BITUMEN-RUBBER ASPHALT: YEAR 2001 DESIGN AND CONSTRUCTION EXPERIENCES

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1. INTRODUCTION

The outstanding success of Bitumen-rubber (B-R) asphalt over the past 15 to 20 years in South Africa has revived interest in this product in recent years. This success became prevalent in 1998 with the report on the 12-year service life of bitumen-rubber asphalt on the Buccleuch Interchange [Potgieter etal 1998].

This paper focus on the practical experiences gained in recent years during the design and construction of the new generation B-R asphalt with special reference to the behaviour of the B-R binder over time.

2. DESIGN PROCESS

2.1 MATERIALS

As with any asphalt the long-term performance of the B-R asphalt is dependent on the quality of the materials, the binder content, and the grading. Attention to detail for each of these components is critical.

2.1.1 Bitumen-rubber Binder

The B-R asphalt is manufactured using non-homogeneous bitumen-rubber binder. The binder is manufactured from blending penetration grade bitumen, extender oil (2 %) and 18 – 24 % rubber crumbs in a patented high-speed blender (3 000 i.e.). The bitumen-rubber blend is then circulated in a holding tank and heated to temperatures of between 190 – 210 ^{o}C to facilitate the chemical digestion process.

The result is a highly viscous binder with a high softening point that is very elastic. It is generally recommended that the results of the bitumen-rubber binder conform to the requirements as set out in Table 1.

PROPERTY	REQUIREMENTS	TEST METHOD
Compression recovery, % after 5 min Compression recovery, % after 1 hour Compression recovery, % after 4 days	80 – 100 70 – 95 25 – 55	SABITA (MB11)
Ring-and-Ball softening point (minimum and range) ^{o}C	55 – 65	SABITA (MB17)
Resilience %	15 – 35	SABITA (MB10)
Flow, mm	10 – 50	SABITA (MB12)
Viscosity at 190 ^{o}C (d Pas)	20 – 50	SABITA (BB13)

Table 1: B-R Binder specifications

The properties of the B-R blend are however very time and temperature sensitive and the manufacturers must supply temperature vs. time property relationship curves before work commences. A typical time, temperature viscosity curve can be seen in Figure 1.

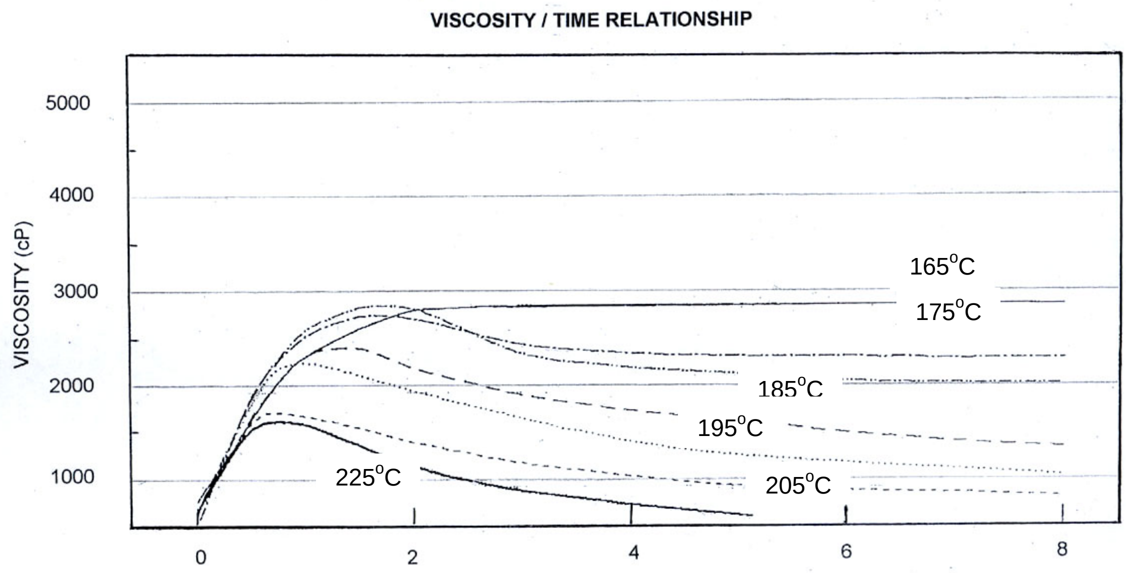

Figure 1: Time, Temperature Viscosity Curve

During the design phase, the professional practitioner must ensure that the B-R binder used in the laboratory is very similar to the B-R binder that will be produced on site during the construction phase of the project.

2.1.2 Aggregate and Fillers

With the increase in traffic and loading on our provincial and national roads the quality of the aggregate is of paramount importance in the manufacturing of a high quality asphalt.

Aggregates must conform to the same requirements as specified for conventional asphalt, i.e. resistance to crushing, 10 % FACT, flakiness, polished stone value (PSV), adhesion, absorption, sand equivalent etc.

Some road authorities require aggregate with higher PSV and 10 % FACT values than the values specified in section 4202(b) of the Standard Specifications for Road and Bridge Works for State Road Authorities.

Active and non-active fillers are generally used in B-R asphalt. The addition of lime and cement is used as active fillers and limestone dust (milled dolomite) is used as non-active filler.

The use of 2 % cement as an active filler with a reef quartzite aggregate was found to improve the immersion index of a B-R semi-open grade asphalt (BRASO) by 20 %.

2.2 GRADING

The grading had a long history of development. The most frequently used gradings are the continuous gradings and the semi-open gradings [Potgieter 2002].

The grading together with the binder content are the most critical elements in the manufacturing of B-R asphalt conforming to the Marshall and other set criteria.

At the start of the design process, five possible gradings are chosen and evaluated according to the specification. Typical gradings are indicated in Figure 2.

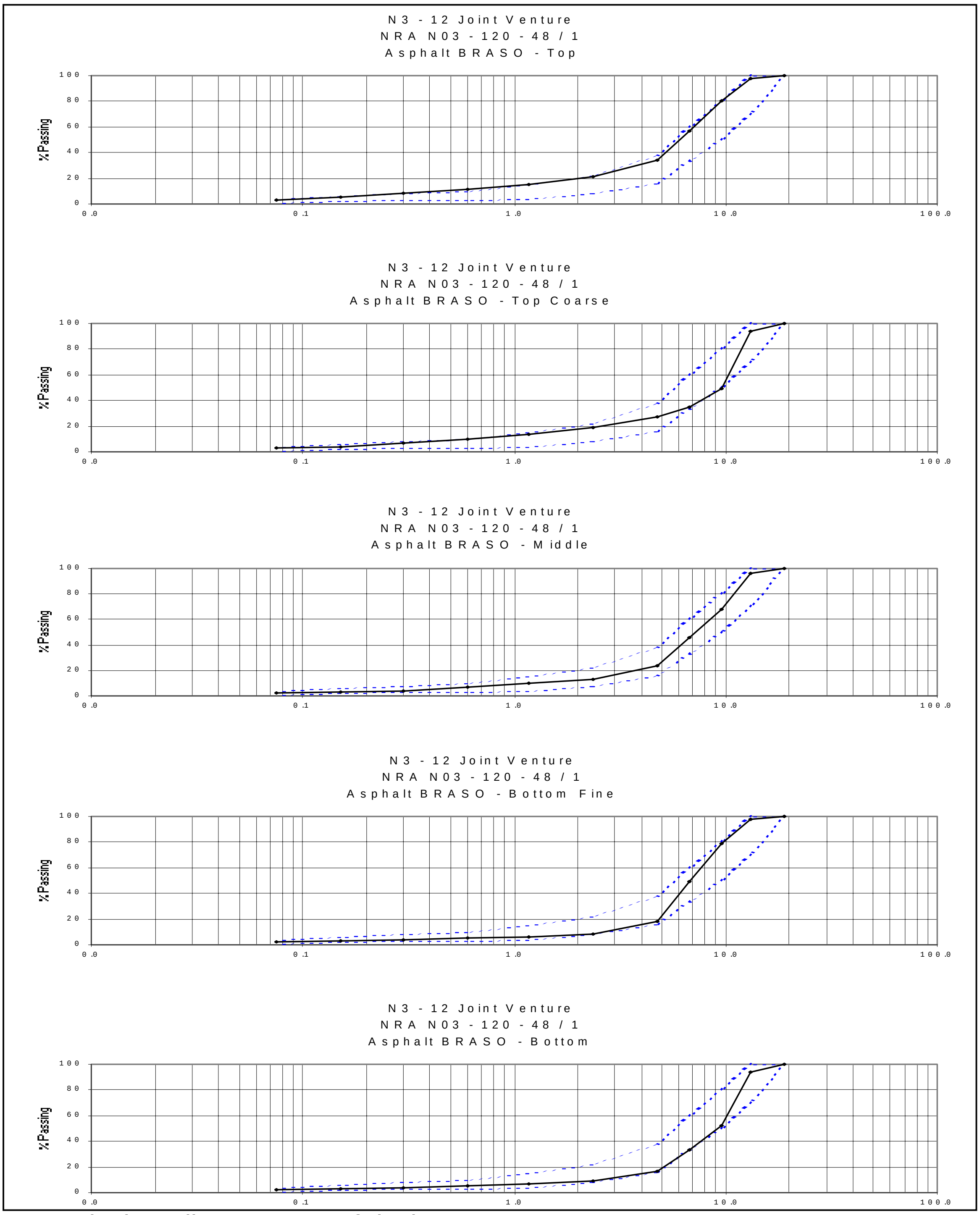

Figure 2: Typical gradings at start of design process

The two most promising mix designs are then selected for further evaluation during the laying of trial sections. Typical gradings for previous bitumen-rubber asphalt mixes are shown in Figure 3.

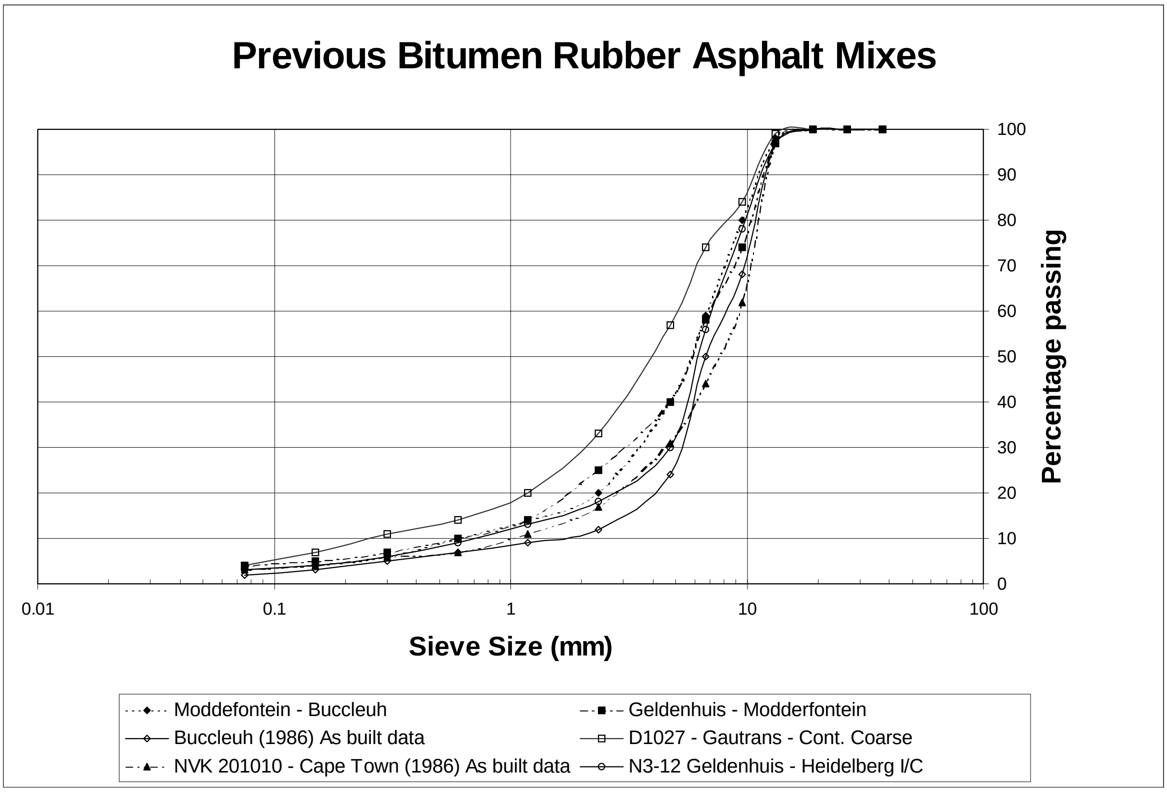

Figure 3: Typical gradings for pervious bitumen-rubber asphalt mixes

During the evaluation of various mixes it was found that the void contents obtained in laboratory mixed samples were marked higher than samples manufactured in the plant. Based on the viscosity temperature and time graphs it was decided to cure the laboratory mixed samples in an oven for 45 minutes after mixing and before compaction. This was done to simulate what happens in the asphalt batch plant.

Void contents obtained from laboratory mixed samples cured at 180 ^{o}C before compaction correlated well with plant mixed samples.

From the trial mixes, a series of special testing was conducted to select and optimise the preferred grading and binder content.

2.3 SPECIAL TESTING

2.3.1 Fatigue

The four point bending beam test at 5 ^{o}C using a sinusoidal loader and with a frequency of 10Hz is used to assess fatigue characteristics.

Two modes of loading can be applied i.e. constant stress, or constant strain. For thin wearing courses only constant strain testing is required. Failure is defined at the point at which the stiffness of the beam is reduced to half of its initial stiffness.

As can be expected from B-R asphalt the Bending Beam fatigue results are well above the recommendations of the Interim Guidelines for the Design of Hot Mix Asphalt in South Africa and typical results are summarised in Table 2.

It is clear that B-R asphalt outperforms conventional asphalt by more than 10 times using fatigue as the criteria.

Strain Level µ	Performance Rating	No. Of Repetitions to failure	Actual Strain Level Applied	Actual Results Obtained BRASO 7,5 %	Actual Results Obtained BRASO 8 %
Low Strain 180 – 230	Good	> 2,4 x 10^{6}	180	> 1 x 10^{7}	> 1 x 10^{7}
	Medium	1 x 10^{o}- 2,4 x 10^{6}			
	Poor	< 1 x 10^{6}			
Medium Strain 320 – 370	Good	> 130 000	320	> 1 x 10^{7}	> 1 x 10^{7}
	Medium	30 000 – 130 000			
	Poor	< 30 000			
High Strain 380 – 430	Good	> 60 000	400	980 000	> 1 x 10^{7}
	Medium	20 000 – 60 000			
	Poor				

Table 2: Comparison of Blending Beam Fatigue results with interim guidelines

2.3.2 <u>Rutting</u>

The rutting or potential permanent deformation was analysed using transportek wheel tracking device. Although wheel tracking tests appear to be well correlated with rutting in the field, there are at present no quantified relationships to link wheel tracking test results to rutting in the field under variable traffic loading and environmental conditions. (Interim guidelines for design of HMA in SA).

The rutting tests performed on a B-R semi open grade mix at an expected field void content of 7 % resulted in very poor rutting values. The test was repeated at 4 % voids, which resulted in better rutting values, but indicated poor repeatability of test with drastically varying results of the same sample.

It also seems as if the age of the bitumen-rubber slab at the time of the test has a definite influence on the rutting value obtained. More research is however needed before any conclusions can be made in this regard.

Case studies have shown that if the assessment of the resistance to permanent deformation of stone-skeleton mixes are not conducted at the design (refusal) void content, their performance may be poor in any form of rutting simulation test. (Interim guidelines for design of HMA in SA). Typical graphs are included in Figure 4.

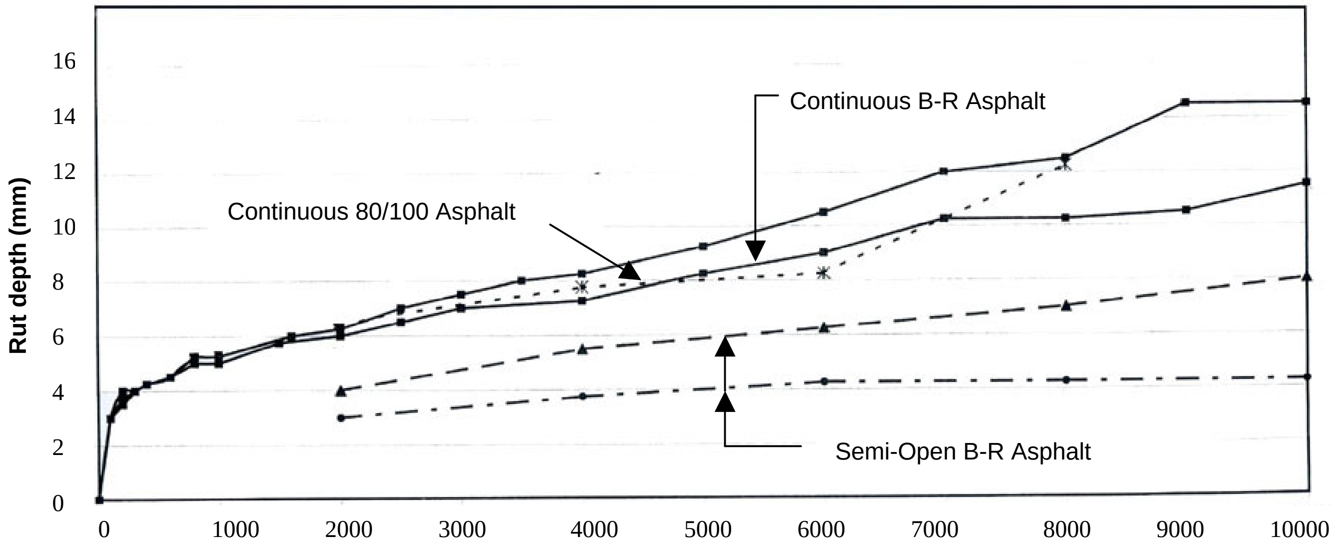

Figure 4: Typical Wheel Tracking Results

2.3.3 Moisture sensitivity (Modified Lottman Test)

The modified Lottman test for measurement of moisture sensitivity relies on ITS measurements taken before and after conditioning by freeze-thaw cycles. A tensile strength ratio (TSR) is then determined. A similar freeze-thaw test is recommended by [Lourens and Jordaan 1989] to assess the potential for stripping in B-R asphalt.

For routine mix design purposes, a minimum TSR of 0,7 is usually specified for mixes in high rainfall areas and high traffic applications, a minimum TSR of 0,8 is recommended. All B-R asphalt tested have TSR values above 0,8.

2.3.4 Dynamic Creep test for evaluating rutting potential

The dynamic creep test specimen is subjected to repeated dynamic loads and the accumulated permanent deformation is monitored as a function of the number of load repetitions. The dynamic creep modules are then calculated as the applied strain vs. the permanent strain.

In recent years, research work has raised some doubts concerning the ability of the dynamic creep test to properly and consistently evaluate the rutting property and consistently evaluate the rutting potential of different mix types. For this reason the dynamic creep test must be used in conjunction with other tests such as the wheel-tracking test.

Typical dynamic creep values for bitumen-rubber asphalt range between 27 MPa and 31 MPa for both continuously grade and semi-open graded B-R asphalt mixes.

3. CONSTRUCTION

3.1 MANUFACTURING OF B-R ASPHALT

The B-R asphalt is manufactured in standard asphalt plants. A high-speed blender and digestion tanks is added to the asphalt plant to facilitate the blending of the B-R binder as shown in figure 5.

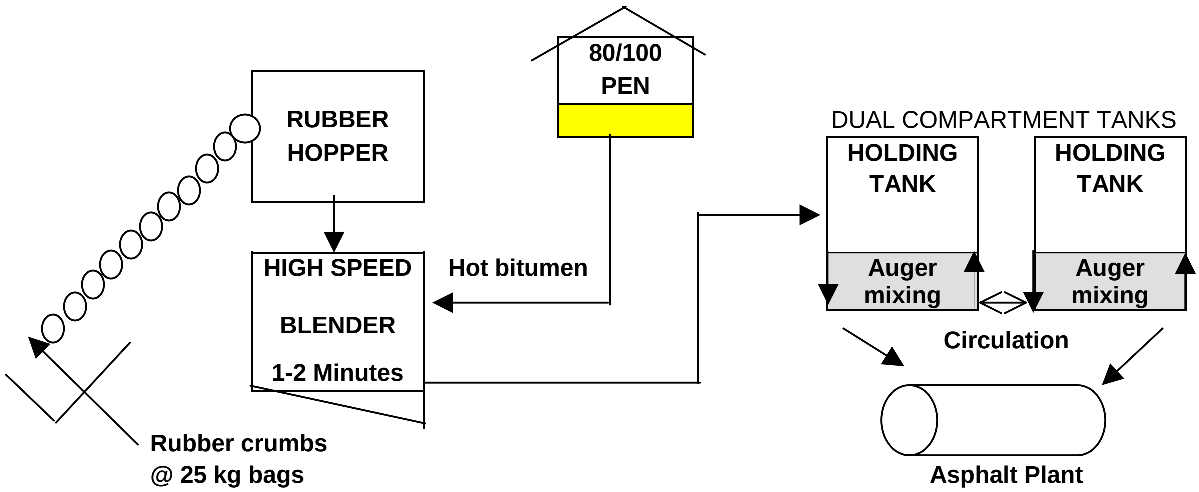

Figure 5: B-R Asphalt Process

A batch of between 10 tons (minimum) and 25 tons (maximum) of B-R binder is blended into an insulated holding tank equipped with heating flues and auger. The blending process takes approximately 90 minutes. The bitumen-rubber blend is heated to 190 – 205 ^{o}C and allowed to digest for approximately 60 minutes after which it is ready for use in the manufacturing of the asphalt.

The B-R binder may not be stored for longer than four hours after completion of the reaction process. Should this time be exceeded the material could be re-constituted with a fresh blending ration of 15 % - 20 % of the degraded blend and 80 % - 85 % fresh blend. The properties of the re-constituted blend must comply in full with the requirements as set out in Table 1.

The B-R binder is pumped from the reaction / holding tank into a header tank. From here, it is metered on a volumetric basis through a calibrated variable speed pump into the mixing drum. The output of the pump is set to provide the required volume of binder as indicated by the rate of asphalt mixing (dry aggregate). The B-R asphalt is then mixed in a conventional manner. Once the quality of the asphalt mix is acceptable, it is conveyed to a mixed material storage silo from where it is loaded onto trucks.

B-R asphalt must only be transported in mechanically sound and fully roadworthy vehicles, with special attention being given to oil and diesel leaks. Due to the relatively high binder content, when compared to conventional asphalt, the fresh B-R asphalt is very susceptible to such fluids and will show fatty patches shortly after construction should such leaks occur.

3.2 PLACING AND COMPACTION

The B-R asphalt is placed and compacted in a conventional way. The paving and tamping screeds of the paver must be set very accurately as the B-R
asphalt is very sticky and streaks easily.

The B-R asphalt is normally compacted using three-point rollers and tandem steel wheel rollers. Pneumatic rollers will only be used when continuously graded B-R asphalt is compacted.

The B-R asphalt normally arrives on site at a temperature of approximately 170 – 190 ^{o}C. After paving the mix is still extremely hot and very susceptible to roller pick-up. The asphalt that is picked up by the roller wheels and allowed to fall back onto the asphalt mat will cause fatty spots on the final surface if rolled in. It is therefore recommended that the rollers stay some distance behind the paver to allow the mat to cool down. Washing-up liquid should also be added to the water used to wet the wheels of the rollers to prevent pick-up.

4. QUALITY CONTROL

4.1 BINDER QUALITY

The B-R binder is a non-homogeneous binder and the characteristics of the binder are time and temperature sensitive. It is therefore important to sample the B-R binder just before being used in the mixing of the asphalt. The batch of bitumen-rubber binder is not used until tested and the viscosity properties conform to that specified in Table 1.

The repeatability of some of the bitumen-rubber characteristics between fresh sample and a reheated sample is average to poor and need to be investigated.

Care should also be taken to ensure that the correct testing procedures are carried out with special reference to temperature control of samples.

4.2 BINDER CONTENT

The binder content should be tested as soon as possible after the manufacturing of the bitumen-rubber asphalt. This test is therefore normally done at the asphalt plant. This is done as the digestion of the rubber continues with time and will influence the binder content result. The binder content can be determined by one of the following three methods:

- Extraction method
- Nuclear binder content gauge
- Incineration oven

The extraction method is still the pre-scribed method. This method is however, time-consuming, messy and can be a health risk due to the use of toluene during the extraction. The nett extracted bitumen content is multiplied with a sample factor that is determined by extracting a lab mixed control sample. The determination of the sample factor is very important and it is recommended that the control sample be extracted directly after being made up. No curing of the control sample in an oven is recommended as this lead to poor repeatability in the determination of the sample factor.

The nuclear binder content gauge (AC2) was found to be a very accurate measuring instrument. The instrument is also calibrated using laboratory made up samples. The big advantage of this instrument is its ease of use and short testing cycle.

The incineration oven (Troxler oven) burns of the binder at a temperature of approximately 500 ^{o}C and automatically calculates the mass loss to determine the binder content. This method is also a quick and easy method for binder content determination.

5. POTENTIAL PROBLEMS

5.1 BITUMEN-RUBBER BINDER

The bitumen-rubber binder is highly viscous and special pumps are required to pump it. These pumps also have a limited life span and should be replaced timeously.

From previous studies [Lourens and Jordaan 1989] it was also found that the high viscosity of the bitumen-rubber binder when mixed with the aggregate to make asphalt is the most important factor, which governs the adhesion of the binder to the aggregate to prevent stripping or internal pumping of the asphalt.

From laboratory studies on particular bitumen-rubber blends it was found that there is a critical time period in which the viscosity reaches its peak before it decreases. Mixing should not be done during this time period, as the 'wetting power' of the blend is then at it is lowest.

5.2 CONSTRUCTION

As mentioned previously the bitumen-rubber asphalt is extremely sticky. Handwork should therefore be limited to the minimum. All excess material should also be removed from the road surface as soon as possible as these materials can be carried over onto newly completed surfacing. The newly completed surface is also very sensitive to oil, hydraulic oil and diesel spillages creating fatty patches.

The sticky nature of the asphalt also makes it prone to segregation and accumulation of fines on auger blades and paver types. Care should always be taken to prevent segregation and all equipment should be thoroughly cleaned at the end of each shift.

A well worked out rolling pattern should be established during the construction of the trial sections to prevent roller pick-up under the wheels and to prevent over or under compaction.

5.3 QUALITY CONTROL AND TESTING

The non-homogeneous character of the B-R binder possesses certain challenges during the monitoring of the work. The best way to overcome these challenges is to have a very well worked out testing programme in place and to do time studies on site to determine to the sensitivity of the mix to time and temperature.

6. SUMMARY AND CONCLUSIONS

- Only basic constituent materials such as bitumen, rubber crumbs, extender oils, and aggregate of high quality, which conforms to the latest specifications, should be used to manufacture a bitumen-rubber binder.
- Strict quality control measures must be in place and only bitumen-rubber binder conforming to all the requirements must be used in the manufacturing of B-R asphalt. Specific indicators such as plate flow, softening point, viscosity, compression recovery, resilience, etc., will confirm that the chemical digestion process followed the correct manufacturing route and that the reaction was carried to completion. If these indicators fall outside the specified limits, it would indicate

that the chemical process followed an undesirable route and that the binder should not be used.

- The Marshall design method is still the bases for the design of the B-R asphalt, but is supplemented by other criteria such as rutting, fatigue, modified Lottman, dynamic creep resilient modules etc.
- Binder content and grading determination should be done as quickly as possible after manufacturing of the asphalt to obtain the most accurate results. This is due to the continued digestion characteristic of the B-R binder.
- Temperature vs. time property relationship curves obtained from the manufacturers should be verified. It is also recommended that time studies be carried out at the onset of a project to determine possible time limitations on construction and testing times.
- Bitumen-rubber asphalt is an excellent product with a proven record of accomplishment of over 17 years in South Africa. With the necessary attention to detail, the expected life span can be as much as 22 years. [Potgieter et al 1998]. The somewhat higher initial construction cost of B-R asphalt are negligible in view of the future savings in traffic accommodation, by-passes and the extended life rendered by the bitumen-rubber asphalt overlay when assessed over the full life cycle.

7. REFERENCES

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