EFFECTIVENESS OF BITUMEN-RUBBER DOUBLE SEAL FOR HEAVY MAINTENANCE

NJJ Jooste and AT Visser*

Technical Director, KBK Engineers (Pty) Ltd, PO Box 74786, Lynnwood Ridge, Pretoria, 0040, South Africa,
**Emeritus Professor, Department of Civil Engineering, University of Pretoria, Pretoria, 0002, South Africa*

klasiej@kbkengineers.co.za *alex.visser@up.ac.za*

ABSTRACT. *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. Bitumen-rubber chip seals have been hugely successful in restoring the integrity of these badly deteriorated roads. 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. 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 the solution of the problem, as well as the suitability of the technology by means of an evaluation with the Treatment Performance Capacity (TPC) approach. The paper will give a brief overview of the design approach of bitumen-rubber chip seals. Thereafter several case studies will be presented to provide the background for the evaluation with the TPC approach. The 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 than single seals. This view is supported by the TPC analyses.*

KEYWORDS: *Bitumen-rubber seals, performance, Treatment Performance Capacity*

1. Introduction

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. Bitumen-rubber chip seals have been hugely successful in restoring the integrity of these badly deteriorated roads. 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 [1, 2].

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 the solution of the problem, as well as the suitability of the technology by means of an evaluation with the Treatment Performance Capacity (TPC) approach [3]. The paper will give a brief overview of the design approach of bitumen-rubber chip seals. Thereafter several case studies will be presented to provide the background for the evaluation with the TPC approach.

2. The composition of bitumen-rubber

Bitumen-rubber used in the projects discussed in this paper consisted 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. Each raw material is selected to add desirable properties to the end product. Table 1 indicates a typical bitumen-rubber composition (COLTO, 1998 [4], TG1, 2007 [5]).

Table 1. *Typical bitumen-rubber composition.*

Component	Percentage by mass
80/100 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, as 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 larger 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 prevent the aging of the bitumen-rubber binder on the road considerably.

Table 2. *Typical grading of the rubber crumb (COLTO, 1998 [4], TG1, 2007[5]).*

Passing screen (mm)	Percentage by 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 [6] 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 [7] , Jooste and van Zyl [8]).

3. The manufacture of bitumen-rubber

Bitumen-rubber is usually blended on site and therefore process control is of utmost importance. 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.

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 [7, 8, 5].

4. Presentation of case studies

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;

Some Special Conditions of Contract are needed for bitumen-rubber sealwork over and above the normal COLTO Specifications, of which the most important are, a good quality base bitumen, consideration of 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. Also of importance is that traffic is spread over the whole of the seal surface at least during the first week after construction [8, 5].

Generally speaking 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 have needed major rehabilitation. This type of reseal is normally brought on by a road in a poor condition with some severe structural defects (TMH9, 1992), but carrying insufficient traffic to justify high rehabilitation cost, or simply a road in poor condition regardless of traffic volumes where insufficient funds are available for a structural strengthening intervention.

Cognisance should be taken that the appropriate binder application rates are largely dependent on the aggregate spread rate and effective Average Least Dimension (ALD) of both aggregate layers. Experience with 19/9.5 mm 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 1.

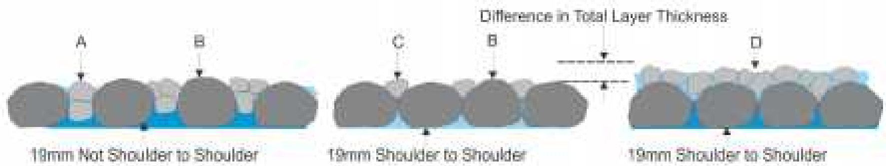

Figure 1. *Difference in layer thickness due to flakiness and spread rate*

Referring to Figure 1, the following explains the symbols:

A = top 9,5 mm stone gets punched into the gaps of the 19mm stone in the wheel paths.

B = A typical one and a half seal with the 19 mm stone protruding through the top 9,5 mm stone. A one and a half seal occurs where either the 9,5mm application is reduced with the 19mm shoulder to shoulder (middle picture); or where the 9,5mm is applied for a true double seal, but the 19mm stone was not applied shoulder to shoulder (first picture). In the latter case, the traffic usually then also displaces the 19mm stone sideways resulting in a bleeding wheel track and a dry slightly raised area in between. This immediately aggravates the rutting on the road.

C = less 9,5 mm stone application to achieve a true one and a half seal.

D = true double seal where the 9,5 mm stone covers the bottom layer of 19 mm stone, with an occasional larger 19mm stone protruding here and there.

These seals will then have different thicknesses, as will be discussed below.

The case studies are presented briefly to provide background to the later analysis. More details, including photographs, may be found in the paper by Jooste [1].

4.1 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 2005. 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 Annual Average Daily Traffic (AADT) in 2005 on this road was approximately 2850, which escalated to approximately 3600 vehicles per day with approximately 15% heavies in 2011. 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 [9]. In 2011 the road was performing well, with about 5% of the area showing defects. 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 [8].

4.2 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, which was the worst, with a 19/9.5 mm bitumen-rubber double seal as a holding action 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 2000 with approximately 15% heavies. The AADT traffic (2011) was in excess of 3100 close to Modimole. The total binder application rate varied between 5 ℓ/m^2 and 5.2 ℓ/m^2.

Other than a few large longitudinal cracks reflecting and some isolated small failures after ten years of service, the bitumen-rubber seal is 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 was visible in the wheel tracks, which is always a good sign in terms of the long term durability, but the texture depth is compromised as a result thereof. As a 19/9.5 mm double seal has a relatively high texture depth after construction, it is rarely found to have a texture depth of less than 0.6 mm during service.

4.3 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 now serves 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.

At the time of construction in 2000, the AADT on this section of road was already in excess of 7000 vpd with approximately 14% 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 at the best shoulder to shoulder application rate possible, the poor base, and patching just prior to reseal, the road was still performing quite well with only a few minor patches and one large one in the road that have to be maintained from time to time were visible after 11 years of service. The visible bleeding areas are not tacky and no pickup of the binder or seal has occurred. Deformation, in terms of rutting, increases slightly each year..

4.4 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 the consultant. In retrospect some mistakes were made of which the most serious was 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 1600 vpd with more than 20% heavies. This has changed dramatically as the coal mines near Delmas has since started transporting coal to a re-commissioned power station at Grootvlei, and in 2011 the ADT was 2880 with more than 50% heavies.

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 is still more than 1 mm. The low texture in the wheel paths is because the 9.5 mm stone punched into the lower stone layer as a result of the heavy truck traffic, whereas the rest of the surface almost appears to have insufficient binder. Even though some crocodile cracking was evident before the reseal, only isolated occurrence of cracking can be observed and only two small structural failures have occurred over the twelve-year period.

4.5 Case study 5: Road P5-1 between roads P101-1 and 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 interprovincial road with a pavement nearing the end of its structural life.

The normal design used by the consultant for old roads, namely using a 19/9.5 mm bitumen-rubber seal was kept throughout the Contract with a tack coat of about 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 of approximately 5 ℓ/m^2. At the time of construction in 2001 the AADT had increased to 3200 vpd with 12% heavy vehicles. After 11 years less than 5% of the area showed minor defects.

Experience obtained with different aggregate sizes and varying the spread rates of aggregate has 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, allowing enough overlap to ensure 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.

On the same 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 with a binder application rate of 2.5 ℓ/m^2. The AADT at time of construction in 2004 was 3250 vpd with 15% heavy vehicles. This single seal section only lasted approximately 3 years after which crocodile cracking and pumping once again started to appear and after 5 years, the road had failed structurally and functionally and this road was due for heavy rehabilitation.

5. Background to the Treatment Performance Capacity

Sousa and Way [3] have estimated, in a rational manner, the pavement treatment life and presented the development of the Treatment Performance Capacity (TPC). This concept will be applied to demonstrate the effectiveness of the double seal treatment on badly deteriorated roads, as presented above.

In the development of the TPC, it was accepted that pavement preservation is considered non-structural treatment and surface treatments should only be used on pavements with low deflection values and low levels of distress. If high deflections (beyond a certain limit for the category of road) are present, rehabilitation of the pavement will be needed. There is also a maximum cracking threshold before a certain treatment is applied. For pavement preservation, it is suggested that a maximum value of 5% cracking be used as the limit for applying pavement preservation treatments. If the pavement is in poor condition, it may have structural problems, thus pavement preservation should not be used as an option in such situations. Preventive maintenance treatments are not cost effective in the late cycle of pavement life [3]. When determining extended life benefits, it has been shown that placing some pavement preservation treatments on pavements in poor condition is not cost effective [3]. In the presentation of the case studies it is evident that the roads were in far more deteriorated condition than envisaged by Sousa and Way [3].

Sousa and Way [3] developed a conceptual measure of treatment effectiveness called the Treatment Performance Capacity (TPC) which is defined as follows:

$$TPC = BC \times SE \times T \qquad [1]$$

where: TPC = Treatment Performance Capacity;

BC = Binder Content per unit area (litres/m^2);

SE = Strain Energy at failure ratio. Ratio of connventional bitumen:polymer binder: bitumen-rubber is 1:1.5:5;

T = Thickness of treatment (mm).

Obviously a fog seal with a regular emulsion will have a much smaller number in terms of TPC than a chip seal simply because it has less binder. Also a bitumen-rubber treatment will show a better capacity number (even if with the same binder content) because it has a higher strain energy at failure than regular binder. The concept that this index is aimed at capturing is simple: more binder is better; better binder is also better; but this factor may be compounded or confounded (possible bleeding or flushing and low skid resistance value) with more binder which also promotes slower aging. A treatment with a large TPC value, when placed under heavy traffic over a badly cracked pavement will have its performance capacity consumed, “drained”, faster compared to when it is placed over a low traffic non-cracked pavement. Obviously a treatment with a low TPC value will have its performance capacity consumed even faster under the same scenarios. The TPC is inherent to each treatment. How long it takes to “consume” that capacity depends on the cracking condition, type and strength of base, traffic and climate where the treatment is applied.

6. Application of the TPC concept to the case studies

The salient features of the case studies for use in the TPC calculations are shown in Table 3. The thickness was estimated from the stone ALD and spread rates. Only the single surface treatment had reached the end of its life. Consequently an estimate was made by experienced engineers regarding the remaining life. It was accepted that if the defects were less than 5%, then the remaining life would be a further 8 years, and for 10 to 15% defects the remaining life would be 5 years.

Table 3. *Determination of TPC for the projects*

Project	Surf	Binder	Thickness (mm)	Applic'n (litre/m^2)	TPC	Life (years)
Case 1: K175	DST	B-R	17	5.1	434	6 + 8
Case 2: P84-1	DST	B-R	16	5.1	408	10 + 8
Case 3: Thabo M	DST	B-R	15	5.1	383	11 + 5
Case 4: P101-1	DST	B-R	15	5.0	375	12 + 4
Case 5: P5-1	DST	B–R	17	5.0	425	11 + 8
	SST	B-R	9	2.5	113	5

In the case studies there was a limited range of binder application rates, as there was medium traffic typically of about 3000 vpd. For illustration purposes several plots will be developed to demonstrate the results. Figure 2 shows the life of the single and double seals in terms of TPC. A logarithmic trend line was added as Sousa and Way [3] found that this model form adequately predicted performance.

Referring to Figure 2 it is evident that the life of the double seal is significantly longer than that of the single seal. Furthermore, TPC is not a unique determinant of life; if the single seal had been constructed with a TPC of 400 (which is impossible as there would be too much binder), it would not achieve the same life as that of the double seal.

For comparison with published information, such as Sousa and Way [3], it should be appreciated that the roads that were treated were identified for rehabilitation, but because of lack of funding, the bitumen-rubber seals were placed as a temporary measure. The road condition prior to resealing was severely cracked and distressed, with high deflections. Nevertheless, the life of the double seal is significantly higher than reported in [3], where the estimated life for a light traffic category was most 12 years for a TPC of 800. This aspect will also be addressed below.

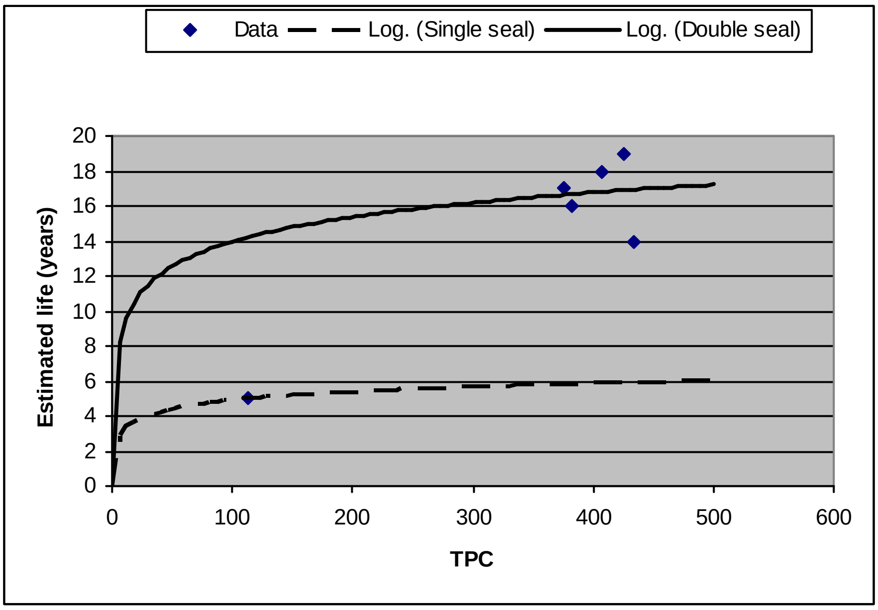

Figure 2. *TPC and associated life for ADT of about 3000 vpd*

In South Africa heavy vehicles are converted to equivalent light vehicles by multiplying the number of heavy vehicles by 40 [9], or if the vehicles are heavily laden/overloaded by 60 for seal design. Not only heavy vehicles play a role in the performance of seals, but light vehicles do too, unlike in the AASHTO structural performance where light vehicles have minimal impact. Figure 3 shows the equivalent light vehicles during the estimated life of a road. The single point at a TPC of about 100 is the single seal. For the double seal the data shows a trend of reducing life with increasing TPC. This is in line with the design procedures. Environmental influences reflected by time, and traffic simultaneously play a role. More binder can be added for lower traffic, hence a higher TPC. For higher traffic the TPC is lower, but the influence of traffic is not as severe as the influence of time.

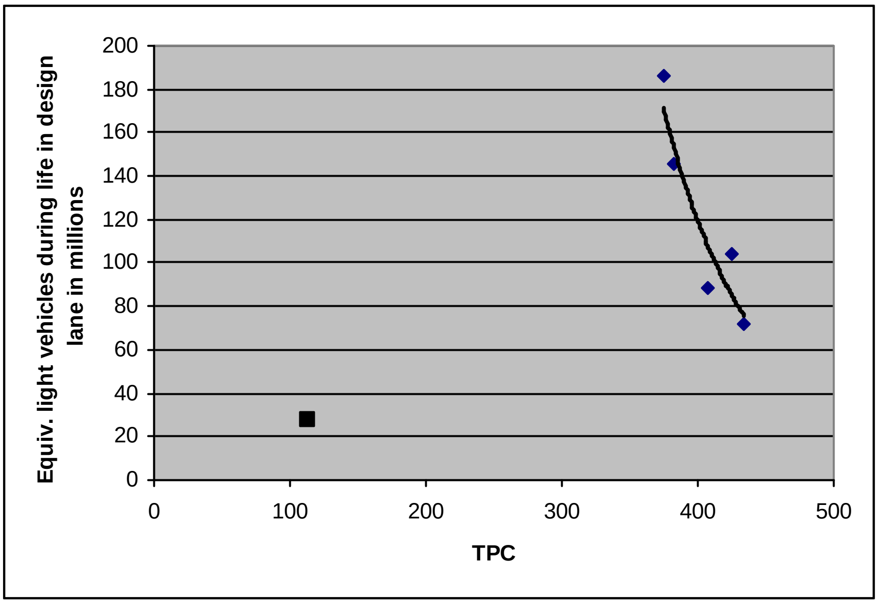

Figure 3. *TPC and associated equivalent light vehicles in the design lane during life*

For a direct comparison with the information provided by Sousa and Way [3], the traffic data was converted to the Caltrans Traffic Index (TI). The TI is calculated from the standard AASHTO 80 kN equivalent single axle loads (ESALs or E80) during the life in the design lane by Equation 2.

$$TI = 9.0 \times \left(\frac{ESALs}{10^6} \right)^{0.119} \qquad [2]$$

No direct axle mass load information was available on the case study projects. Hence an estimate was made of the E80s per heavy vehicle, knowing the types of vehicles that were operating on the roads. Figure 4 shows the data for the case study sections. Since the TI is a logarithmic function, it does not show sensitivity towards the TPC. All the projects had a TI between about 10 and 12, whereas the TPC ranged from about 100 to 400. In the data for the Coastal and Valley regions provided by Sousa and Way [3] the life for a TI between of 8 and 12 on a poor original cracking condition is a maximum of 6 years. This issue will be discussed below.

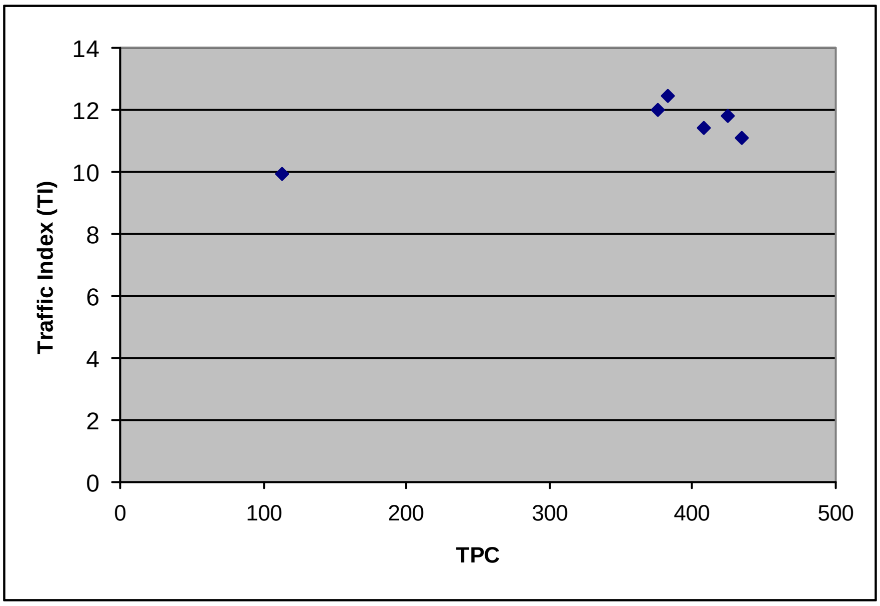

Figure 4. *TPC related to the Caltrans Traffic Index*

7. Discussion of the TPC concept applied to the case studies

The outstanding performance of the 19/9.5 mm double seal is one of the highlights of the information presented. The estimated life of more than 15 years is far beyond that which has been reported elsewhere, and the TPC concept does not normalize the data. The roads were also severely distressed and would normally not have received a surface treatment. Part of the solution is the very high bitumen-rubber application rates; even much more than the design codes [9] used at the time. Another part of the solution is that a bitumen-rubber seal is highly effective in sealing the cracked pavement. The very high first application ensures that there are no voids. Under the action of truck tyres high water pressures are generated during heavy rainfall and this water could be forced into the pavement through voids. Lastly, it was found that there must be good compatibility between the bitumen and the rubber crumbs. Earlier unpublished work had shown significant failures of bitumen-rubber seals because of problems with the binder. An engineering solution which was readily applied consisted of identifying a specific refinery, and the bitumen produced had to have a penetration of 80 ± 6. Although there is much criticism of the engineering validity of the penetration test, it was able to encompass the variability of the chemical constituents. Bitumen-rubber produced in this manner was used in the case studies.

The TPC concept, although conceptually sound, is not directly transferable to different environments. For example, a TPC of 400 does not necessarily determine the life of the treatment. TPC may have to be stratified in terms of surfacing type, pavement layer composition and resultant deflections, climate and traffic. Conversion of the traffic to equivalent light vehicles relates well to the TPC for explaining performance of bitumen-rubber seals. It also assists in identifying the maximum binder application rates to prevent bleeding.

8. Conclusions and recommendations

The case studies have demonstrated the effective lives of bitumen-rubber double seal treatments. These are much longer than envisaged at the construction stage. The lives are also much longer than presented in the literature, even when comparing a statistic such as the Treatment Performance Capacity (TPC). The TPC was not able to explain the difference in performance, and it is recommended that further validation be performed of the TPC across a range of environments.

It is hypothesized that the exceptional performance is attributable to the high binder application rates which are higher than the design codes of the time suggested, a high first spray ensuring that no voids are present to permit stripping, and special care in ensuring bitumen and rubber compatibility.

It is recommended that tests be conducted to determine the strain energy of the specially formulated bitumen-rubber as well as other run-of-the-mill binders to determine the reasons for the superior performance, as this is a common factor in the TPC calculations for which a value is assumed.

9. Bibliography

[1] Jooste, NJJ, 2011. A consultant's perspective on the use of bitumen-rubber in especially double seals. Proc. 30th Southern African Transport Conference, Pretoria, South Africa, 11 to 14 July.

[2] Potgieter, CJ and Visser, AT, 2003. Bitumen-rubber chip seals as used in South Africa. Proc. Asphalt Rubber 2003, Brasilia, Brazil.

[3] Sousa, JB and Way, GB, 2011. Treatment Performance Capacity – Concept Validation. Proc. 30th Southern African Transport Conference, Pretoria, South Africa, 11 to 14 July.

[4] Committee of Land Transport Officials COLTO, Standard Specifications for Road and Bridgeworks for State Authorities, 1998 Edition, South African Institution of Civil Engineering (SAICE).

[5] Technical Guideline TG1, 2007 -The use of Modified binders in road construction, second addition, Asphalt Academy (AsAc).

[6] Potgieter C.J. and Van Zyl G.D., 1992, Performance Audit of Arm-R-Shield Bitumen-rubber, Phase III – Part II, March, CSIR report – DPVT/C 192.3b.

[7] Jooste N.J.J, Judd D., Hattingh J., Sadler D. and Muller J., 2008. The use and performance of bitumen-rubber in spray seals in RSA, 1st International Spray Sealing Conference, Adelaide Australia.

[8] Jooste N.J.J., van Zyl G.D., 2010. The use and performance of bitumen-rubber in spray seals for holding actions in RSA, 2nd International Spray Sealing Conference, Adelaide Australia.

[9] Technical Recommendation for Highways TRH3:1997 Design and Construction of Surfacing Seal. Committee for State Road Authorities, Pretoria.