BITUMEN RUBBER ASPHALT IN SOUTH AFRICA AND EXPERIENCE IN CHINA

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ABSTRACT

This paper describes an update and overview of the use of Bitumen-Rubber (BR) in South Africa. The South African experience with the transfer of the Bitumen-Rubber Technology to mainland China is also discussed briefly. The design procedures and construction practices used for the construction of Bitumen-Rubber Asphalt in rehabilitation projects in South Africa are also discussed. Bitumen- Rubber Asphalt / Hot Mix Asphalt (BRHMA) is normally used where the other asphalts have already failed or where the existing base courses are in severe distress. In addition they must also provide additional structural capacity for 10 to 15 years under severe traffic conditions.

This paper describes and discusses the following aspects:

- The constituent materials used in the manufacture of BR binder and the BRHMA. The South African materials specification is furnished and discussed.
- The SA asphalt mix design process including the type selection; the volumetric design process and the BRHMA end point specification.
- Further developments (rutting, fatigue, energy methods, moisture sensitivity, Dynamic Creep).
- BRHMA structural equivalency which is based on the work done by the CSIR on behalf of the California Department of Transport (CALTRANS).
- Construction of BRHMA.
- Environmental aspects and costs related to this technology.
- A South African experience in the introduction of this technology to mainland China.

Summary and Conclusions

The perception that the cost of BRA is higher than conventional or polymer asphalt fails to take into account the costs related to

- The use of reduced thicknesses of BRHMA versus other asphalts as per the CALTRANS / CSIR Projects
- Savings in traffic accommodation and bypasses when alternative crusher run designs are used.
- The cost implications related to the environmental issue of disposing of scrap tyres.

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1. INTRODUCTION

The Arm-R-Shield BR Technology was first introduced to South Africa from Arizona Refining of Phoenix, Arizona in the USA in 1983 [1] by Tosas (Pty) Ltd. This technology therefore has an excellent 24 year road performance history in surface treatments and Hot Mix Asphalt used for the maintenance and rehabilitation of our road network.

The outstanding road performance of Bitumen Rubber Asphalt (BRHMA) over the past 24 years in South Africa is well documented. This success became evident in 1998 with the report on the 12-year service life of bitumen rubber asphalt on the Buccleuch Interchange [Potgieter et al 1998]. This asphalt is now 21 years old and still in service under severe traffic condition on the N1 freeway. Currently a BR 13,2 single seal has been constructed on the N1 between the Buccleuch Interchange and the Allandale Interchange near Midrand. This will act as a Stress Absorbing Membrane Interlayer (SAMI).

2. BITUMEN – RUBBER BINDER CHARACTERISTICS

As is well known and well published the BR binder has markedly different characteristics to both conventional and polymer modified bitumen. This is, simply put, is due to the fact that a BR binder contains 20-24% crumb rubber by mass of total blend (Cost wise this equates to R 300-R 360 per ton of binder for the crumb rubber) compared to conventional bitumen (0%) and to polymer modified bitumen (2 – 6%)

(Cost wise this equates to R 340 – R 1020 per ton of the binder for the SBS). A fact not realized by road engineers is that the very best raw materials go into the manufacture of tyres. Those very same tyres when scrapped are used to manufacture rubber crumbs for BR.

The high percentage of crumb rubber produces the following characteristics in the BR binder which are not found in other bituminous binders,

- A very large increase (10-15 times) in the viscosity in the temperature range (190-200ºC).
- A large increase in the Softening Point (R&B).
- A resilience or “rebound recovery“ when tested using a modified penetration test – needle with a ball at the end.
- An elastic recovery of a BR binder sample which is compressed to half the sample’s original height.
- A very large increase in the flow characteristics at 60°C. This results in “no drain down“ of binder from the asphalt even at very high (8.5%) Optimum Binder Contents.
- Higher binder contents which result in higher film thicknesses on the aggregate.

3. MANUFACTURE / BLENDING EQUIPMENT

The BR binder is manufactured by blending a penetration grade bitumen with crumb rubber and an oil additive. A high speed / high shear patented blender is used for this operation as shown in Photograph 1 below.

Photograph 1 Mobile Bitumen Rubber Blender

Photograph 2 Containerised Bitumen Rubber Blender used in China

4. BASIC BR MATERIALS

4.1 Base bitumen

The base bitumen is a standard penetration grade conforming to SANS 307 Edition 3.6 2002.

The grade of base bitumen is supplier specific. Tosas (Pty) Ltd. produce a special grade for the manufacture of their Arm-R-Shield BR.

4.2 Crumb Rubber

The crumb rubber used is manufactured from scrap car and truck tyres. The process of mechanical comminuting is carried out at ambient temperature in order to obtain the correct particle shape (morphology) and texture. The correct shape and texture or morphology results in a specific loose bulk density requirement. This aspect is very important [2] Rubber crumbs produced by the cryogenic (freezing process) are not recommended and are not permitted in South Africa due to the undesirable morphology. The crumb must be dry, free flowing and comply with the requirements of Table 1 below.

Table 1 Rubber crumbs[3]

Property	Requirements	Test method
Sieve analysis, as a percentage by mass passing through the 1,18 mm sieve, % 0,60 mm sieve, % 0,075 mm sieve, %	 100 40 - 60 0 - 5	TG 1 MB-14
Natural rubber hydro-carbon content (minimum), %	25% min.	BS903 Parts [4] B11 & B12
Resilience (raw) (minimum), %	40	TG1 MB-10
Loss in resilience (maximum), %	60	TG1 MB10
Bulk density, g/cm^3	Max. 300	TG1 MB-16

Table 2 Extender oil[3]

Property	Requirements	Test method
Flash point, Min, ^oC	180	ASTMD 92 (5)
Percentage by mass of saturated hydrcarbons Percentage by mass of aromatic unsaturated hydocarbons	25(Max) 55(Min)	ASTMD 2007 (5)

At least two weeks prior to commencement of the BR blending operation, the contractor must provide a written method statement of how he intends manufacturing the BR. This should include details of the proposed plant, the percentage of crumb rubber, the blending / reaction temperature, reaction time and percentage of extender oil he intends to use. His method statement should be substantiated by graphs of time versus ring and ball softening point and flow for the full reaction period. These are referred to as behaviour curves. No bitumen-rubber blend may be used until these have complied with the specified requirements.

The bitumen-rubber blend must satisfy the requirements in Table 3 below.

Table 3 B-R blend[3]

Property	Requirements
Percentage of rubber by mass of the total blend, %	20 - 24
Percentage extender oil by mass of the total blend (maximum), %	4
Blending / reaction temperature, ^{o}C	180 - 210
Reaction time, hours	1 - 4

A continuous record is kept on the site by the contractor of the percentage rubber in the mix and the reaction temperatures and times. The bitumen-rubber binder must be sampled within five minutes prior to the mixing of the asphalt and must comply with the requirements in Table 4.

Table 4 Modified B-R binder[3]

Property	Requirements	Test method
Compression recovery, % after 5 minutes after 1 hour after 4 days	 80-100 70-95 N/A	TG1. MB-11
Softening Point (Ring-and-ball), ^{o}C	55 - 65	TG1/MB-17
Resilience, %	13 - 35	TG1/MB10
Flow, mm	10 - 50	TG1/MB12
Viscosity at 190 ^{o}C, cPoise	2000 - 5000	TG1/MB13

The Bitumen-Rubber binder after blending and after reaction is normally stored at 190-210 ºC. The BR Binder must be used not later than 6 hours after reaction is complete. For this reason the use of a two compartmented reaction/storage tank is essential.

The reconstitution of the bitumen-rubber blend is generally discouraged and not recommended in South Africa. However, Technical Guideline TG1 October 2001does allow up to a maximum of 20% an old BR to be re-constituted by the addition of the correct new amounts of base bitumen and crumb rubber [3].

5. AGGREGATE AND FILLERS[6]

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

5.1 Aggregate [6]

- The aggregate crushing value (ACV) of the coarse aggregate, must not exceed 25. The minimum dry 10 % FACT values of the –13,2 mm +9,5 mm fraction must be at least 210 kN. The wet / dry ratio must not be less than 75 %.

- The flakiness index for B-R surfacing asphalt must not exceed 25 % for the 19,0 mm and 13,2 mm fraction and 30 % for the 9,5 mm and 6,7 mm aggregate. In addition, at least 95 % of all particles must have at least three fractured faces.
- The polished stone value of aggregate, when determined in accordance with SABS(5) method 848, must not be less than 50.
- When tested in accordance with TMH1(6) method C5, the immersion index of a mixture of the binder and aggregate proposed for use must not be less than 75 %. The aggregate used for the test mixture must have a grading within the actual limits for the mix concerned.
- When tested in accordance with TMH1(6) methods B14 and B15, the water absorption of the coarse aggregate must not exceed 1 % by mass, and that of the fine aggregate must not exceed 1,5 % by mass, unless otherwise permitted.
- The total fine aggregate used in all asphalt mixes must have a sand equivalent of at least 50, when tested in accordance with TMH1(6) method B19, and the natural sand where it is permitted to be mixed with the aggregate must have a sand equivalent of at least 30.
- The contractor must, by conducting the necessary tests, satisfy himself that he will be able to produce a mixture meeting the design requirements specified hereinafter, using the aggregate he proposes to supply, within the grading limits specified.
- The grading of the combined aggregate including any filler added in an approved working mix must be within the limits stated in table 5 for the various mixes. The approved grading is designated the target grading. The mean grading of each lot of the working mix (minimum of 6 test per lot) determined from samples obtained in a stratified random sampling procedure, must conform to the approved target grading within the tolerances specified.

5.2 Fillers[6]

If the grading of the combined aggregates for asphalt surfacing mixes shows a deficiency in fines, an approved filler may be used to improve the grading. Filler may consist of active filler as defined hereinafter or of inert materials such as rock dust having the required grading necessary to improve the grading of the combined aggregates up to a maximum of 2 %.

The engineer may order the use of any active filler to improve the adhesion properties of the aggregate. Active filler consist of milled blast furnace slag, hydrated lime, ordinary Portland cement, Portland blast furnace cement, fly-ash, or a mixture of any of the above materials. Active filler must have at least 70 % by mass passing the 0,075 mm sieve and a bulk density in toluene falling between 0,5 and 0,9 g / m ℓ. The voids in dry compacted filler must be between 0,3 % and 0,5 %, when tested in accordance with British Standard 812.

Table 5 Grading for BRHMA in South Africa[6]

Sieve size (mm)	PERCENTAGE PASSING BY MASS						
	Continuously graded		Semi-open	Open 13,2 mm Minimal			GAP and SEMI GAP
	13,2mm max	19,0mm max	19,0mm max	Type 1	Type 2	Type 3	
19,0	100	100	100	100	100	100	NOT PREFERED AT PRESENT
13,2	100	84 - 96	70 - 100	90 - 100	70 - 100	100	
9,5	80 - 100	70 - 84	50 - 82	30 - 50	50 - 80	50 - 70	
4,75	50 - 70	45 - 63	16 - 38	10 - 20	15 - 30	20 - 30	
2,36	32 - 50	29 - 47	8 - 22	8 - 14	10 - 22	5 - 15	
1,18	-	19 - 33	4 - 15	-	-	-	
0,6	13 - 25	13 - 25	3 - 10	-	6 - 13	3 - 8	
0,3	8 - 18	10 - 18	3 - 8	-	-	-	
0,15	-	6 - 13	2 - 6	-	-	-	
0,075	4 - 8	4 - 10	1 - 4	2 - 6	3 - 6	2 - 5	
Nominal Properties by mass							
Aggregate	91,0 %	91,0 %	90,5 %	93,5 %	93,5 %	93,5 %	
Modified Binder	7,0 %	7,0 %	8,5 %	5,5 %	5,5 %	5,5 %	
Active Filler	2,0 %	2,0 %	1,0 %	1,0 %	1,0 %	1,0 %	

6. ASPHALT MIX DESIGN

6.1 BRHMA type selection[9]

The characterization of a mix type depends primarily on the spatial composition of the mix (e.g. nominal size, gradation, aggregate, filler and binder characteristics of the mineral components). The selection of a mix type can be optimised by considering the relative demand for each of the different design objectives (i.e. stability, durability, rutting, fatigue, etc.) which in turn is influenced by external factors such as expected traffic, pavement and climatic situation, environmental influence (noise, stormwater, etc) and other special design considerations.

The spatial composition of the mix (i.e. stone- or sand-skeleton) and hence the type of gradation are perhaps the most important choices to be made as far as mix type selection is concerned. The aggregate packing characteristics to a large extent determine the binder content and volumetric properties of the final mix. These elements in turn determine the relative resistance of the mix to deformation, deterioration caused by the environment, etc. Table 6 lists the types of gradation covered by these guidelines and also shows a relative rating of the most important performance properties associated with each type.

The selection of a nominal aggregate size is limited by the asphalt layer thickness. Current specifications limit the maximum aggregate size to not more than half of the thickness of the compacted asphalt layer. Designers should however, consider decreasing this limit (i.e. increasing the ratio of layer thickness to maximum aggregate size) whenever conditions are anticipated in which compactibility or segregation may pose problems during construction.

Increasing the nominal aggregate size generally increases the stability of the asphalt but reduces the workability of the mix. Segregation also becomes more problematic when larger aggregate sizes are used.

Table 6 Mix types and typical performance properties

Type of gradation and binder	Typical applications	Performance rating* for						
		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	2	4	2
SMA with bitumen rubber	rut-resistant surfacing	3	5	4	4	4	4	4
Open graded with bitumen-rubber	functional layer	3	5	3	4	1**	5	4
Semi-open with bitumen rubber	flexible surfacing/overlay	3	5	5	3	4	4	3

* 1 = Poor, 5 = Good ** Impermeable support layer or membrane required

6.2 Volumetric design and performance testing[9]

After the design objectives have been determined, the mix type has been selected and the various components have been evaluated, the actual design process can begin. The basic design procedure consists of the following steps:

- Sample preparation (including sourcing of suitable materials and the proper sampling thereof), compaction and volumetric calculations. This involves compacting specimens at different binder contents and understanding both the compaction characteristics as well as the volumetric and engineering characteristics of the mix as determined in the laboratory and as expected immediately after construction and during its lifetime in the field.
- Engineering properties. Where there is uncertainty and risk, some engineering properties should be determined to increase the level of confidence to that which is required for the application, and to verify the properties expected from the volumetric calculations.
- Field trials. During construction some field trials should be carried out to assess whether the field mixing and compaction processes can produce a layer with the required properties.

The basic steps required for volumetric design and performance testing are shown in Figure 2. Although the overall process as illustrated in Figure 2 is common to all mix types, specific criteria and procedures apply to individual mix types.

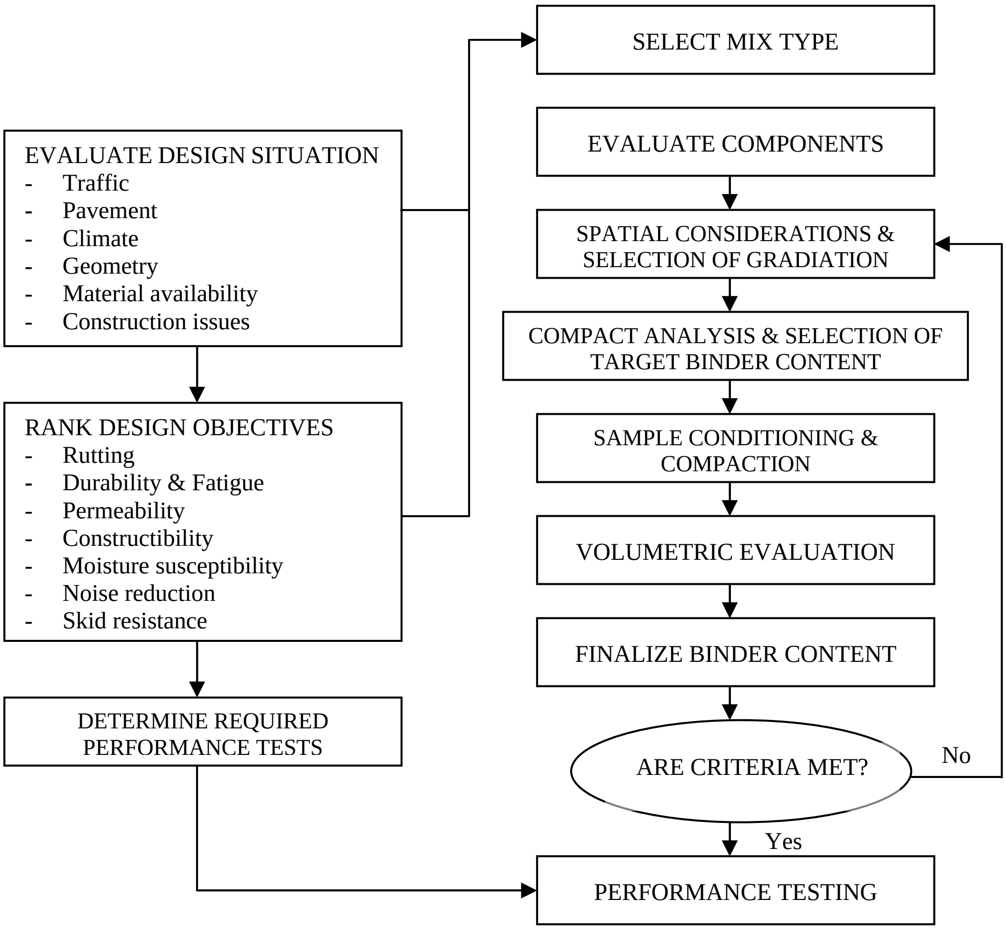

Figure 2 Design process for spatial design and binder content selection

Before the selection of a target gradation and the calculation of volumetric design parameters are started, designers should be aware of the intended spatial composition of the planned mix. In particular, designers should be aware of the packing characteristics of the planned mix type and how this influences the volumetric design parameters. The type of skeleton structure that is aimed for in the design should be kept in mind and the evaluation and selection of the gradation should ensure that the appropriate packing mechanism is attained. Two opposing packing mechanisms govern the packing of aggregates:

- Substitution, in which the space occupied by the fine aggregate fraction is replaced by an increase in the concentration of the coarse aggregate fractions. This mechanism applies to sand skeleton mixes.
- Filling, in which the spaces between coarse aggregates are filled by an increase in the concentration of fine aggregate. This mechanism applies to stone skeleton mixes.

These two packing mechanisms serve different purposes and have different advantages as far as stability, durability and compactability are concerned. The selection of a target gradation and analysis of volumetric parameters should be relevant for the particular type of packing mechanism that is aimed for in the design.

<u>6.3 End point specification</u>

Table 7 below lists the project specification requirements for the process and acceptance control during the site construction period.

Table 7 BRHMA end product specification

<table>
<tr><th rowspan="2">Requirements</th><th colspan="3">Graded Asphalt</th></tr>
<tr><th>Continuously</th><th>Semi-Open</th><th>Open</th></tr>
<tr><td>Void in mix (table 5)</td><td>2 - 6</td><td>3 - 7</td><td rowspan="10">NOT READY FOR PUBLICATION YET</td></tr>
<tr><td>Voids in mineral aggregate (%)</td><td>17 min</td><td>-</td></tr>
<tr><td>Indirect tensile strength (MPa)</td><td>550 min</td><td>600 min</td></tr>
<tr><td>Dynamic Creep (MPa) at 40°C</td><td>10 min **</td><td>15 min **</td></tr>
<tr><td>*Marshall stability (kN)</td><td>8 - 15</td><td>6,5 -12,5</td></tr>
<tr><td>*Marshall flow (mm)</td><td>2 - 5</td><td>2 - 5</td></tr>
<tr><td>Filler/bitumen Rates</td><td>1,0 - 1,5</td><td>1,0 - 1,5</td></tr>
<tr><td>Film thickness</td><td>5,5 min</td><td>5,5 min</td></tr>
<tr><td>Density (% max)</td><td>97 % - design voids but not less than 93 %</td><td>97 % - design voids but not less than 93 %</td></tr>
<tr><td>SHRP Gyratory</td><td>N_{in} = 9, N_{des} = 128 N_{max} = 208</td><td>N_{in} = 9, N_{des} = 128 N_{max} = 208</td></tr>
</table>

* The stability and flow in the RSA are considered not to be all that applicable to B-R asphalt. It is rather investigated using the X-Y recorder in conjunction with the Marshall press and ITT test. This enables the elastic modulus, plastic modulus, energy stored, hysteresis, toughness of the B-R asphalt, etc, (refer section 4) to be determined.

7. FURTHER DEVELOPMENTS

Standard laboratory tests in use in the RSA for quality control are those listed for rubber crumbs (table 1), extender oil (table 2), BR modified binder blend (table 3 and 4), gradings for BRHMA (table 5), B-R asphalt end-product specifications such as ITT, Cantabro, Schelenberg drainage test, permeability, etc (refer table 7).

Tests discussed hereafter for permanent deformation, fatigue and energy methods are not obligatory for contractors as yet, since they are still in the development phases. However, the RSA Consulting Engineers already use these in the design phase.

7.1 Permanent deformation

BRHMA's are almost always used in very highly trafficked area where permanent deformation or rutting is rife. With the expected increases in traffic volumes, vehicle loading and tyre pressure, there is a definite need to adapt hot mix design methods to ensure that BRHMA mixes are sufficiently stable to accommodate these increases. Of the available tests, wheel-tracking tests appear to have the strongest correlation with rutting in the field. The test comprises the compaction of a slab while a solid rubber wheel (400mm diameter, 100mm wide) is used for rutting evaluation. Transportek RSA performs this test at 60°C using a 600kg wheel load and the permanent deformation at various wheel pass repetitions.

Typical graphs are included in figure 3. The initial results indicate that a continuously graded asphalt performs the same with a BR binder as with conventional binder. However, the semi-open grading BRHMA out performed all.

7.2 Fatigue

In the RSA the four point Bending Beam Test at 5°C using a sinusoidal load with a frequency of 10Hz is used to assess fatigue characteristics. Two modes of loading can be applied i.e. constant strain or constant stress. Failure is defined as the point at which the stiffness of the beam is reduced to 50% of its initial stiffness. Typical results are shown in figure 4. It is clear that BRHMA (all grades) outperform the conventional asphalt by more than 100 times using fatigue as the criteria.

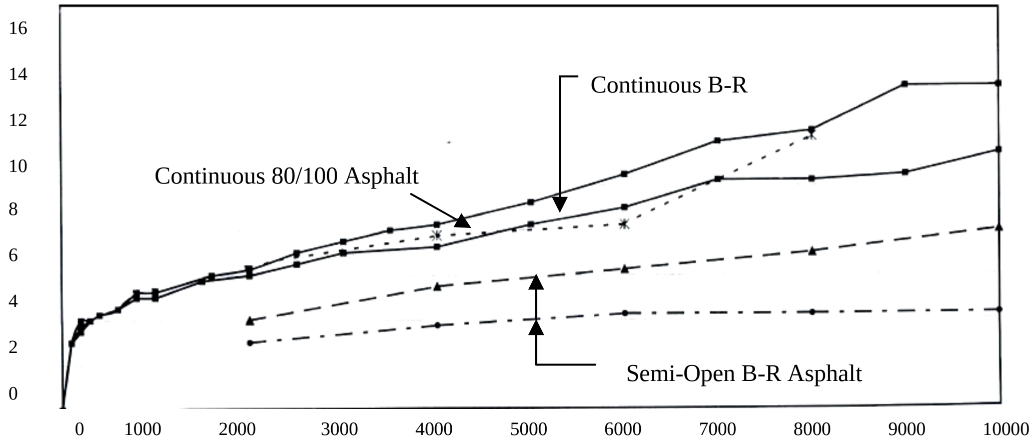

Figure 3 Typical wheel tracking results

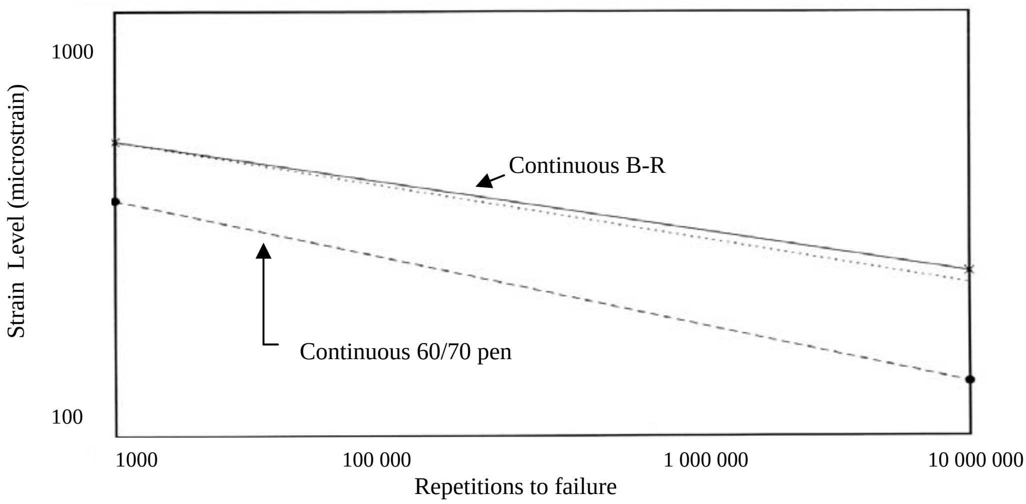

Figure 4 Typical wheel tracking results

7.3 Energy methods

At present we have no measure to quantify as to when a BRHMA will perform on average or excellently. Also, BRHMA does cost more than conventional asphalt. This extra cost can be off-set by reducing the thickness of the BRHMA surfacing.as is practiced in the USA in California.

Typical laboratory results obtained thus far appears in figure 5 below. Note that Stability-Flow and ITT graphs are used in practice as simplified stress-strain diagrams. Figure 6 demonstrate how much more energy can be stored in a under the curve for a BRHMA.

For the above research work a load cells and X-Y plotters is coupled to the Marshall press as well as the ITT equipment. The resultant elastic modulus, plastic modulus, area under the stress-strain curve, energy stored, hysteresis, toughness, etc are all being investigated at present. Hopefully we will be able to identify those characteristics which make a particular BRHMA a poor or excellent performer so that we can adjust payments accordingly, i.e. should we find that the BR binder is largely improved by more rubber crumbs and more natural rubber, then we need a method to quantity this property and to adjust measurements and payments accordingly.

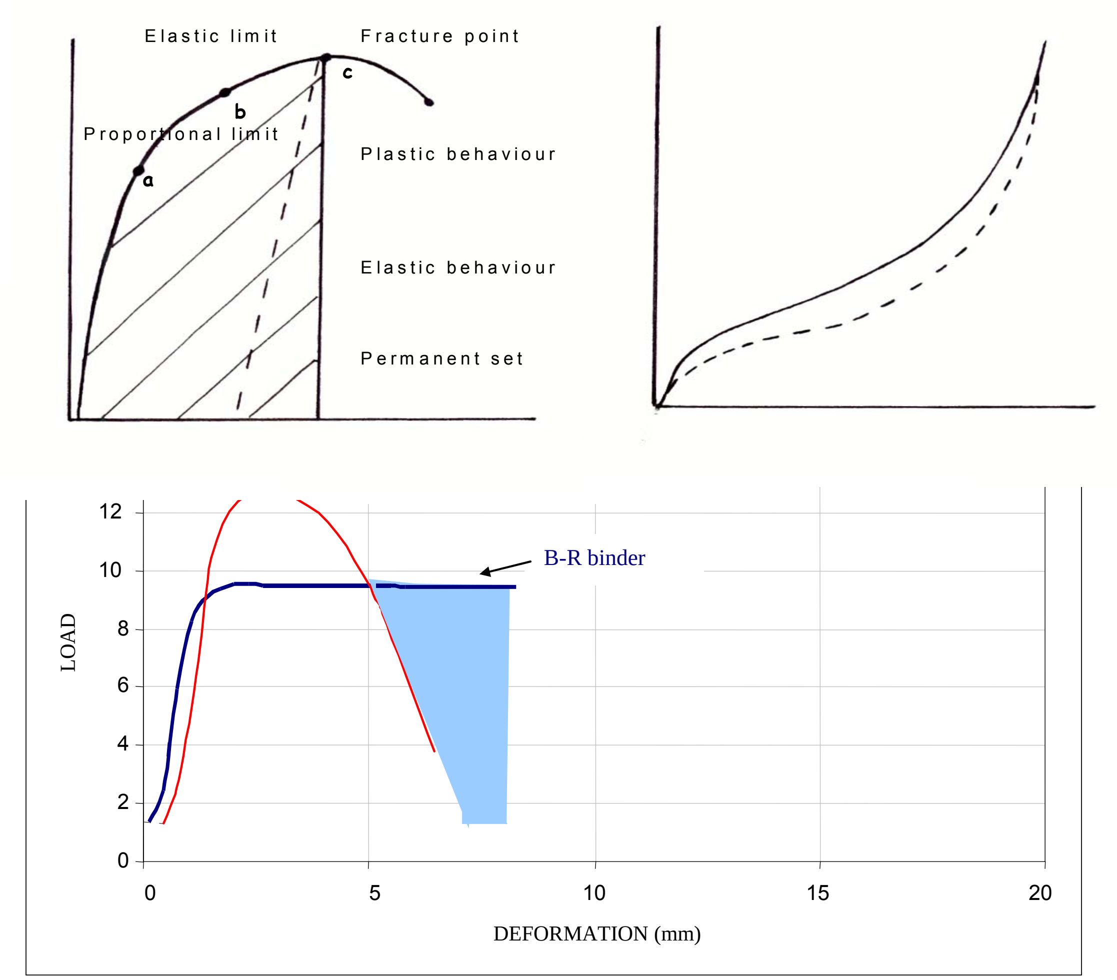

Figure 5 B-R Asphalt energy curves

7.4 Moisture sensitivity (Modified Lottman Test)

The modified Lottman test for measurement of moisture sensitivity basically 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 Jordan 1989(10) to assess the potential for stripping in BRHMA.

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 good BRHMA's tested have TSR values above 0,8.

7.5 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 20 MPa and 30 MPa for both continuously grade and semi-open graded BRASO.

7.6 B-R structural equivalence / Asphalt Thickness Reduction[11]

The South African Heavy Vehicle Simulator (HVS) was used in a project on behalf of the California Department Transport (CALTRANS) of the USA by the Division of Roads and Transport Technology of the CSIR in October 1993 [13] This project was to compare the performance of asphalt made from conventional penetration grade bitumen versus Arm-R-Shield Bitumen Rubber. These tests were further validated in California using a HVS unit purchased from South Africa. [13]

This project resulted in Caltrans using reduced layer thicknesses when using BRHMA versus asphalt made from conventional bitumen.

It should be noted that currently the Californian Economy is the sixth (6) largest economy in the world and that they have legislated that approx. 25% of all HMA used must contain BRHMA by 2010. The reduced thicknesses are shown Figures 8 below.

The B-R asphalt survey revealed that the BRHMA, used in conjunction with SAMI's (Stress Absorbing Membrane Interlayer) in numerous cases, provided superior structural capacity. It also contributed towards totally eliminating and reducing reflective cracks from underlying pavement layers. These are shown in Table 8 below.

The savings on asphalt thickness when compared to conventional asphalts are considered significant. The somewhat higher initial construction costs of the BRHMA is more than offset by the extended service life. In fact, if the lesser thickness of the bitumen rubber asphalt is constructed, the initial construction costs will be less than for a conventional dense graded asphalt overlay.

Table 8 Structural equivalents

Conventional dense graded asphalt (mm)	Equivalent bitumen rubber gap-graded asphalt (mm)	Equivalent bitumen rubber gap-graded asphalt on SAMI (mm)
37	30	-
60	30	-
75	45	30
90	45	30
105	60	45
120	65	45
135	45 BR + 45 (AC)	60
150	45 BR + 60 (AC)	60

Table 9 Crack reflection retardation equivalencies

Conventional dense graded asphalt (mm)	Equivalent bitumen rubber gap-graded asphalt (mm)	Equivalent bitumen rubber gap-graded asphalt on SAMI (mm)
45	30	-
60	30	-
75	45	-
90	45	-
105	60	30

7.7 Manufacturing of BRHMA

The BHMA is manufactured in standard asphalt plants and are paved and compacted with standard paving equipment. Figure 7 below is a schematic layout of the system used to store and feed the blended BR binder to a standard Hot Mix Asphalt (HMA) plant.

Approximately 15 Ton batches of the BR binder are blended into one tank of a two compartmented BR reaction and storage tank. After reaction the BR binder is pumped into a ring main under pressure. This ring main is connected to the HMA plant binder weigh tank. On demand the correct amount of BR is pumped from the ring main into the binder weigh tank and then into the HMA pugmill.

As the BR binder is used/drawn out of the first tank, blending into the second tank is started to ensure a continuous feed of treated BR binder to the HMA plant.

With this method approx. 90 Metric Tons /day have been blended for a HMA plant in China.

This method ensures that the BR binder is used within a 2 - 4 hour period per batch.

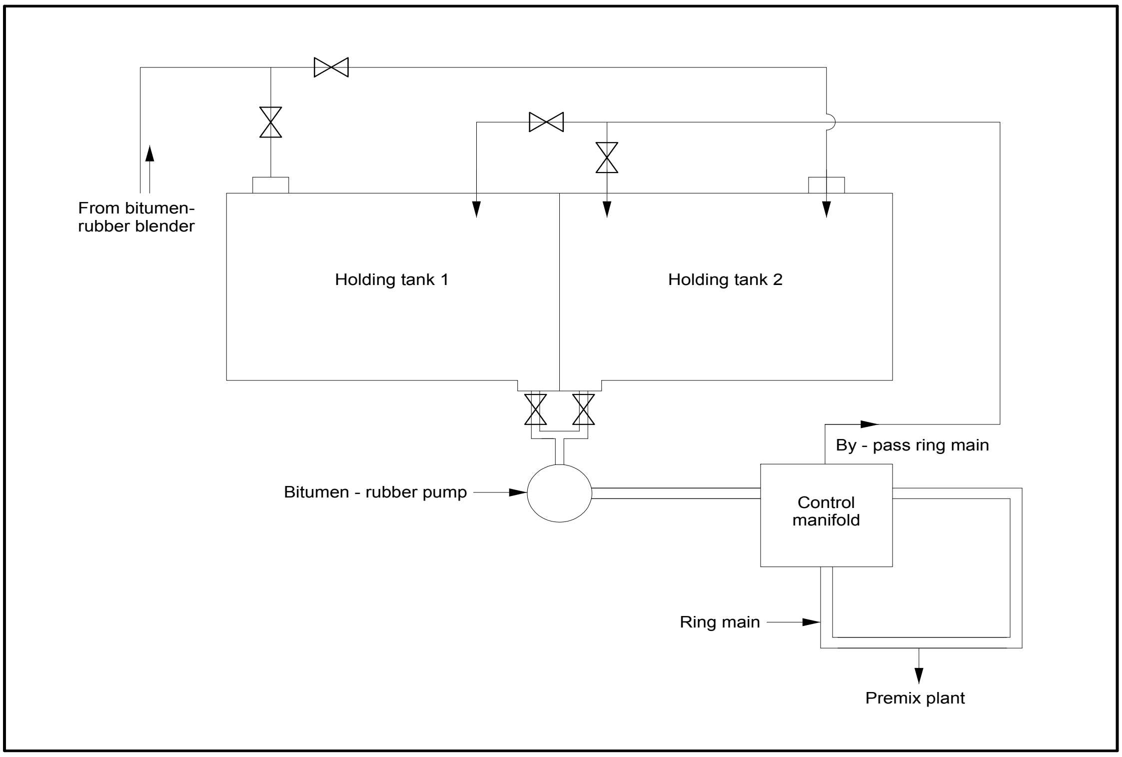

Figure 7 BR Binder feed to the Hot Mix Asphalt plant.

7.8 Placing and compaction

The BRHMA is paved and compacted in the conventional way. The BRHMA is normally compacted using three-point rollers and tandem high frequency vibratory rollers. Pneumatic rollers will only be used when continuously graded BRHMA is compacted.

The BRHMA should arrive on site at in the temperature range 160-165 ^{o}C. Temperatures higher than this will result in shoving of the asphalt mat. Normally the exit temperature of the BRHMA from the mix plant can be easily controlled. The roller speed is also very important and should not exceed 4.5 kh./hour. The number of rollers used to achieve density is very important and Troxler type Nuclear density meters should be used to determine the correct number of passes to achieve the specified density. The site of taking the Troxler measurement should be marked and density cores should be taken at these locations. Industial type liquid soaps should also be added to the water used in the rollers. This will ensure no pick-up of asphalt on the roller wheels.

8. ENVIRONMENTAL ASPECTS

8.1 Scrap tyres – An International Solid Waste "Nightmare"

The disposal of scrap tyres is currently a major problem throughout the developed world. Approx. 300 million scrap tyres have to be disposed of per year in the USA (and some 89 million per year in the UK. This gives one a scale of the growing problem.

These scrap tyres are dumped on large landfill areas and contain form 5 – 15 million tyres – Photograph 1 below. In the USA fires at these sites have been known to burn from 3 -9 months resulting in costs of up to US $ 5 million per fire. These fires result in both air and ground pollution as one tyre contains approx. 1 US gallon of oil.

In the developing countries such as China, India and South Africa the economic growth rates are high. This has resulted in improved standards of living, increased savings and a very high growth rate in the number of cars coming onto these countries roads. The growth of new car sales in South Africa per year is now very high. More cars – more scrap tyres.

The increased use of the BR Technology on roads will greatly reduce the solid waste problem posed by scrap tyres.

The other large benefit is that of Life Cycle Cost advantages.

9. THE TRANSFER OF THE SOUTH AFRICAN BR TECHNOLOGY TO CHINA

Since 2002 an initiative to transfer this technology to mainland China has been in progress. Many presentations were made at various cities throughout China in this regard. Detailed verification testing of raw materials had also taken place.

A special improved BR Blender based on the original unit imported form the USA in 1983 was manufactured for China together with the two compartmented reaction and storage tank as shown in Figure 8 above. For security reasons these were housed in standard six and twelve meter containers as shown in Figures 9 and 10 below.

Two trial sections have to-date been constructed in 2005 and in September 2006. 2 – 4 new trials are being constructed in 2007.

The 2006 trial section was 2km. long and 16 meters wide. 6500 Tons of BRHMA were paved. Two mix types were paved namely a Bitumen Rubber Asphalt Semi-open grade and Porous Asphalt. The Porous BR Asphalt was identical to that which was laid on the Ben Schoeman Highway between Corlett Drive and the Buccleugh Interchange. This section performed well under very heavy traffic despite no cleaning having been carried over a 9 year period.

The design was carried in conjunction with the Beijing Design Department using the Marshall Method.

Photograph 3 – The BR Asphalt Semi Open (BRASO) Graded Mix

Photograph 4 – View showing the BRASO mix (LHS) and Porous Asphalt (RHS)

10. SUMMARY AND CONCLUSIONS

10.1 An Outstanding Technology

The characteristics of this product are totally different and superior the other binders used. This has resulted in a better performance on the road including long term durability.

10.2 Proven Track Record

We have a 24 year proven track record, we have the technology, we have the equipment, we have the knowledge and expertise to use the BR Technology. All we now need is the engineering and political will to make better use of this technology.

- This track record applies to both asphalt and concrete roads.

10.3 Life Cycle Costs

- The Life Cycle costs of this technology are better than other binders, but should be updated to include the reduced thickness cost factor plus the environmental cost saving when using scrap tyres.

10.4 Environmental Importance

The massive solid waste problem of scrap tyres can to a large degree be addressed by the aggressive use of this proven technology.

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