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TOWARDS IMPROVED UNDERSTANDING OF SEAL PERFORMANCE

GD van Zyl, A van der Gryp

Mycube Asset Management Systems, 52 Gazania Street, Welgemoed, Cape Town, 7530

Department of Transport and Public Works, Western Cape Provincial Administration, P.O. Box 2603, Cape Town, 8000

Abstract

The South Africa National Roads Agency (SANRAL) initiated a major research study on the performance of thin bituminous surfacings as part of the new drive towards a more appropriate pavement design process. One goal within the total framework of the study is to minimise cost by utilising information available from properly maintained pavement management systems. As part of a Long Term Pavement Performance monitoring program the Provincial Administration of the Western Cape annually assesses 510 road sections for calibration of HDM models. Analysis of this data set provided information for discussion in this paper. Following a short background to thin bituminous surfacings, the paper discusses the main risks of surfacing failure during its life and then focuses on the performance of surfacings as a result of binder hardening and the impact thereof.

1 INTRODUCTION

Road pavements are typically designed for a period of twenty years, assuming that regular routine maintenance and periodic maintenance in the form of regular reseal work, will be carried out. Even though it is acknowledged and reported internationally that the average effective life of sprayed seals is in the order of ten years and that neglecting timeous reseal work will result in rehabilitation at approximately ten times the cost of a reseal, it appears as if the performance of bituminous surfacings and their impact on pavement performance are not properly taken into account during design stages as well as for purposes of proper asset management.

The South Africa National Roads Agency (SANRAL) identified this shortcoming and initiated a major research study on the performance of thin bituminous surfacings as part of the new drive towards a more appropriate pavement design process.

One goal within the total framework of the study is to minimise cost by utilising information available from properly maintained pavement management systems. In this regard valuable information was obtained from the Roads Branch of Western Cape Provincial Government.

The Provincial Administration of the Western Cape initiated a Long Term Pavement Performance monitoring program in 1996, comprising in total 51 road sections, each further divided into twenty 50 m segments. One of the main purposes of regular assessment is to obtain appropriate data for calibration of the HDM models and data conversion from the TMH9 visual assessments to HDM format.

These road sections represent different pavement structures, climatic environments, traffic situations and bituminous surfacing types. Apart from regular mechanical measurements, visual assessments are carried out annually according to both HDM4 requirements and the TMH9 methodology.

Initial evaluation of the available data indicates that the binders in seals indeed hardens over a period of approximately ten years, where after crocodile pattern cracking starts to occur.

The purpose of this paper is share information regarding seal performance as obtained from the initial data analysis as well as to highlight how this information will be utilised in the total study .

This paper provides a short background to thin bituminous surfacings used in southern Africa, discusses the main risks of failure during its life and then focuses on the performance of surfacings as a result of binder hardening and the impact thereof.

2 BITUMINOUS SURFACINGS AND PURPOSE

2.1 Purpose

The main purpose of a bitumen surfacing in southern Africa is to:

- Protect the base from moisture ingress
- Protect the base from traffic wear and
- Provide all weather skid resistance

2.2 Surfacing types

Bituminous surfacing types, for purposes of this paper, is divided into asphalt overlays and surface dressings as shown in Figure 1.

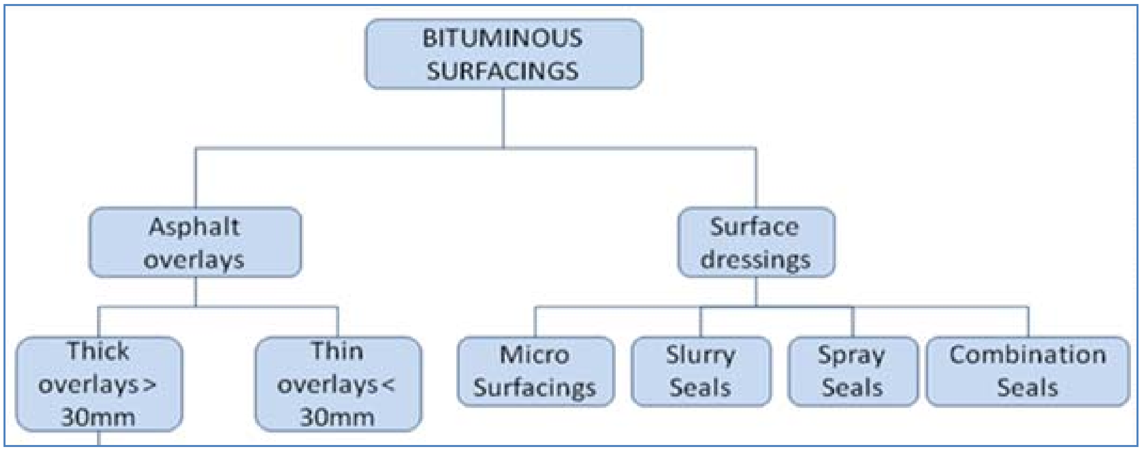

Figure 1 Bituminous surfacing types

More than 80% of the surfaced road network in southern Africa is currently covered with sprayed seals and combination seals e.g. Cape seal

3 PERFORMANCE OF SURFACE DRESSINGS

3.1 General experience and observations

Based on observations and feedback from practitioners, the performance of surface dressings could be divided into three phases namely:

- Phase 1 - Initial stage (Typically within a year after construction)
- Phase 2 - Stable phase
- Phase 3 - Brittle phase

The risk of, and expected type of failure during the three phases, is different for different surfacing types.

The most common defects/failures on surface dressings assessed for pavement management systems in southern Africa are:

- Hardening/ Oxidation
- Aggregate loss
- Surfacing Cracking

- Surfacing failures (delamination)
- Loss of texture (skid resistance) due to
  - Embedment (bleeding/ fattiness)
  - Aggregate wear and polishing

3.2 Hardening and oxidation

Bituminous binder ages with time, the rate being dependent on temperature and exposure to the atmosphere, which is often influenced by the thickness of the surfacing (Oliver).

Visual assessment methods in southern Africa, independently developed since the late 1970s, incorporated the "Dry/Brittleness" of the binder in a seal as a standard defect (TMH9, Namibia)

Evaluating the hardening of the bituminous binder (Dry/brittleness according to TMH9) and development of fatigue cracking (Surfacing cracks and crocodile cracking) produced some interesting findings, which could be summarised as follows:

- Even though concerns have been raised regarding the subjective assessment of binder condition within a bituminous surfacing, evaluation of the data set indicated that the assessment of hardening/ oxidation of the binder show definite trends. The data as recorded for four sections are displayed in Figure 2.

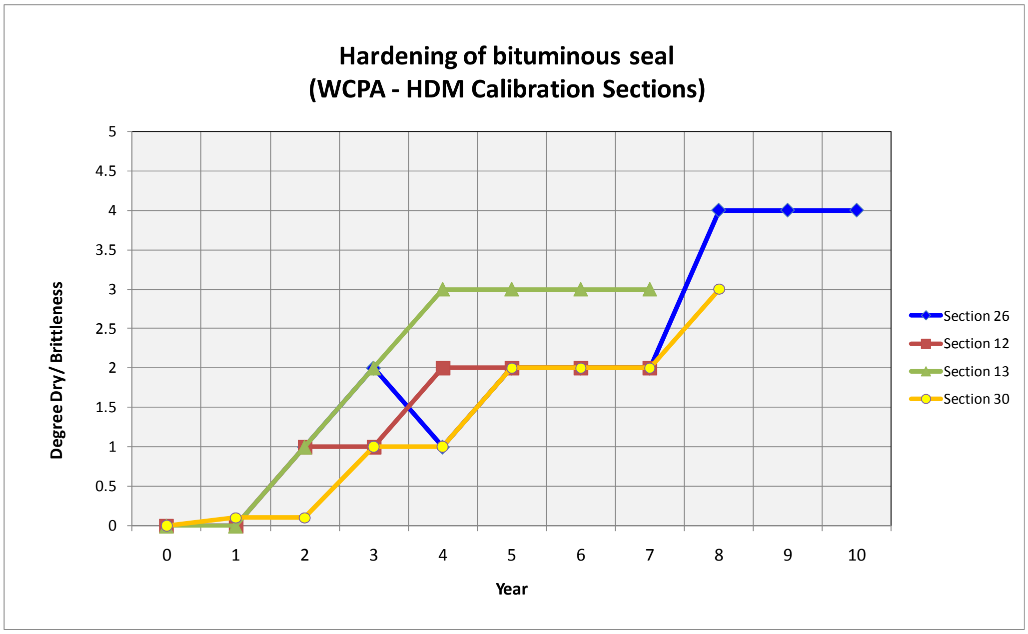

Figure 2 Increase in Degree of "Dry/ Brittleness"

- Seal ages before a dry/brittleness of degree 3 is recorded are, amongst other factors, dependent on the seal type (Aggregate size) as shown in Figure 3:

- o T7 (6.7 mm single seal) with conventional binder = 5-7 years
- o T9 (9.5 mm single seal) with conventional binder = approximately 8 years
- o T13 (13.2 mm single seal) with conventional binder = 9-11 years

Notes:

- Each linear trend line represents the average of 20 road segments
- The larger the aggregate size, the higher the binder application

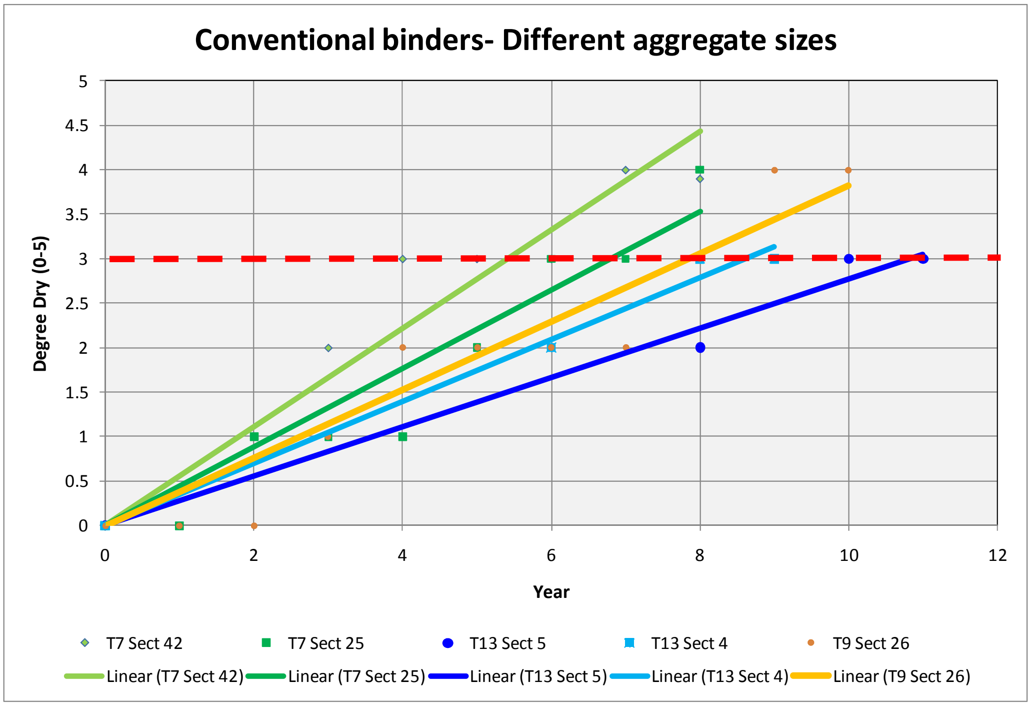

Figure 3 Ageing as a function of aggregate size

- There appears to be a definite difference in the ageing characteristics between different types of modified binder seals e.g. average time to Degree 3 dry/ brittleness being recorded:
  - o L13 (13,2 mm with Homogeneous polymer modified cold binder) = 6-7 years
  - o M13 (13,2 mm with Homogeneous polymer modified hot binder) = 8-9 years
  - o R13 (13,2 mm with Non-Homogeneous polymer modified hot binder) = 11-12 years

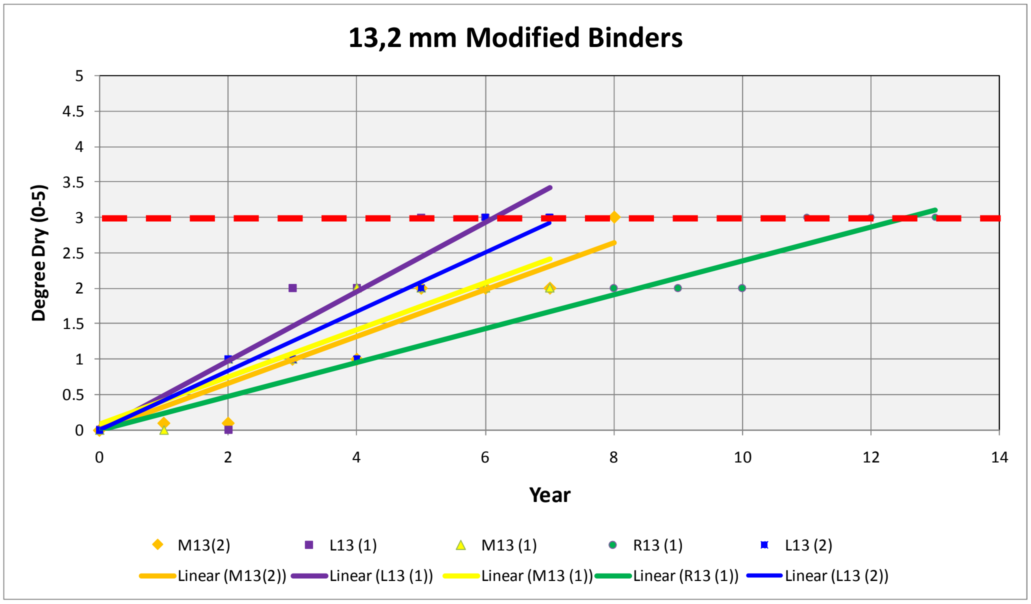

Figure 4 Ageing of modified binder seals

- Application of rejuvenators or diluted emulsions has a positive effect on the dry/ brittleness of the binder. All cases evaluated show an extended life of three to four years before the dry/brittleness is again rated as “Degree 3”

3.3 IMPACT OF BINDER HARDENING ON THE PERFORMANCE OF SEALS

The oxidation/hardening of bituminous binders has both negative and positive effects on the performance of the seal. The perceived effects are discussed under the following headings namely:

- Impact on fatigue crack development
- Impact on embedment potential
- Impact on aggregate loss

3.3.1 Impact on fatigue crack development

TMH9 describes surfacing cracking as cracking only occurring in the bituminous surfacing as a result of shrinkage of the binder. Although there are several arguments against the stated mechanism of crack forming, observations over more than thirty years have resulted in this defect being incorporated into the standard visual assessment methodology. The development and progression (TMH9) are as follows:

- Fine star pattern cracking firstly appear on the non/low-trafficked areas such as on the surfaced shoulders or in-between the wheel tracks or, in the case of very low volume roads, over the full surfaced area.
- Cracking then progresses into a typical crocodile skin pattern.

Photograph 1 Surfacing cracking

An alternative mechanism, which currently receives more support is as follows:

- Oxidation and hardening of the bituminous binder occur (Fact)
- Possible vertical moisture ingress through a more permeable seal, which could result in softening of any granular base
- The bituminous surfacing stiffens, with time, to such an extent that it becomes sensitive to even slight deflections
- Hardening of the binder in the wheel tracks is slower as a result of the kneading action of tyres
- Fatigue of this stiff layer occurs, resulting in a typical fatigue crack pattern

Evaluation of the WCPA data set indicates the following

- Even on roads, which are considered to be structurally sound and without rut deformation, crocodile pattern cracking is typically observed on the road surface soon after the binder condition is rated as a Degree 3 – Typically within a year. Figure 5 shows the hardening of the binder on three road sections and the first signs of fatigue/crocodile pattern cracking.

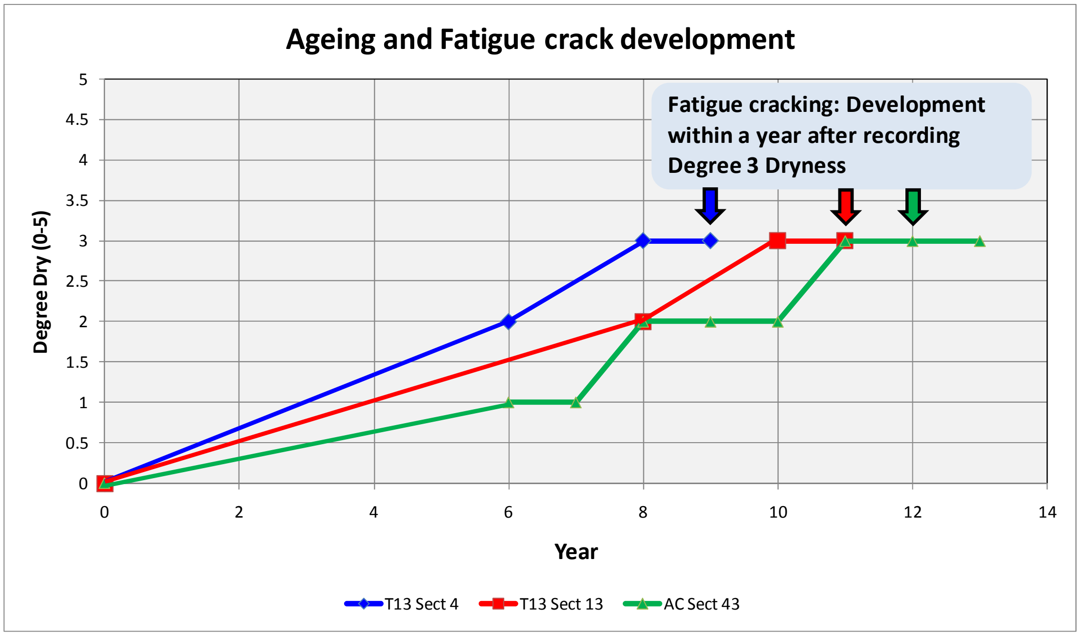

Figure 5 Fatigue crack development as a function of binder ageing

Even though the sample size is small, the trend results tie in with the experience of personnel of the Roads Branch, and to a large extent with performance models already incorporated into the WCPA Pavement Management System (Van der Gryp Henderson and van Zyl, 2010).

Based on the average life of bituminous seals from experience in South Africa, Australia and recently reported in New Zeeland (Towler et al), being in the order of nine to ten years, a huge backlog in reseal work has developed in southern Africa.

Information has been obtained from three road authorities in southern Africa regarding the age of bituminous surfacings on proclaimed rural roads within their jurisdiction.

As shown in Figure 6, Figure 7 and Figure 8 the percentage of seal ages more than ten years on each surfaced road network are as follows:

- Road Authority A = 61%
- Road Authority B = 43%
- Road Authority C = 80%

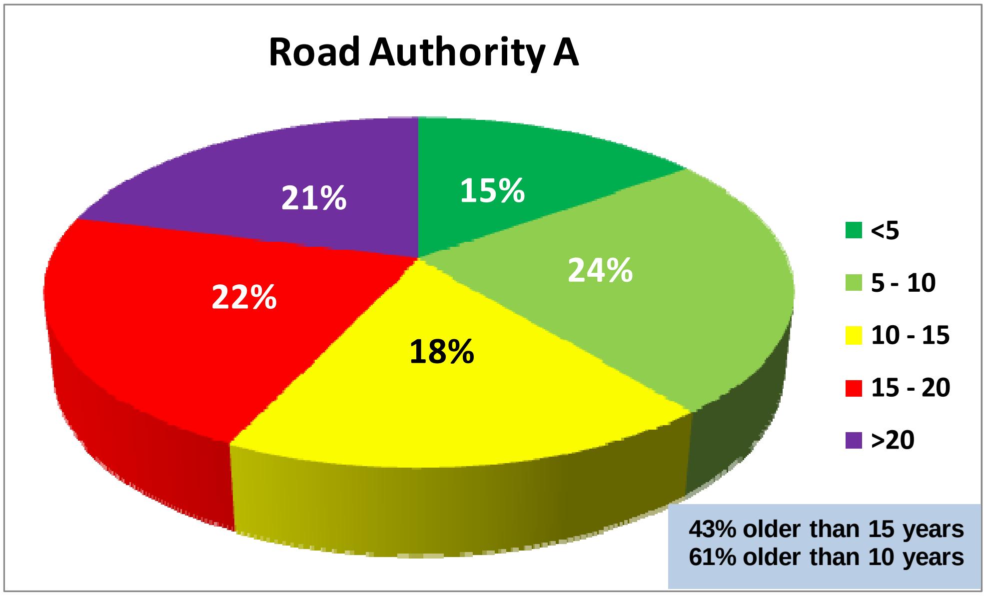

Figure 6 Last seal age per category (Road Authority A)

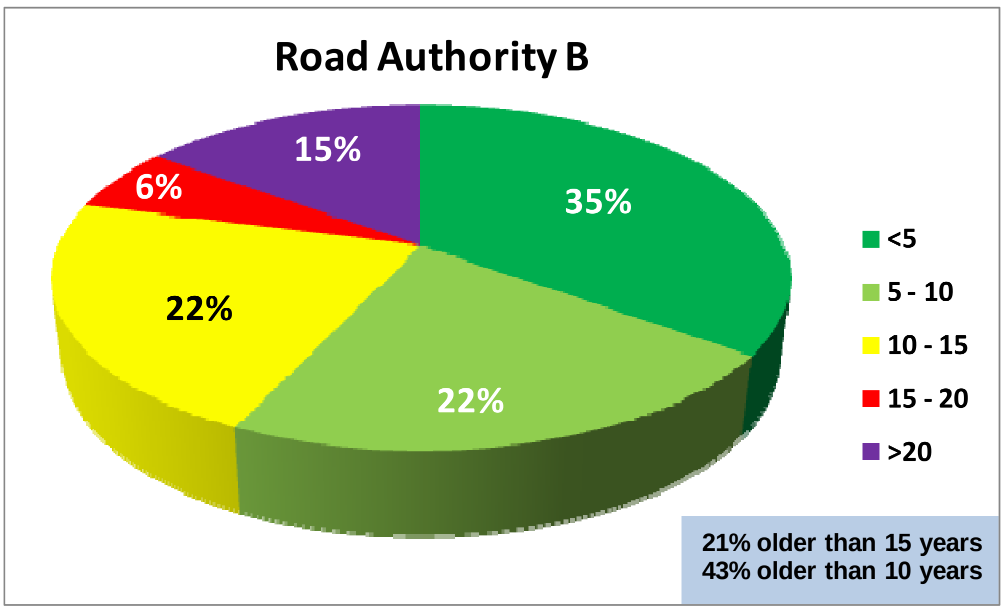

Figure 7 Last seal age per category (Road Authority B)

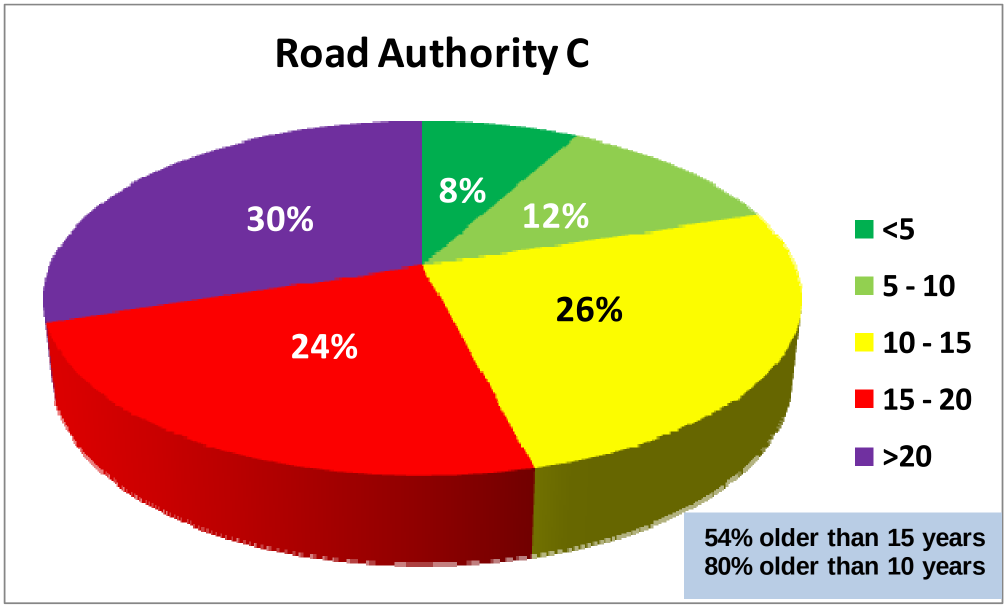

Figure 8 Last seal age per category (Road Authority C)

3.3.2 Impact on Embedment/ Flushing/Bleeding

Results from this study indicate that the degree of fattiness tend to stabilise within two years. However, it is acknowledged that the traffic volumes on these road sections are generally low and that the sample size is too small draw proper conclusions.

Embedment occurs as a result of the vertical force on individual stones within the seal matrix. The rate and degree of embedment is a function of the stiffness of the underlying layer, the load on individual stones, the stiffness of the binder and the friction between aggregate particles.

One of the positive effects of binder oxidation/ hardening is that the seal, with time starts to act as a layer to distribute the load. The effect on individual stones and the embedment potential, therefore, reduces as the binder hardens.

The risk of bleeding during the life of the surfacing due to embedment, is explained in Figure 9.

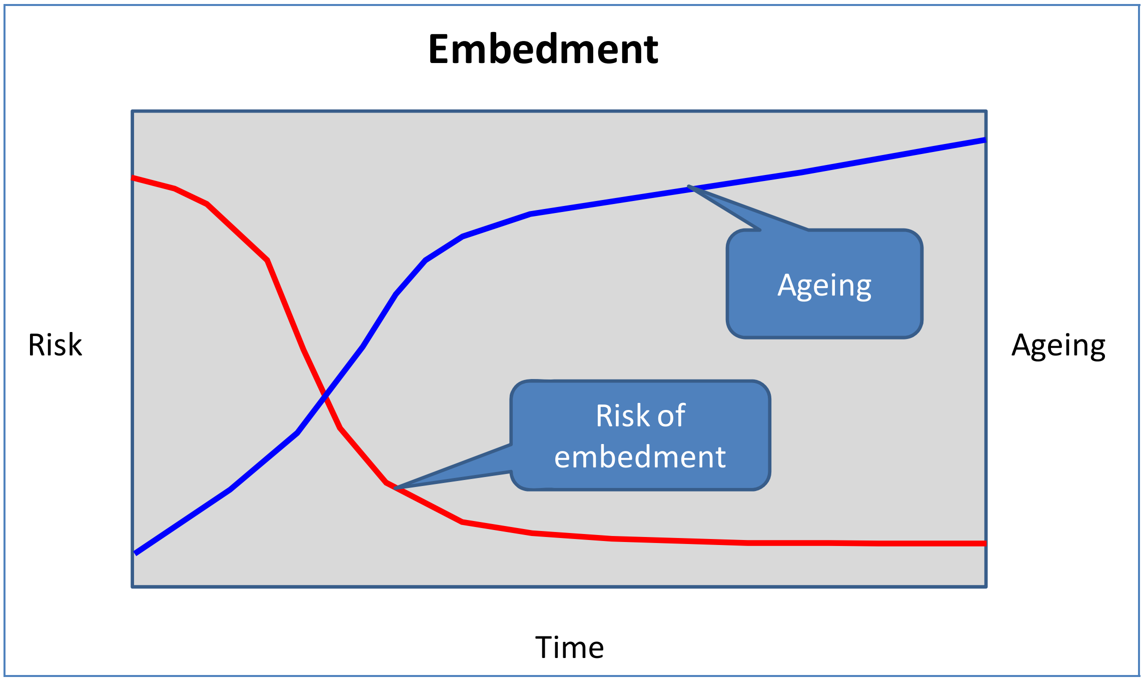

Figure 9 Risk of embedment with time

Note:
The loss of voids in the aggregate matrix for design purposes (TRH3), is estimated from ball penetration testing (TMH6) and the expected traffic volume. Dramatic increases in heavy vehicle loads and tyre pressures have taken place since the related studies (Marais,) and urgently requires update.
Modelling should include:

- Aggregate size and shape in contact with the sub-straight
- Inter-particle friction (aggregate properties) and geometry of the seal
- Stiffness of the binder
- Load and tyre pressure variation

3.3.3 Impact on load distribution and pavement structural capacity

Historically the contribution of a surfacing seal to the structural capacity of the pavement was considered to be insignificant. Where it was accepted that an asphalt layer would distribute the load and add to the structural capacity, it was assumed that, in the case of a seal, the load is directly transferred from the wheel to the base.

Taking into account the geometry of different seal types and the ageing of the binder, the hypothesis is that the seal, apart form reducing moisture ingress, could certainly contribute to the structural capacity of the pavement. The degree is determined by the degree of binder ageing and the friction between the aggregate particles.

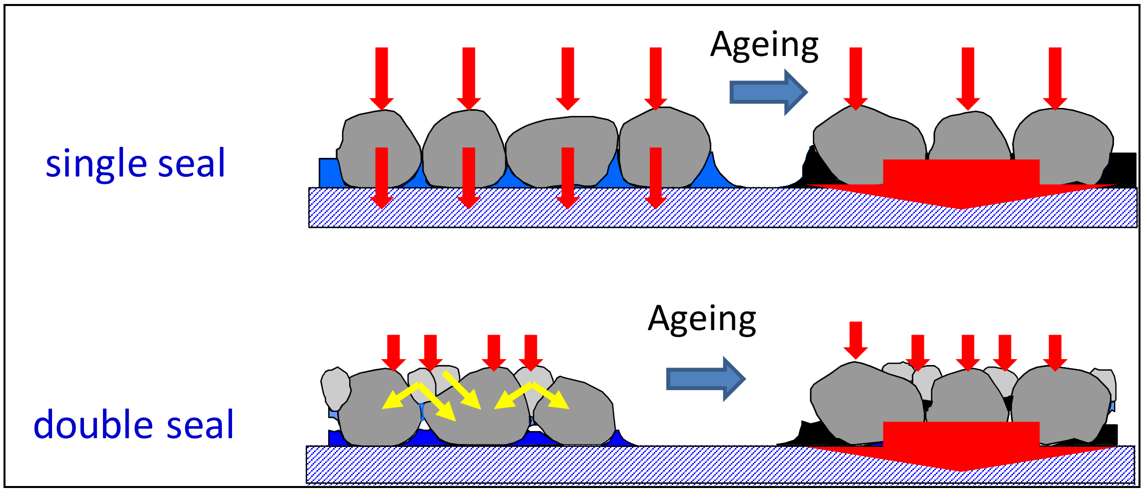

Figure 10 Effect of ageing on load distribution

The concept is explained in Figure 11. Initially the load on the single seal is directly transferred to the underlying layer. With ageing of the binder, the seal act start to act as a layer. The contribution to the structural capacity drastically reduces when fatigue of the layer results in cracking.

In the case of the double seal, the friction between aggregate particles already adds to the strength of the seal. The binder also ages with time, resulting in increase of the layer stiffness. In case of the bitumen rubber binder, the rate of ageing is much slower and time to fatigue much longer.

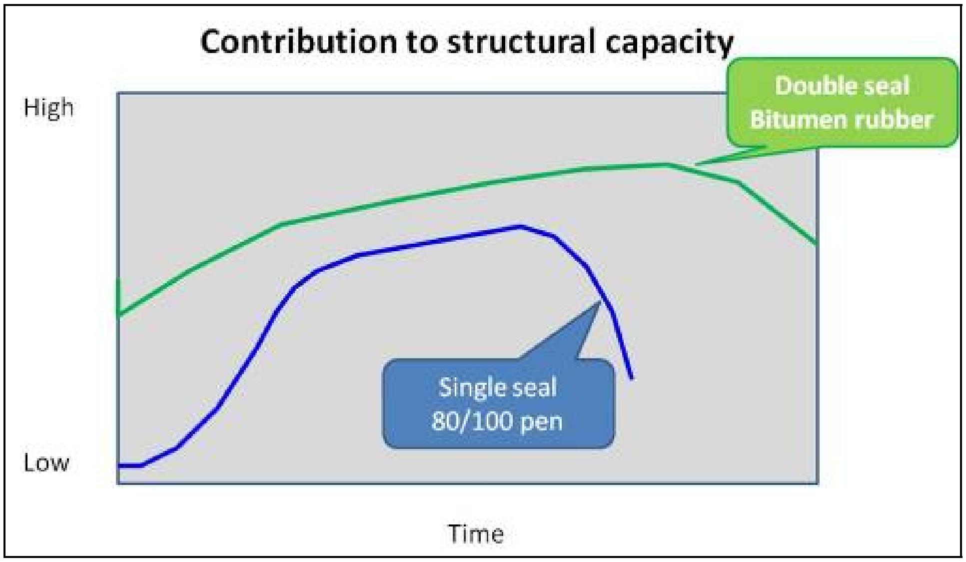

Figure 11 Seal contribution to pavement structural capacity

Note: The concept will be evaluated by testing the stiffness and fatigue characteristics of different seal types at different ages

3.3.4 Impact on aggregate loss

Aggregate loss is dependent on the adhesion between the bituminous binder and the aggregate, the cohesion within the bituminous binder and the horizontal forces applied by the traffic on the seal.

The risk of general aggregate loss, as shown in Figure 12 for spray seals, is highest just after construction and decreases with time with most aggregates found in southern Africa. Seal deterioration due to aggregate loss, as evaluated from the available data, is almost insignificant.

However, it is acknowledged that seals constructed with specific aggregates such as certain quartzites and granites, do show an increase in risk of aggregate loss with time, probably due to ageing of the binder and poor bond strength.

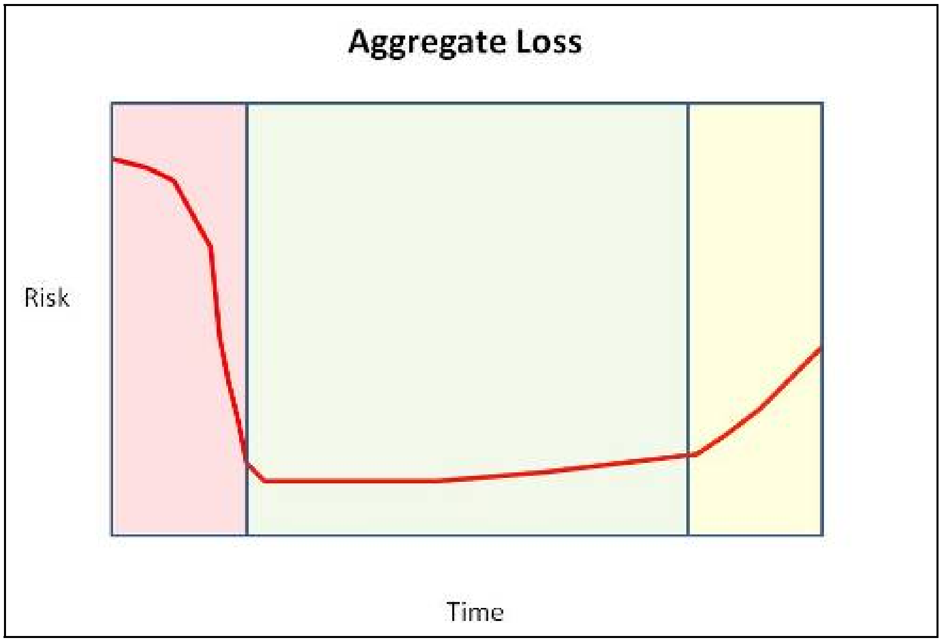

Figure 12 Risk of aggregate loss (Spray seals)

Loss of aggregate soon after construction mainly occurs a result of low bond strength, aggravated by low temperatures and/or moisture (rain), influencing the adhesion and/or cohesion. Experience in South Africa indicates that, once the seal has “settled” (increase of surface contact area and binder cohesion development) the risk of aggregate loss is generally low. Situations vary, but severe aggregate loss (stripping) seldom occurs after the first winter.

4 SUMMARY AND CONCLUSIONS

During the early life of the seal, the binder is soft and pliable, accommodating slight movements/deflections in the pavement structure. Therefore, it initially provides, dependent on the geometry (seal structure), low additional strength to the pavement structure but high resistance to vertical moisture ingress. With time the binder hardens through oxidation with increase in stiffness and more contribution to the structural strength of the pavement. Towards the end of the surfacing life it is assumed to become more permeable and so stiff that fatigue failure, occurs due to even slight deflections, resulting in cracking, delamination (surfacing failures), water ingress into the pavement layers and potholing.

The stiffness of the seal and sensitivity to fatigue is believed to be a function of the binder type, age, temperature and film thickness.

The initial study on seal performance, based on the annual visual assessment (1996 – 2009) of approximately a thousand road segments, showed some definite trends in terms of binder hardening and fatigue crack development and tied in with international experience that bituminous surfacings should not be allowed to age beyond ten years. In this regard, information obtained from three major road authorities in southern Africa, indicates a huge backlog in reseal work in the region.

Although the sample is still relatively small in terms of different aggregate types, it confirmed the general engineering opinion that the risk of aggregate loss and bleeding reduces dramatically after the first year.

The study will continue through sampling of different seal types (including binders) from different age groups and climatic environments, testing of permeability, stiffness development and fatigue characteristics to provide information that could be used for component modelling.

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KEY WORDS

Seal performance, binder hardening, impact on pavement structural capacity