<tr>
<td>Softening point (R&amp;B) (°C)²</td>
<td>55 - 65</td>
<td>MB 17</td>
</tr>
<tr>
<td>Resilience at 25°C (%)</td>
<td>13 - 40</td>
<td>MB 10</td>
</tr>
<tr>
<td>Flow (mm)</td>
<td>10 - 50</td>
<td>MB 12</td>
</tr>
<tr>
<td>Dynamic viscosity at 190°C (dPa.s)³</td>
<td>20 - 50</td>
<td>MB 13</td>
</tr>
</tbody>
</table>

Notes:

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

² Although it has been reported that the use of stirrers has no effect on the test result, in cases of disputes, the reference method excludes the use of stirrers.

³ Test performed with a Haake or similar hand-held viscometer.

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.

![Graph showing viscosity changes over time at different temperatures](image)

**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).

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 5 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 6.
Table 6: Typical temperature/time limits for bitumen-rubber

<table>
<thead>
<tr>
<th>Short term handling</th>
<th>Long term storage</th>
<th>Mixing and laying</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max temp (°C)</td>
<td>Max temp (°C)</td>
<td>Max temp (°C)</td>
</tr>
<tr>
<td></td>
<td>Max holding time (hrs)</td>
<td>Max holding time (hrs)</td>
</tr>
<tr>
<td>165</td>
<td>24</td>
<td>150</td>
</tr>
<tr>
<td>Note:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>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.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

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 SANS 3001-AG10: Aggregate crushing value of coarse aggregates, should not exceed the following values for the applications mentioned:

- 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 SANS 3001-AG4: *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**

<table>
<thead>
<tr>
<th>Passing (mm)</th>
<th>Retained (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>14</td>
</tr>
<tr>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
</tr>
</tbody>
</table>

**Resistance to polishing**

The polished stone value (PSV) of the aggregate, when determined in accordance with SANS 3001-AG11: *Polished stone value of aggregates* should generally not be less than 50, although values below this limit may be acceptable in certain instances.

**Adhesion**

It is recommended that the modified Lottman test described in ASTM D4867 be used to assess the potential for stripping in BRA. This test determines a tensile strength ratio (TSR) which measures the indirect tensile strength (ITS) before and after conditioning by freeze-thaw cycles. A minimum TSR of 0,8 is appropriate for mixes used in higher rainfall areas under high traffic applications.

**Absorption**

When tested in accordance with SANS 3001-AG20 and AG21: *Determination of the water absorption of aggregate retained/passing a 5mm sieve*, it is recommended that the water absorption should not exceed 1% by mass of the coarse aggregate, and 1,5% by mass of the fine aggregate.
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 SANS 3001-AG5: *Sand equivalent value of fine aggregates*. Sand for blending with the aggregate should have a sand equivalent of at least 30.

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.

Grading

Recommended gradings of the blends of aggregate including any filler as described under Fillers (Page 20) are indicated in Table 8 for the various mix types. These gradings are guidelines only and the actual grading accepted for the project - designated as the project grading - should form the basis for applying the tolerances given in Table 13.

**Table 8: Aggregate gradings for bitumen-rubber asphalt**

<table>
<thead>
<tr>
<th>Sieve (mm)</th>
<th>Continuously graded</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Medium</td>
<td>Coarse</td>
<td>Semi-open graded</td>
<td>Open-graded</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>100</td>
<td>85 - 100</td>
<td>84 - 100</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>80 - 100</td>
<td>70 - 85</td>
<td>68 - 83</td>
<td>55 - 75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>50 - 75</td>
<td>45 - 65</td>
<td>29 - 43</td>
<td>20 - 30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>30 - 45</td>
<td>25 - 45</td>
<td>12 - 20</td>
<td>5 - 15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>-</td>
<td>17 - 30</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0,600</td>
<td>13 - 25</td>
<td>13 - 25</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0,300</td>
<td>8 - 18</td>
<td>10 - 18</td>
<td>-</td>
<td>3 - 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0,150</td>
<td>-</td>
<td>6 - 13</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0,075</td>
<td>4 - 8</td>
<td>4 - 10</td>
<td>1 - 4</td>
<td>2 - 5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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 the proportion by mass of active filler exceed 2%.

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 materials.

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.
3. Occupational health, safety and the environment

The general properties and characteristics of bituminous products that could give rise to adverse health, safety and environmental effects are well documented in other Sabita publications, and are therefore not repeated in this document. For a more detailed 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 handling 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 heating 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.
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 supervised 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, regardless 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 ensure 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 section it is assumed that the design of bitumen-rubber asphalt will be carried out by persons familiar with the design of asphalt with conventional binders. Consequently, the full design process is not covered; rather certain aspects particularly pertinent to bitumen-rubber asphalt are highlighted in this section. The reader is referred to other documents in general use describing the design process.

Selection of mix type

This mix design procedure applies to bitumen-rubber hot mix asphalt where rubber crumb is 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 the same way as mixes using unmodified bitumen, but with variations of standard procedures and the addition of some special tests. These procedures are covered in this chapter.

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

To assist the selection of an appropriate mix type in terms of a set of typical design objectives, Table 9 lists the performance ratings for the different mix types.
# Table 9: Mix types and performance ratings

<table>
<thead>
<tr>
<th>Gradation type</th>
<th>Typical applications</th>
<th>Performance ratings (1 = poor, 5 = excellent)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ease of design</td>
</tr>
<tr>
<td>Continuous</td>
<td>Flexible surfacing overlay</td>
<td>2</td>
</tr>
<tr>
<td>SMA</td>
<td>Rut resistant surfacing</td>
<td>3</td>
</tr>
<tr>
<td>Open</td>
<td>Functional layer</td>
<td>3</td>
</tr>
<tr>
<td>Semi-open</td>
<td>Flexible surfacing layer</td>
<td>3</td>
</tr>
</tbody>
</table>

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
- 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 as shown in Table 10 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.

**Table 10: Schedule of tests on component materials**

<table>
<thead>
<tr>
<th>Material</th>
<th>Test</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse aggregate</td>
<td>Aggregate crushing value</td>
<td>SANS 3001-AG10</td>
</tr>
<tr>
<td></td>
<td>Flakiness index</td>
<td>SANS 3001-AG4</td>
</tr>
<tr>
<td></td>
<td>Sieve analysis</td>
<td>SANS 3001-AG1</td>
</tr>
<tr>
<td></td>
<td>Polished stone value</td>
<td>SANS 3001-AG11</td>
</tr>
<tr>
<td></td>
<td>Water absorption +5mm</td>
<td>SANS 3001-AG20</td>
</tr>
<tr>
<td>Fine aggregates</td>
<td>Sieve analysis</td>
<td>SANS 3001-AG1</td>
</tr>
<tr>
<td></td>
<td>Water absorption -5mm</td>
<td>SANS 3001-AG21</td>
</tr>
<tr>
<td></td>
<td>Sand equivalent</td>
<td>SANS 3001-AG5</td>
</tr>
<tr>
<td>Bitumen</td>
<td>Penetration value</td>
<td>EN 1426</td>
</tr>
<tr>
<td></td>
<td>Softening point</td>
<td>ASTM D36</td>
</tr>
<tr>
<td></td>
<td>Viscosity</td>
<td>ASTM D4402</td>
</tr>
<tr>
<td>Rubber crumb</td>
<td>Grading and loose fibre content</td>
<td>MB - 14</td>
</tr>
</tbody>
</table>
**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 procedure**

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 supper-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 assimilate age hardening under plant conditions before compacting the briquette.
### Table 11: Test references

<table>
<thead>
<tr>
<th>Procedures</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation of asphalt specimens for Marshall testing and voids analysis</td>
<td>SANS 3001-AS1: Making of asphalt briquettes for Marshall tests and other specialised tests</td>
</tr>
<tr>
<td><strong>Variations:</strong> Mixing and compaction temperatures</td>
<td></td>
</tr>
<tr>
<td><strong>Marshall compaction:</strong> Continuous-graded and semi-open graded mixes - 75 blows</td>
<td></td>
</tr>
<tr>
<td>Open-graded mixes - 50 blows</td>
<td></td>
</tr>
<tr>
<td>Determination of bulk density of a compacted mixture and calculation of void content</td>
<td>SANS 3001-AS10: Determination of bulk density and void content of compacted asphalt</td>
</tr>
<tr>
<td>Determination of maximum void-less density and bitumen absorption</td>
<td>SANS 3001-AS11: Determination of the maximum void-less density of asphalt mixes and the quantity of binder absorbed by the aggregate</td>
</tr>
<tr>
<td>Determination of durability (TSR) Modified Lottman Test</td>
<td>ASTM D4867 M</td>
</tr>
<tr>
<td>Determination of dynamic creep</td>
<td>CSIR RMT 004</td>
</tr>
<tr>
<td>Determination of indirect tensile strength</td>
<td>ASTM D4123</td>
</tr>
</tbody>
</table>
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:

\[
\frac{\text{mass of bitumen-rubber added to aggregate blend}}{\text{mass of soluble bitumen-rubber binder determined by extraction}} \]

•
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 factor 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 (% 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. 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 for bitumen rubber asphalt

<table>
<thead>
<tr>
<th>Nominal mix proportions (% by mass of total mix)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
</tr>
<tr>
<td>Mixed aggregate</td>
</tr>
<tr>
<td>Bitumen rubber binder</td>
</tr>
<tr>
<td>Active filler</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Design criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marshall stability (kN)</td>
</tr>
<tr>
<td>Marshall flow (mm)</td>
</tr>
<tr>
<td>Voids in mix (%)</td>
</tr>
<tr>
<td>Indirect tensile strength (kPa)</td>
</tr>
<tr>
<td>Immersion index (%)</td>
</tr>
<tr>
<td>Static creep modulus (MPas)</td>
</tr>
<tr>
<td>Dynamic creep</td>
</tr>
<tr>
<td>Film thickness</td>
</tr>
<tr>
<td>Gyratory voids @ 300 gyrations</td>
</tr>
<tr>
<td>Tensile Strength Ratio (TSR) (modified Lottman)</td>
</tr>
</tbody>
</table>

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 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 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 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 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 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 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 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, the temperature of the pre-blended bitumen-rubber should be reduced immediately to retard the reaction and thus the degradation of the binder properties.

**Asphalt mixing plants**

Bitumen-rubber asphalt should be mixed in a mixing plant with a proven capability of producing a BRA 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, 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.

**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.

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.

**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 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

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 will be counter-productive to the achievement of adequate 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 underlying 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 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 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 $\text{dm}^2$ should be aimed for, depending on the condition of the surface on which the tack coat is sprayed.

Storage

Precautions for the storage of mixed asphalt should 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: 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 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](image)
**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 1ℓ samples of bitumen-rubber binder;
- Sample frequency i.e. one sample every 5\textsuperscript{th} 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 5\textsuperscript{th} 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
- Bitumen content
- Density
- Air voids
- Texture depth (open graded only)
- Durability

<table>
<thead>
<tr>
<th>Property</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate grading</td>
<td>100 tons</td>
</tr>
<tr>
<td>Bitumen content</td>
<td>100 tons</td>
</tr>
<tr>
<td>Density</td>
<td>500 m\textsuperscript{2}</td>
</tr>
<tr>
<td>Air voids</td>
<td>100 tons</td>
</tr>
<tr>
<td>Texture depth (open graded only)</td>
<td>5 000 m\textsuperscript{2}</td>
</tr>
<tr>
<td>Durability</td>
<td>400 tons</td>
</tr>
</tbody>
</table>

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 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**

<table>
<thead>
<tr>
<th>Passing sieve (mm)</th>
<th>Permissible deviation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16,0</td>
<td>0,0</td>
</tr>
<tr>
<td>14,0</td>
<td>± 5,0</td>
</tr>
<tr>
<td>10,0</td>
<td>± 5,0</td>
</tr>
<tr>
<td>2,0</td>
<td>±4,0</td>
</tr>
<tr>
<td>1,0</td>
<td>±4,0</td>
</tr>
<tr>
<td>0,600</td>
<td>±4,0</td>
</tr>
<tr>
<td>0,300</td>
<td>±3,0</td>
</tr>
<tr>
<td>0,150</td>
<td>±2,0</td>
</tr>
<tr>
<td>0,075</td>
<td>±1,0</td>
</tr>
<tr>
<td>Bitumen-rubber binder content by mass of total mix</td>
<td>±0,4</td>
</tr>
</tbody>
</table>

**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)*
References


10. *Occupational exposures to bitumen’s and their emissions:*
    WHO/International Agency for Research on Cancer, October 18, 2011.


15. *California stack emission testing of asphalt-rubber and conventional asphalt concrete*, Bay Area Air Quality Management District, Northern California Rubberized Asphalt Concrete Technology Center, 2/5/02.
