A CONSULTANT'S PERSPECTIVE ON THE USE OF BITUMEN-RUBBER IN ESPECIALLY DOUBLE SEALS

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ABSTRACT

In life-cycle assessments conducted over the past 25 years, bitumen-rubber has proven itself as the most cost-effective modified binder in the South African bituminous product spectrum. It has been proven that by using bitumen-rubber, the life cycle cost decreases significantly whilst effectively increasing the functional performance and salvaging the otherwise rapidly deteriorating South African roads. The deterioration of the South African road network is considered to be primarily the result of a lack of timely maintenance intervention on the ageing existing infrastructure. In order to retain the performance properties of the bitumen-rubber blend, South African roads engineers have adopted design methods and construction techniques to ensure that only minimal cutter is added to the bitumen-rubber blend before application (this does not apply to winter-grade applications). The objective of this paper is to present case studies and performance of unusual projects where bitumen-rubber was used successfully in single and double seals in order to demonstrate how the design parameters were extended. A brief overview is given of the properties and manufacture of bitumen-rubber, which is common to the projects which will then be discussed. These case studies will demonstrate that although bitumen-rubber single seals provide a useful action on badly deteriorated roads, bitumen-rubber double seals are more cost-effective and have a longer life.

1 INTRODUCTION

According to *The Shell Bitumen Handbook* (2003) there are some 250 uses of bitumen. One of these uses is for road-building purposes. Penetration grade bitumen is normally specified for road-building purposes. As the bitumen is responsible for the visco-elastic behavioural characteristic of the surfacing, it plays a major part in determining many aspects of road performance, particularly concerning resistance to permanent deformation and cracking. Due to the increase in heavy traffic on our roads and the backlog of resurfacing them, the use of modified bitumen is not only on the increase, but also in many cases essential, such as in the resurfacing of older roads.

The role of bitumen modifiers is to increase the resistance of the surfacing to permanent deformation at higher temperatures without adversely affecting the properties of the bitumen at lower temperatures. Essentially, satisfactory performance of bitumen on the road can be ensured if four properties are controlled. These are rheology, cohesion, adhesion and durability. Crumb (granulated) tyre rubber modification addresses all four of these properties to a greater or lesser degree. Due to the aging road network, the use of granulated tyre rubber modification in spray seal applications is on the increase in South Africa. In the past this type of bitumen in spray seal applications was mostly used in singlesurface seal applications, but its use in double surface seal construction is on the increase due to its excellent performance on roads which need an extraordinary "holding action" due to the lack of funds for either road reconstruction or heavy rehabilitation.

The objective of this paper is to present case studies and performance of unusual projects where bitumen-rubber was used successfully in single and double seals. A brief overview is given of the properties and manufacture of bitumen-rubber, which is common to the projects which are then discussed. It is demonstrated that although single seals provide a useful action on badly deteriorated roads, double seals are more cost-effective and have a longer life.

2 THE COMPOSITION OF BITUMEN-RUBBER

Bitumen-rubber consists of a mixture of penetration-grade bitumen, mechanically ground and graded rubber crumb and aromatic oils, blended in specific ratios under very controlled conditions. The manufacturing of bitumen-rubber is therefore not a process of indiscriminate addition of scrap rubber to bitumen. By careful selection of raw materials, the end product's performance is enhanced. Each raw material is selected to add desirable properties to the end product. Table 1 indicates a typical bitumen-rubber composition (COLTO, 1998, TG1, 2007).

Table 1: Typical bitumen-rubber composition.

Component	% by mass
Penetration grade bitumen	78
Granulated rubber crumb	20
Extender oil	2

2.1 Penetration grade bitumen used as base bitumen

The source and grade of base bitumen is important since the chemical properties of bitumen vary in accordance with the type of crude oil being processed, as well as the refining process. Penetration grade bitumen with a penetration of 80-100 has been extensively used throughout RSA for bitumen-rubber seal type applications. The base bitumen complies with the national standard requirements of the South African National Standards - SANS 307 specification for penetration grade bitumen.

2.2 Important considerations related to rubber crumb properties

The source of peelings and buffings is important since the ratio of natural and synthetic rubber used in the manufacturing has a significant influence on the behaviour of the final bitumen-rubber blend. The type of hydrocarbon present in the rubber determines the degree and rate of reaction between the rubber crumbs and the hot bitumen. The relative reactivity of the various types of rubber found in scrap materials decreases, being higher in natural than in synthetic and neoprene rubber. Rubber crumb that is high in natural rubber content has a greater degree of reaction between the rubber and the bitumen at high temperature. The natural rubber also provides better elasticity and adhesion than synthetic rubber. For this reason a minimum of 25% by mass of rubber component of the blend must be natural rubber determined by means of thermo-gravimetric analyses.

The surface area of material, and therefore the grading (Table 2), also greatly affects the degree of chemical reaction. The large particles remain functionally undissolved rubber floating in the bitumen with a small percentage of gel on the surface. The small particles form a large amount of gel so that the compound is a matrix of gel, bitumen and resilient rubber which defies separation.

Morphology of the rubber particles is the most important factor affecting elastic recovery and hence performance of the bitumen-rubber binder and is a function of the method of manufacture. Buffings mainly have smooth-faced particles with an elastic recovery of 21%. Ambiently-ground crumb (the South African method) has a particle surface covered with porous nodules with an elastic recovery of 35%. Cryogenically-produced crumb (general method used in the USA) is smooth-faced angular cracked particles which have elastic recovery of only 6%. The preferred method is obviously the ambiently-ground one with its much higher elastic recovery.

Crumbed (granulated) rubber also contains approximately 40% of carbon black, a natural antioxidant, which will substantially prevent the aging of the bitumen-rubber binder on the road.

Table 2: Typical grading of the rubber crumb (COLTO, 1998, TG1, 2007).

Passing screen (mm)	Mass
1,180	100
0,600	40 – 70
0,075	0 – 5

2.3 Properties of the extender oil / cutter used in bitumen-rubber

Extender oils and cutters are used in varying quantities depending on the source of bitumen, the topographical area and the season. Work by Potgieter and Van Zyl (1992) has shown that the highly-aromatic high flash-point extender oil dissolves the fine rubber fraction particles and causes the coarse fraction rubber crumb to swell substantially, therefore increasing the viscosity of the material. This produces a product with improved flexibility, elasticity and adhesion while reducing temperature susceptibility. Because such a small quantity of extender oil is added to the bitumen-rubber blend, it has an almost negligible effect on the chemical constitution of the bitumen and also does not interfere with the stability and durability of the chemical components of the bitumen (Jooste et al, 2008, Jooste and van Zyl, 2010).

3 THE MANUFACTURE OF BITUMEN-RUBBER

Bitumen-rubber is usually blended on site and therefore process control is of utmost importance. All responsible suppliers should be in possession of detailed production procedure manuals which detail the respective blend procedures to be followed. The addition of the correct amount of extender oil to the bitumen is normally done at the refinery. Prior to a batch of bitumen-rubber being blended, the bitumen is heated to about 210˚C before the rubber crumb is added. Technologically advanced high-speed homogenous mix blender systems are used to add the rubber crumb uniformly to the bitumen by allowing the operator to control digitally the feed of raw materials in precise proportions. Prior to application, this blend of bitumen, extender oil and rubber crumb is then left to react for approximately one hour at the reaction temperature.

The rubber particle progressively converts from a resilient particle to a gel and finally to an oil when the rubber has been completely dispersed. The elastomeric particle provides resilience, whereas the gel improves the low temperature properties while increasing the softening point and viscosity. The oil phase improves the durability and increases flexibility. The morphology of the rubber particle also affects the degree of chemical reaction.

In South Africa, the principle that has been adopted is to minimise the quantity of any cutters added so as to achieve the best possible properties. The complex nature of the blend of hydrocarbons, oils and gels, means that its viscosity changes significantly over time at elevated temperatures. The bitumen-rubber blends without cutters have a restricted shelf life that has necessitated the production of softening point, viscosity and flow time relationship curves which gives the engineer insight into the performance or reaction of the product, as shown in Figure 1 (Sadler, 1998).

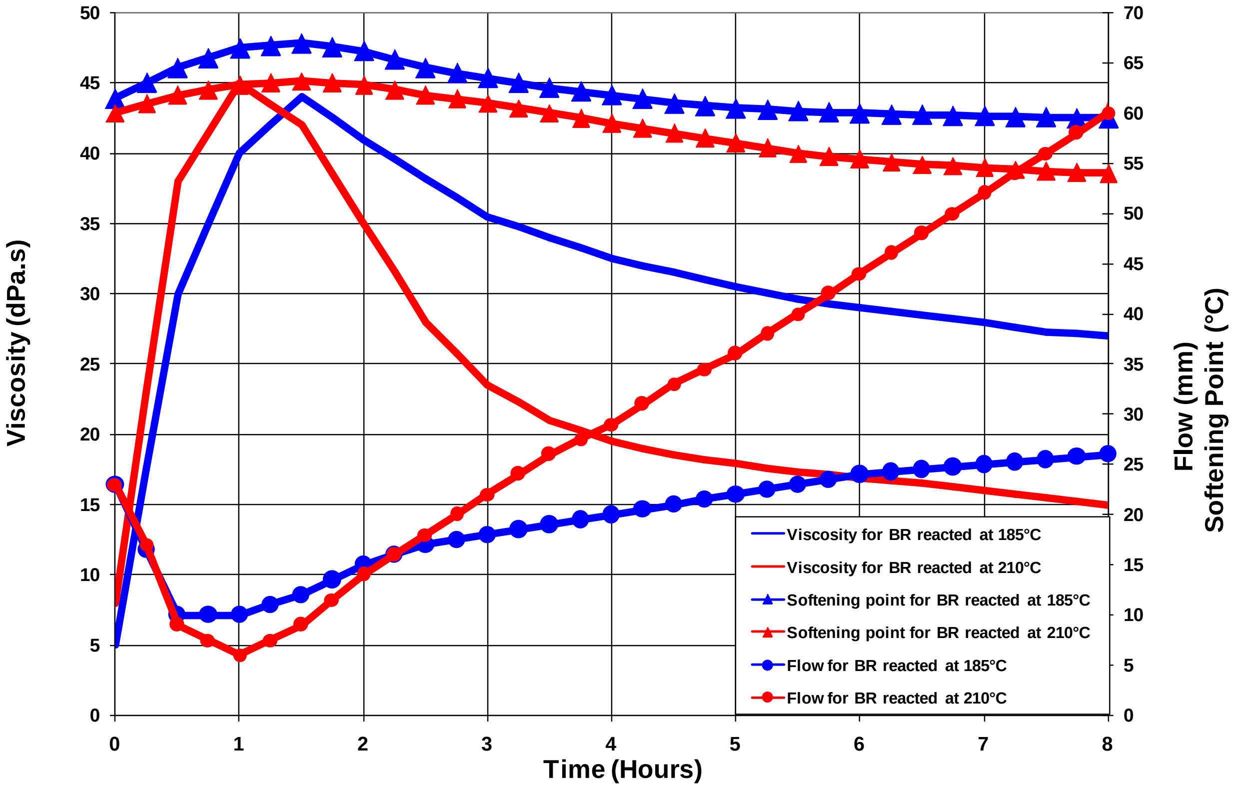

Figure 1: Effect of blend temperature on the properties bitumen-rubber

A hand-held rotary viscometer with a rotor cup which can measure dynamic viscosity in the range of 0.5 - 10 dPa.s is used in the field as a go/no-go indicator test. The viscosity test is the most sensitive of the product release criteria and the South African experience is, if the viscosity at 190°C is greater than 20 dPa.s, then the site parameters will be within its release criterion specifications. It is vital that this be constantly measured during seal construction (Jooste et al, 2008, Jooste and van Zyl, 2010, TG1, 2007)

4 ADVANTAGES AND DISADVANTAGES OF BITUMEN-RUBBER

The bitumen-rubber product has excellent ability to reduce the reflection of cracks through the new seal and to “re-heal” itself. UV resistance is achieved by the antioxidants in the form of carbon black in the rubber crumb. The function of a surfacing seal is to cover an old wearing course or base and provide an impermeable riding surface. The aim of a good seal therefore is to apply the most binder possible without flushing / bleeding taking place. The case studies presented in this paper will show that in some instances of bitumen-rubber double seals, up to double the normal binder application have been used with great success. Another advantage is that enough binder can be used in the first tack coat spray using bitumen-rubber binder, so as to avoid causing a surface seal with voids in the lower part of a double seal. This prohibits the possible stripping of the seal after construction during times of high rainfall and hot days when moisture may be able to penetrate the seal under traffic. Studies by de Beer et al (1997) have indicated that measured vertical contact stresses under heavy vehicle tyres can in certain instances reach values of 0,7 to 2,75 MPa. It is therefore safe to assume that the hydraulic water pressure below these same heavy vehicle tyres may also reach these peak contact stress values during times of heavy rain. On the other hand there are some disadvantages also. Unfortunately the one most significant drawback in the construction of especially a BR double seal is in most cases the unavoidable flushing in the wheel track after some time. This is especially likely to occur if the road surface is narrow and the traffic composition is on the heavy side. Only isolated instances have been found where the flushing is so severe that all skid resistance has been lost. Another disadvantage in the use of BR surface seals is their inability to self-heal when the traffic drops to too low a figure. In such cases the use of a BR binder would in any event not have been the most economical choice.

5 BITUMEN-RUBBER USED IN SURFACING SEALS

In South Africa, bitumen-rubber is normally used as the binder for surfacing seals in the following applications:

- Single seals, the most common, where the binder is covered by a single layer of single-sized aggregate (typically 13,2mm), and could be a stress-absorbing layer where the intention of the seal is to bridge active cracking;
- Double seals, where a combination of two layers of binder and aggregate are applied, used mainly to achieve a thick bitumen-rubber/aggregate composite seal to reseal roads that otherwise would need reconstruction;
- Stress absorbing membrane inter-layers (SAMI’s) that usually consist of a single seal either with 13,2mm or 19mm stone that is usually covered by an asphalt layer to form a composite bituminous system. The SAMI is designed to prevent reflective cracking and to increase shear resistance. Although the author has used such overlays with success, these do not fall within the scope of this paper.

There are some Special Conditions of Contract needed for bitumen-rubber sealwork over and above the normal COLTO Specifications, of which the most important are, a good quality base bitumen, weather limitations, the application of tack coat, overspray on adjacent strips and the application of bitumen-rubber time limits and aggregate application. It is vital for successful single and especially double seal applications being constructed in summer that the construction be carried out without additional cutters needed for cold weather applications. This is especially important when the seal is to be constructed as a SAMI. Also of importance is that traffic is spread over the whole of the seal surface at least during the first week after construction (Jooste van Zyl, 2010, TG1, 2007).

6 CASE STUDIES

The case studies presented are reseal projects where a double seal was constructed mainly to achieve a very thick bitumen-rubber/aggregate composite seal to reseal roads that otherwise would need major rehabilitation. This is normally brought on by a road in a poor condition with some severe structural defects (TMH9, 1992), but insufficient traffic to justify the high rehabilitation cost, or simply a road in poor condition regardless of traffic volumes where insufficient funds are available for a structural strengthening intervention.

A. CASE STUDY 1: ROAD K175 NEAR ETWATWA (DAVEYTON)

The road, especially the surface layer, was in an extremely poor condition exhibiting a very dry, brittle and continuous (fatigue) cracked surface layer with some structural cracking and patches. Due to the varying texture depth a fine slurry texture treatment was applied, prior to the application of 19.0 mm and 9.5 mm bitumen-rubber double seal. In essence the existing road surface layer was long overdue for a reseal, with the pavement structure still in a reasonable condition. FWD deflections were varying with Ymax values between 0.3 to 0.7 mm, indicating a distressed pavement. Rutting on average was in the vicinity of 5 to 10mm. The AADT in 2000 on this road was approximately 2600, which has now (2011) escalated to approximately 3500 vehicles per day with approximately 14% heavies. The total binder applied was 5.1 ℓ/m^2, which was 1.5 ℓ/m^2 higher than the minimum suggested by TRH3 (1997).

Viewed in sequence, Photograph 1 shows:

- Condition before - Continuous fatigue cracking in wheel tracks
- Condition after slurry texture treatment
- Condition after one year
- Condition now after almost 6 years

Photograph 1: Road K175 near Etwatwa (Daveyton), Gauteng.

Conclusions drawn from observations indicate that the application rate was appropriate to minimise crack reflection while still providing a texture depth in excess of 1 mm after 6 years (Jooste and van Zyl, 2010).

B. CASE STUDY 2: ROAD P84-1 - MODIMOLE (NYLSTROOM) TO VAALWATER

Major portions of this road (which is more than 200 km long), were in a shocking state. Only R3 million was available for the repair of the road. It was decided to resurface the first 6 km of this road with a 19/9.5 mm bitumen-rubber double seal as a “patch”. This was done purely as a holding action on the section of road, as the surface layer and the pavement structure had failed in many areas. Patching was only done on failures which could not be resurfaced. Crocodile cracks and surface cracks were left as is and the double seal constructed after a diluted bitumen emulsion pre-treatment.

The resurfacing itself was completed in March 2001. This holding action was done with an expected life of approximately 5 years. The AADT at time of sealing (2001) was approximately 2200 with approximately 15% heavies. The AADT traffic now is in excess of 3000 close to Modimole. The total binder application rate varied between 5 ℓ/m^2 and 5.2 ℓ/m^2.

Viewed in sequence, Photograph 2 shows:

- Condition before – Poor riding quality and failed patches
- Condition before - Continuous fatigue cracking in wheel tracks
- Close-up of the condition after 6 years
- General condition now after 9 years

Photograph 2: Road P84-1, first 6 km from Modimole (Nylstroom) towards Vaalwater.

Other than a few large longitudinal cracks reflecting and some isolated small failures after ten years of service, the pavement is still holding without any crocodile cracks and/or pumping visible. The riding quality is still unacceptable, as the double seal could not rectify the shape of the deformed base.

A slight degree of fattiness is visible in the wheel tracks, which is always a good sign in terms of the long term durability, but as always the texture depth is compromised as a result thereof. As a 19/9.5 mm double seal has a relatively high texture depth to start off with, it is rarely found to be substandard when evaluated with TMH 9 (Jooste and van Zyl, 2010).

C. CASE STUDY 3 : THABO MBEKI ROAD (VOORTREKKER ROAD) THROUGH MOKOPANE (POTGIETERSRUS)

This is the old N1 which had passed through the town of Mokopane prior to the toll route construction, and served as alternative route. At time of the resurfacing of the first km from the southern side into town, this section was structurally totally inadequate to carry the traffic for the next 10 years and a “holding action” which included some patching and a 19/9.5 mm bitumen-rubber double seal was suggested as an interim solution until funds could be obtained for rehabilitation. This section of road is, for the most part, a double carriageway with almost all the heavy vehicles travelling in the slow lanes.

The 2000 AADT on this section of road was already in excess of 7000 with approximately 22% heavy. Total binder application rates varied between 4.8 and 5.3 ℓ/m^2

Although embedment occurred in certain areas as a result of not applying the 19 mm stone in the best shoulder to shoulder application rate possible, the a poor base, and patching just prior to reseal, the road is still performing quite well with only a few minor and one large patches in the road that have to be maintained from time to time. The visible bleeding areas, as shown in the second image, are not tacky and no pickup of the binder or seal has occurred to date. Deformation, in terms of rutting increases each year. However, only a few instances of deformation, cracking and/or pumping are visible in these areas after 11 years of service.

Photograph 3 shows the general condition now, showing fattiness without tackiness or pick-up in the slow lane after 11 years (Jooste and van Zyl, 2010).

Photograph 3: Thabo Mbeki Road (P1-5) through Mokopane (Potgietersrus)

D. CASE STUDY 4: ROAD P101-1 BETWEEN ROADS P5-1 AND N17-2

The road was rehabilitated during 1999. As a result of insufficient funds to complete the rehabilitation, the decision was made to resurface a section of road with a 19/9.5 mm bitumen-rubber double seal. This was the very first bitumen-rubber double seal done by KBK, and looking back we realise that some mistakes were made of which the most important one that of not constructing the 19 mm bottom stone layer in a shoulder-to-shoulder matrix.

All the super load, and grain transport loads in the vicinity are carried on this section of road. It is also the shortest link between the N17 and the P5-1, between Delmas and Springs, and also the last link where heavy vehicles can exit the N17 before it becomes part of the existing toll route. The AADT at time of construction was approximately 3500 with more than 20% heavies. This has changed dramatically as the Leeuwpan Coal Mine near Delmas has since then started transporting coal to a re-commissioned power station at Nigel.

Total binder application rates varied between 4.7 and 5.3 ℓ/m^2. The double seal in the wheel path has flushed considerably through the years, but it still has a minimum surface texture of approximately 0.4 to 0.5 mm. The general texture, as shown in Photograph 4, is still more than 1 mm. Even though some crocodile cracking was evident before reseal, only isolated occurrence of cracking can be observed and two small structural failures have occurred over the twelve-year period. Viewed in sequence, Photograph 4 shows:

- General condition just before patching and resurfacing in 1999
- During construction. Completed section on left with 19 mm on the right
- Close-up of the seal condition outside the wheelpath after 12 years
- General view and traffic after 12 years

Photograph 4: Road P101-1

Recent photos show the surface in the wheel path to have flushed considerably through the years, but it still has a fair amount of surface texture and has stood up to more than the anticipated traffic extremely well, with only a few small isolated failures now evident. In the beginning the application of the 19 mm stone was not constructed in as tightly as possible shoulder-to-shoulder manner. The result was that in the wheel paths the 9.5 mm stone has been punched into the 19 mm stone by the heavy traffic and has therefore become flushed, whereas the rest of the area almost seems to have received either too little binder or just enough (Jooste and van Zyl, 2010).

E. ROAD P5-1 BETWEEN ROADS P101-1 AND ROAD D77

After the detail assessment of this section of road in 1996, it was concluded that the remaining service life was less than 5 years. This section of road was re-evaluated in February 2000, confirming that it was at the end of its structural and functional life.

The AADT measured in 1997 was just in excess of 2000 vehicles (fairly low traffic volume). Considering the relatively low traffic at the time and high cost of rehabilitation, the decision was made to try and hold the road for another six years before rehabilitation. The 19/9.5 mm bitumen-rubber double seal was considered an appropriate choice in this case with its high FWD deflections, and also being a relatively important inter provincial road with a pavement nearing the end of its structural life.

The normal design used by KBK for old roads using a 19/9.5 mm bitumen-rubber was kept throughout the Contract with a tack coat in the region of 2.7 ℓ/m^2 and a penetration coat of approximately 2.3 ℓ/m^2, giving a total application rate of the bitumen-rubber binder at approximately 5 ℓ/m^2.

Experience obtained with different aggregate sizes and by varying the spread rate of aggregate indicated that:

- A larger than average ALD 19 mm e.g. >12.5 mm reduces the risk of bleeding.
- A proper shoulder-to-shoulder spread of the large aggregate is essential. If this is not achieved, the 9.5 mm stone is punched in between 19 mm stone by the traffic, resulting in a fatty wheel path within a relatively short period of time. In some cases even within a year.
- The fairly generous amount of 2.3 ℓ/m^2 as penetration coat allows the application of enough 9.5 mm stone leaving the 19 mm stone only visible here and there. The thick penetration coat also gives excellent resistance to possible stripping during the rainy season.
- One should use a fish-plate on the spray tanker on the edges of the road surface and overlap outside any wheel path with enough overlap as to ascertain that a full application rate of binder is applied below every seal stone application. Even though this means overspray when constructing the last adjoining seal layer.

Viewed in sequence, Photograph 5 shows:

- General condition after 5 years showing no defects
- Transverse cracking reflecting through outside of the wheel track after 9 years. Self-healing of the cracks in the wheel track
- Close-up of seal after 9 years
- Structural failure (excessive rutting) but seal still reasonably intact

Photograph 5: Road P5-1 to the east of Springs within Gauteng

7 COMPARISON OF BR SINGLE AND DOUBLE SEALS

On Road P5-1, due to a lack of funds, a similar section was later on resurfaced under another contract with a 13 mm bitumen-rubber single seal. This single seal section only lasted approximately 3 years after which crocodile cracking and pumping once again started to appear and now, after 5 years, the road has failed structurally and functionally and this road is now up for heavy rehabilitation. Although a 19/9.5 mm bitumen-rubber double seal is almost twice as expensive as the 13 mm single seal, the total cost of construction is usually less than 30% to 50% higher due to the normal non-relevant items of such a contract such as P&G's, patching, etc. Back calculated in terms of value for money, the double seal has in this case totally outperformed the single seal and although each type of seal has its application, the author is quite convinced that a 13 mm bitumen-rubber single seal is not the answer where a holding action has to be done on a deteriorated section of road. It would also seem that the much thicker film thickness achieved with 5 ℓ/m^2 of binder on the 19/9.5 mm bitumen-rubber double seal is adequate to prevent water from penetrating the top layers of the road even where rutting has occurred and in situations with fairly moderate traffic such as in the region of roads with an AADT of between 1000 and 3500 vehicles.

8 APPLICATION OF BITUMEN-RUBBER DURING COLD WEATHER

The South African standard specifications limits seal work using a bitumen-rubber binder to periods when the road surface temperature is 25ºC and rising. Minimum overnight temperatures are not specified, but a night-time low of 10ºC is considered minimum. The basis for the temperature limitations is to ensure good adhesion between binder and aggregate during the initial days of the seal, when there is most risk of aggregate loss.

This means that the effective sealing period is limited to the summer months of October to April. Most parts of South Africa have summer rainfall and therefore the actual opportunities to seal are sometimes reduced significantly. Typical properties are given in Table 3 (TG1, 2007).

Table 3: Comparison of the typical properties of various bitumen-rubber grades

PROPERTY	UNIT	TEST METHOD	NATIONAL SPECIFICATION		TYPICAL RESULTS		
			SR-1 (SEAL)		BITUMEN -RUBBER	AUTUMN GRADE BITUMEN -RUBBER	WINTER GRADE BITUMEN -RUBBER
			MIN	MAX			
Compression recovery						Refer to binder suppler	Refer to binder suppler
5 minutes	%	MB-11	70	-	91		
1 hour	%	MB-11	70	-	89		
4 days	%	MB-11	25	-	44		
Softening point (R&B)	ºC	MB-17	55	62	58		
Resilience	%	MB-10	13	35	30		
Flow	mm	MB-12	15	70	31		
Dynamic viscosity (Haake @ 190ºC)	dPa.s	MB-13	20	40	28		

The addition of cut-back to bitumen-rubber changes the properties of the intended binder to an extent that could affect one or more of the following:

- the early life performance
- the underlying bituminous surface in the case of reseals
- a layer placed over the seal, in the case where the seal is an interlayer
- for further data re the winter grade application please refer to the binder supplier.

The recovery of performance properties of the cut-back bitumen-rubber is dependant on time and weather conditions. The process for the cutter volatiles to escape will be quicker in hot weather and under the action of traffic. Resilience is one of the most important properties for the performance of the binder in applications intended for bitumen-rubber. Low resilience values mean that the binder will not be “tough” to withstand high stresses. For this reason the author is of the opinion that for double seal applications summer construction without cutters is best (Jooste et al, 2008).

9 DISCUSSION OF ISSUES ASSOCIATED WITH BITUMEN RUBBER

A number of experience-related considerations are discussed next:

- The use of bitumen-rubber in double seal applications takes the suitability of the bitumen-rubber binder to an even higher level. Examples of badly-deteriorated roads (case studies) were given and in all cases, despite different degrees of deterioration of the surfacing before resealing, the advantage of the double seal is clearly illustrated.

- Despite that fact that the material cost is close to double when compared to a single seal, the double seal provides an excellent alternative to increase the life expectancy of almost any road (obviously with the proviso that the road must still be structurally reasonable sound) to more than double the intervention holding actions.
- Please note that although the material cost may be double, this by no means implies that the total construction cost will be double. The other construction-related costs such as all the fixed costs and time-related costs, patching, shoulder re-graveling and pre-treatment of the existing road surface, usually eclipse the materials-related seal costs.
- Another positive of BR as tack coat with the relative higher application rate over other normal or modified binders is its high resistance to stripping.
- The resurfacing of old roads with its higher measured FWD deflections is better served by BR.
- BR modified binder with 20% rubber crumb is less prone to loss of modifier due to over-heating and other related mistakes than other modified binders such as S-E2 or S-E1 binders where only 3% to 4% modifier is used. A 1% loss in the latter has therefore a much higher influence on the characteristics of the binder.
- As with most modified binders, the use of BR has to be done with proper site supervision taking into account the ambient and surface temperatures, dry (water) pre-coated aggregate, application of seal stone to the sprayed binder as soon as possible, equipment tested to adhere to the specifications, continuous viscosity testing of the binder during construction of the seal, etc.
- Some pre-coating fluids cause the stone to become sticky which is to be avoided by the selective use thereof.
- The use of a steel drum roller is not important, as long as the use of at least two heavy pneumatic rollers is applied for longer than normal rolling.
- Also of importance is that in the use of BR in sealwork, the binder stiffens up quickly and the seal stone hardly ever takes the form of its measured ALD. This in effect increases the effective ALD of the seal stone, which has to be taken into account in the design and construction of the seal.
- Experimentation with bitumen-rubber application rates, aggregate sizes, shape and spread rates through trial and error has resulted in the selection of much higher application rates than would be suggested by the 1997 version of TRH3. However, as indicated below by applying the design total ALD as the sum of the two separate ALD's of the 19 mm and 9.5 mm stone the correct application is achieved even when using the TRH 3 design manual as is discussed next.

Performance of the 19/9.5 bitumen-rubber double seal at various application rates and compared with the design application rates indicated that the rates suggested by TRH3 of 1997 were too low.

Adjustments to the design methodology for TRH3 2007 now suggest much higher application rates for this type of seal. Back calculations from the Gautrans design method and now verified with field performance indicate that a conversion factor from conventional binder to bitumen-rubber of between 1.6 and 2.2 is appropriate, but dependent on the total layer thickness achieved through construction. It appears as if the conversion factors suggested in TRH3 (2007) as shown in Table 4 could be slightly increased.

Cognisance should be taken that the appropriate binder application rates are largely dependent on the aggregate spread rate and effective ALD of both aggregate layers.

Experience with 19/9.5 double seals showed that the aggregate shape, relative size difference between the two sizes and spreading of the larger aggregate, could play a major role in the performance of the seal and risk of aggregate loss or bleeding. This is illustrated in Figure 2 (Jooste and van Zyl, 2010).

Example: A seal constructed with cubical 9.5mm aggregate on a dense shoulder to shoulder spread of cubical 19 mm aggregate, is sensitive to aggregate loss and requires much more binder than a seal constructed with flaky 9.5 mm aggregate.

Table 4 : Adjustment for S-R1 binder application (TRH3 Table 7-8)

S-R1 ADJUSTMENT (Conventional to modified binder)			
Traffic (ELV)	Single seal	Double Seal	*Split application double seal*
< 5000	2.0	1.8	-
5000 - 20000	1.9	1.7	-
> 20000	*1.8*	*1.6*	-

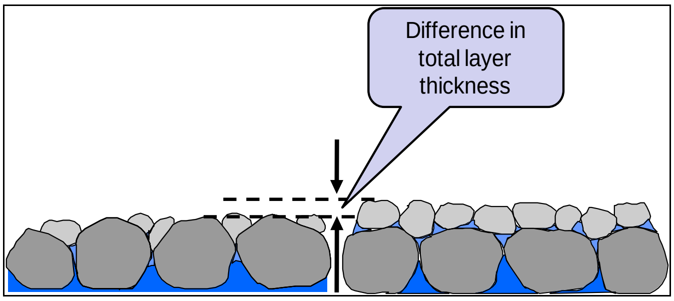

Figure 2: Difference in layer thickness due to flakiness and spread rate

Taking cognisance of the successes achieved and how the 19/9,5 bitumen-rubber seal is constructed has resulted in a much better understanding of how such a seal should be designed with confidence. The application rates obtained using the 2007 version of TRH3 and correct interpretation of ball penetration testing and total layer thickness, result in appropriate application rates.

The case studies presented confirm the effectiveness of bitumen-rubber, at high application rates, to prevent crack reflection and moisture ingress, which has resulted in extended service lives before rehabilitation will be required (Jooste and van Zyl, 2010).

10 CONCLUSIONS

The objective of the paper was to present a Consultant's perspective on the use of bitumen rubber. Performance that exceeded the design requirements and the client's expectation has made a BR double seal a cost effective treatment, particularly on severely deteriorated roads. Single seals with bitumen rubber have also been effective, but not in all cases.

Practical guidelines developed from experience show that there is scope for re-evaluation of current design guides as the properties of BR have somewhat changed over the years and are also product specific in some instances. Binder application rates for good performance can be higher than suggested by TRH3 (2007). Although visually the seals may look fatty, the texture depth invariably meets minimum requirements and the thick binder films provide a water-tight surfacing.

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