Experiments with Preventative Maintenance on Low Volume Surfaced Roads.

L Tsanwani, N Rasimphi, M Gangashe, S Jordan, S Mapukata, I Nduku, B Makhunga and N Dywili

South African National Roads Agency SOC Ltd (SANRAL): Southern Region

Abstract— Cost effective measures of certain projects requires innovative strategies as alternative preventative maintenance of low volume surfaced roads. The road identified for experimental of innovative strategies preventative maintenance was R58 section 1 and 2 in the Eastern Cape. Traffic of not more than 100 ADT required a different method of preserving the road asset. Due to no maintenance the binder had aged with narrow road width resulting in rutting along the wheel path. Cost effective maintenance methods had to be considered for such low volume road by using alternative strategies to preserve the road asset. Alternative strategies implemented included surface rejuvenation of fine cracked, dry and brittle seal surface using anionic emulsion fog spray and cutback bitumen to penetrate the surface seal and assist in closing up cracks prior to patching. Low cost repair options included a combination of seven different repair methods alternative to standard design practices to use on sections of the road where they were thought to be best suited. The predominant repair method implemented was an application of *Ralumac rut fill slurry* as an alternative to base patches and it was more cost effective considering the amount of traffic carried by the road and the age of the pavement. Post construction monitoring is showing successful outcomes and proved that the applied strategies are performing well with a lot of lessons learnt. Route R58 has set a benchmark for further implementation and development of alternative preventative maintenance strategies to maintain low volume road while preserving our road assets in a more cost-effective manner.

Keywords—preservation; low cost strategies; preventative maintenance, innovative strategies

I. INTRODUCTION

Fast growing population and road infrastructure demands have increased in the past decades for developing countries such as South Africa. Maintenance of such road infrastructure plays a major role in the country's economic growth and accessibility. Due to constrains in the country's economy with limited budget to maintain roads infrastructures to the required standard. Cost effective preventative maintenance on low volume roads need to be considered. This often result in priority been given to major road networks which connects big cities while neglecting intermediate and minor road networks that connect farmlands and rural settlements until they are extensively deteriorated. SANRAL as an asset preservation agency ensures its surfaced road networks are maintained every 7-10 years through its service life to achieve its design life expectancy before rehabilitation stage is reached. Conventional methods of maintenance have been largely used to maintain road networks and remain costly due to constant increase in material prices and plant, however certain low volume surfaced roads can considerably maintained using alternative strategies which are cost effective.

The road identified to trial alternative preventative maintenance methods was R58 between Norvalspont and Burgersdorp in the Eastern Cape with an ADT of less than 100 ADT. Such low volume roads required different methods of preserving the road asset that are more cost effective and efficient. Due to lack of maintenance on the road, the binder had aged and became dry and brittle. Narrow road width resulted in extensive rutting along inner and outer wheel paths as well as extensive surface edge breaks.

The normal remedial measures would have been fog spray, rut fill, gravel shoulder repairs, base and surface patch followed by resurfacing. Innovative road maintenance methods had to be considered for such low volume road by using alternative strategies to preserve the road asset. Innovative strategies implemented included surface rejuvenation of fine cracked, dry and brittle seal sections using diluted anionic emulsion fog spray and cutback bitumen to penetrate the seal and assist in closing up cracks. Seven different combinations were adopted as an alternative to standard design practices to use on the different sections of the R58 road. The predominant repair method implemented was an application of *Ralumac rut fill slurry* to address exhibited rutting considering the amount of traffic on the road and the age of the pavement. Other methods of repairs included crack sealing using geotextile seals, and base patches using Emulsion Treated Base (ETB). The road then received different thin surfacing seal combinations of 4.75mm grit seal, 10 mm single seal and 10/4.75 mm double Grit seal using MC3000 cutback binder and SC-E1 Modified emulsion (10/4.75mm seal).

II. RESEARCH OBJECTIVES

The objective of this research is to look at how we can implement and develop strategies to maintain low traffic volume roads while preserving our road asset in a more cost-effective manner. The experimental section was used to trial different combination of innovate repair options with the following objectives:

1. Discover innovative strategies that are economically friendly without compromising on quality and performance expectancy of the road network.
2. Cost effective measurers that allows one to manage the risk while balancing what is necessary and what is required for that particular maintenance strategy.
3. To establish low cost innovative strategies for road surface maintenance.
4. Observe performance of various products that can be useful for many newer entrants into the industry.

This research aims to look at how risks associated with the use of alternative road surface maintenance strategies and how they can be mitigated. This paper also provides a feedback on the experimental project that was done on route R58 using more cost-effective methods of road surface maintenance.

III. DESIGN FACTORS

Risk matrix and risk management adopted for this project converged standard design practice as to manage risk. Standard design procedure for conventional methods of repairs were followed, whilst considering best suitable alternative repair strategies that are cost effective. After comparing the cost estimates for conventional preventative road surface maintenance, a decision was made considering the traffic volume of the road section to trial alternative maintenance strategies. The risk assessment included the following standards and analysis:

1. **Climatic Region:** The region experiences hot wet summers and dry cold winters. Daytime summer (December to February) temperatures average 31 °C, cooling to an average of 15 °C overnight. In winter (June to August), daytime temperatures average around 18 °C, dropping to an average of 1 °C during the night. The summer temperature extremes can reach as high as 41 °C, while the winter extremes can drop to sub-zero during the winter months (1).

   The region experiences vast fluctuation in temperatures which has a huge influence on binder oxidation resulted in the dryness and brittleness of the existing road pavement surface. The area's rainfall is in summer and most frequently to rain overnight and occasionally short periods of thunder storms with suspended water ponding on rut section which resulted in water ingress through reflective cracks on the road surface. The road falls under climatic region of the weinert N value ranges between <2 (wet) and 2-5 (Mod). The climatic conditions play a huge role, as it influences the selection of the appropriate binder to be utilised (1).

   The rainfall in this region averages 407mm per year and mainly follows a summer rainfall pattern. The rainy season starts in October and ends in April, with peak rainfalls in the months of December and March. The driest period occurs in the months of winter, from May to September

I. **Traffic Assessment:** Historic traffic growth remain essential and also form part of your risk assessment and risk matrix, accurate traffic volume plays a major role in decision making and selection of innovative and alternative methods of road surface maintenance. For our project the design traffic volume was not more than 100 ADT which allowed a deviation from conventional methods of maintenance, whilst implementing more cost-effective methods of maintenance (2).

II. **Topography and Geology:** The experimental road is constructed on a flat terrain with relative steep sections. The geometric design of the road should be taken into consideration when selecting the types of remedial actions and when deviating from conventional repair methods. (2) The geology of the larger surrounding area belongs to the Beaufort Group of the Tarkastad and Adelaide Supergroup. The road falls under climatic region of the weinert N value ranges between <2 (wet) and 2-5 (Mod) implying that chemical decomposition will be the main mode of weathering, because of the relatively high humidity and rainfall. In general this area is associated with mudstone and sandstone containing dolerite intrusions.

III. **Mechanical Survey**: The mechanical survey conducted during investigation included riding quality using international roughness index as the unit measure and rutting.

   Average IRI was measured on both left and right wheel paths. 80^{th} percentile of roughness over the section of the road was found to be sound. The rut measurements were taken on the left (outer) wheel path and showed some irregular measurements which corresponded to the measurements from the visual assessment. Some high spikes could however be attributed to edge breaks protruding into the road. 80^{th} percentile of the analysed rut data was falling mostly under sound and warning condition, with some severe subsections.

IV. **Intrusive Investigations:** Intrusive investigation conducted included test pitting and DCP (dynamic cone penetrometer) to determine the underlying layers properties and characteristics while classifying them in accordance to COLTO material classification for granular material and also to determine the bearing capacity of each individual layer. This included determining the layer thickness of each layer in accordance to the underlying layers horizons. Table 2-5 summarizes the results and material classification for each individual layer.

Table III-1: Summary of Material Properties

Layer	Material Properties	
	Section 1	Section 2
Base	70 - 220 mm (Avg. 140mm), G5 to G6 (With CBR's ranging from 51 to 156 at 98% compaction), Mudstone/Dolerite Crusher run	95 - 105 mm (Avg. 100mm), G5 (With CBR's ranging from 73 to 155 at 98% compaction), Grey Dolerite Crusher run
Subbase	210 - 450 mm (Avg. 285mm), G5 to G7, Coarse sand with Dolerite	140 - 200 mm (Avg. 185mm), G6, Coarse sand with Dolerite
Selected Layer	290 – 820 mm (Avg. 458mm), G5 to G8, Gravelly Sand	130 – 230 mm (Avg. 200mm), G6, Brown, Coarse dolerite gravel

IV. IV INITIAL VISUAL ASSESSMENT AND DEFECTS

The existing surface type was predominantly 9.5mm and 13.2mm seal for Sections 1 and 2 respectively, with only short lengths of the road having a 13.2/6.7mm double seal or a 19mm Cape seal.

In general, 6.7mm and 9.5mm section appeared to be very dry and brittle, with degree 2 and 3 crocodile cracks accompanied by light pumping in certain areas. The extent of crocodile cracking was severe and was a matter of concern. The surface texture was very coarse as a result of aggregate loss. Figure 3-1 and 3-2 shows typical surface distress noted.

Figure III-1: large extent of crocodile cracks

Figure III-2: Degree 2 and 3 crocodile cracks

Section with 13.2mm/6.7mm seal also exhibited dryness and brittleness, with extensive rough surface due to severe aggregate loss and longitudinal cracking along the centreline with localised transverse cracking as shown on figure 3-3 and 3-4.

Figure III-3: Slurry repairs aggregate loss

Figure III-4: Longitudinal Cracking

The 19mm cape seal section appeared to be also very dry and brittle with serve crocodile cracking of degree 4 to 5 with relatively smooth texture as shown on Figure 3-5 and 3-6 respectively.

Figure III-5: Degree 4 Crocodile cracks on the Cape Seal

Figure III-6: Large extent of the cracked section

Section with narrow road width of 6.2m had major structural distress. Major rutting and shoving of asphalt surfacing was observed on localised sections, severe edge breaks and drop off with revelling shoulders. Figure 3-7 to 3-9 shows the types of structural defects noted during visual assessment.

Figure III-7: Typical Edge drop off

Figure III-8: High frequency of patches

Figure III-9: Severe rutting and shoving (localised)

V. DEVELOPED INNOVATIVE MEASURERS

In view of the above observation and findings, seven combinations of innovative repair strategies were developed, which were found to be best suited for each section. The combination of innovative strategies included existing surface rejuvenation, pre-treatment and final surface. The combinations were represented as shown on Figure 3-10 and discussed below.

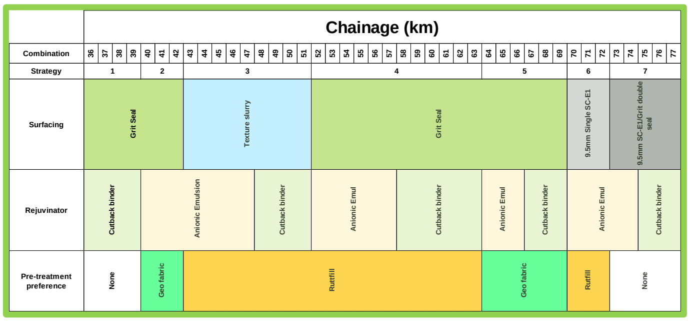

Figure III-10: Representation of Implemented Strategies

- **Combination 1: Rejuvenation and Pre-treatment (Cutback binder), followed by Grit Seal.**

A surface rejuvenation (cutback binder) and the standard pre-treatments regime were done and the finishing took form of a grit seal. The section was selected due to the relatively small amount of structural distress as well as the little geo-fabric patching was required (1).

- **Combination 2: Rejuvenation (Anionic Emulsion) and Standard Pre-treatment, followed by Grit Seal**

A surface rejuvenation (anionic emulsion) and the standard pre-treatment which included asphalt patching, base patching, geo-fabric patches and rut fill slurry with the finishing that took form of a grit seal.

The section was selected due to the relatively small amount of structural distress, similar to combination 1 (1).

- **Combination 3a: Rejuvenate (Anionic Emulsion) and Pre-treatment, followed by a texture slurry**

A surface rejuvenation (anionic emulsion) and the standard pre-treatment regime proceeded with the exception made to replace base patches and surface patches by rut fill where these pre-treatments were triggered because of rutting only and with rut fill and geo-fabrics where there was rutting with associated cracking. This was however done when extensive lengths were encountered with these defects. On shorter lengths, were it was uneconomical to do rut filling, standard pre-treatments applied. For the finishing it was suggested that a texture seal be placed across the road width to blend in with the areas of rut fill slurry, however the section received grit seal surface finishing.

This section focused on areas with extensive lengths of base patching and surface patching because of high degrees of rutting and rut fill slurry proceeded as an alternative pre-treatment (1).

- **Combination 3b: Pre-treatment together with texture slurry**

Combination 3b proceeded the same as combination 3a, except that the rejuvenator used was cutback binder and the finishing took form of grit seal (1).

- **Combination 4a: Rejuvenate (Anionic Emulsion) and Pre-treatment, followed by Grit Seal.**

Combination 4a proceeded the same as combination 3a, except that a texture slurry was not done and the finishing took form of a grit seal (1).

- **Combination 4b: Pre-treatment followed by Grit Seal**

Combination 4b proceeded the same as combination 4a, except that the rejuvenator used was cutback binder.

- **Combination 5a: Rejuvenate (Anionic Emulsion) and Standard Pre-treatment followed by Grit Seal.**

Combination 5a proceeded the same as combination 2, except that this section had a greater amount of structural distress.

- **Combination 5b: Standard Pre-treatment followed by a Grit seal**

Combination 5b proceeded the same as combination 5a, except that the rejuvenator used was cutback binder.

- **Combination 6: Rejuvenate (Anionic Emulsion) and Pre-treatment, Texture Slurry followed by a 9.5mm single seal**

Combination 6 proceeded the same as combination 3a, except that the finishing took form of a 9.5mm single seal (SC-E1 binder) instead of a grit seal.

- **Combination 7a: Rejuvenate (Anionic Emulsion) and Standard Pre-treatment, Texture Slurry followed by a 9.5/4.75mm double seal**

Combination 7a proceeded the same as combination 2, except that the finishing took form of a 9.5/4.75mm double seal (SC-E1 binder).

Combination 3 – 7 – deviated from standard pre-treatment regime, whereby extensive section where base and surface patches were supposed to be done, were treated using rut fill slurry as an alternative and geo-fabric patches on sections that exhibited surface cracking. The innovative strategies were more cost effective than conventional repair methods.

Extensive usage of cutback binder was as a result of dry and brittle road surface and the aim was to rejuvenate the aged binder and close fine cracks prior to any pre-treatment. Cutback bitumen MSP3 was used as rejuvenator on certain sections together with 30% anionic stable grade fog spray on the remainder of the road section. The extent of the road was surfaced using cutback bitumen (MC3000) as a tack coat for grit seal. High degree of bleeding is being experienced on some sections of the road which is binder rich. Bleeding and flushing on geotextile patches is excessive due to high binder content and a use of cutback binder as tack coat for grit seal as our surface dressing.

Sections that were rejuvenated using diluted anionic stable grade emulsion of 50% diluted SS60 seems to behave well without any form of binder flushing or bleeding. However challenges were experienced during constructions especially on steep gradient and sharp curves due to low viscosity of the dilution which intend to runoff. Figure 3-11 and Figure 3-12 shows the two types of rejuvenation applied.

Figure III-11: Diluted SS60 Rejuvenator

Figure III-12: MSP3 Cutback Binder Rejuvenator

VI. REMEDIAL MEASURERS

(a) Rejuvenator (MSP3)

Cutback binder is a tricky product to work with, but the end result is better than a fog spray. It is very time consuming – taking a lot more time to break than a fog spray. With an application rate of 0.5ℓ/m², it takes 36 to 48 hours to break, which means you need to have day/night closures in place. From our experience on this project, when you increase the application rate to 0.6ℓ/m², it could take 48 to 60 hours to break. Even after it broke, you still need to monitor it because the product stays tacky for a while, especially when it is very hot.

(b) 30% spray grade anionic emulsion fog spray

Much easier product to work with as it breaks very quickly and can open to traffic within 2 to 6 hours, depending on the ambient temperature. A big disadvantage is that the product is very low viscosity and runs across the road into trafficked lanes, especially at super elevation when spraying in half widths. This can be mitigated by having labour on hand to brush "runs" with hand brooms.

In summary, the MSP3 is the better product as it brings more life into the existing seal. However, caution must be taken on the selection of tack coat to be used for final surfacing as to mitigate high degree of bleeding and bitumen flushing.

(c)Patching and pre-treatment

Alternative pre-treatment measures trialed on various section of the road as discussed included geotextile patches and extensive rut filling as well as some conventional repair methods such as base patches and surface patches for section with severe pavement distress with associated cracking of degree 4 to 5 respectively.

Figure III-13: Typical Geotextile Patch

Figure III-14: Rut fill slurry using Microsurfacing machine

Slurry rut fill repairs (rapid setting slurry) were applied on distressed areas where rutting of 15 to 25mm deep occurred in combination with crocodile cracks of degree 2 or less. It has become apparent that the cracks are reflecting through the rut fill slurry as well as the new seal. As a levelling layer/holding action this could be deemed to be acceptable, however, if a longer-term repair is required the better alternative would be to repair ruts (in combination with cracks) by means of asphalt surface inlays. The slurry rut fill repairs appear to be most effective in areas where no associated cracking exists.

Rapid Setting Slurry or Microsurfacing: Such low traffic roads with deformations and extensive rutting, patching had to be reduced to absolute minimum. It remains vital to make rational decision when considering using certain alternative repair options as supposed to conventional methods such as base patching to repair ruts. Microsurfacing includes *Ralumac rut fill slurry*, which was extensively used on R58 project to address the exhibited ruts. However, it is important to understand the design and the properties of the rapid setting slurry to ensure compatibility between aggregates to be used and the type emulsion. Rapid setting slurry mostly uses cationic emulsion with additive that enhance the setting time. The designs for Rapid Setting slurries and Microsurfacing is highly specialised and selection of additives can be complex, so it is recommended that the design of Rapid Setting Slurries and Microsurfacing to be left to the supplier of the product. It is also advisable to understand the effect of the additives on the setting time, a balance should be obtained ensure no early breaking during construction, but sufficient additive to open for traffic as early as possible (3).

VII. IN-SERVICE PERFOMANCE

The road Sections performed well in the first 18 months post construction without any major damages, due to abnormal rainfall experienced during the past months, sections with reflective cracks and with crack propagation allowed water ingress. Constant rainfall resulted in suspended water ponding on both left and right inner wheel paths of the road with rut development and pumping due to repeated loading which accelerated cracks propagation and further deteriorations were evident after two weeks of constant rainfall which subjected to disintegration of surfacing seal and underlying pre-treatment. However, this occurred only on localised sections that were noted to be relatively flat and prohibited surface water run off as such damage most likely occurred on the inner wheel paths.

VIII. COST ANALYSIS

The section of the road for experimental of cost effective maintenance of was approximately 73.9 km long with varying width between 6.2m and 6.4m respectively. The cost estimate for conventional methods averaged at **R81,950,429.25** in 2015/2016, which was **R1,092 672.39** per km. Alternative low cost preventative maintenance costed around **R61,400,185.77**, which was **R830,855.02** per km. A total savings of **R19,348,303.64** was obtained by deviating from conventional methods to low cost preventative maintenance which were found to be more cost effective.

Currently conventional road maintenance projects cost approximately **R110 million** on average. Such project can be carefully reviewed in terms of their traffic volumes, so to implement alternative preventative maintenance methods that can be largely considered as part of cost effective methods of road maintenance.

IX. CONCLUSSIONS AND RECOMENDATIONS

Use of cutback binders in the beginning of summer need to be carefully designed taking into consideration the application rate. Sections that were rejuvenated using diluted anionic stable grade emulsion seem to be behaving well without any form of binder flushing or bleeding compared to sections with cutback binder.

Sections indicating base failures need to be assessed carefully in deciding when to push the limits and opt for non-conventional ways as at times the non-conventional measure acts as a bridging layer. Due to bleeding observed, application rate of binder to the geotextile patches should be reduced significantly as well as application rate of tack coat for sand seals. Adequate caution should be exercised to ensure that surfacing aggregate does not "punch in" into the rutfill.

The experimental section is performing well with most section holding well; however, there are some section with cracks reflection and minor damages which were expected. The road sections have settled and cured with marginal bleeding on sections that were binder rich. This experimental section sets a bench mark to further implement innovative strategies trial on this particular road sections to evaluate its performance at various climatic regions.

In concluding, the following needs to be considered when dealing with such projects:

1. Special attention should be given to combination enrichment, repair and surfacing.
2. The effects of cutters and rejuvenators on various types of binders should be considered when deciding on the products to be used.
3. The conditions of the road and climatic conditions vary from place to place, the choice of binder to be used whether anionic or cationic also depends on the electro-chemical conductivity of the aggregate. Not one type of emulsion is suitable for every work. It depends upon whether the aggregate is acidic or basic in nature. More research should be done to ensure compatibility of the products and material to be used.
4. Drainage should be considered as it has huge impact on the performance of the road. Finding suitable rejuvenation method may take time due to delays in deciding on the right combination method taking cost into consideration. Problems in supply of the material- lack of available localised resources may delay the project.
5. Thorough visual inspection must be conducted and sound engineering decision must be taken and on sections whereby alternative or cost-effective methods of repair are not suitable, one should revert back to conventional methods of repairs such as base patch and surface patch.

Implemented innovative strategies for preventative maintenance of low volume surfaced roads were more cost effective as compared to the conventional methods of repairs. Minimum risk during construction as most repairs options can be done using labour intensive based methods, which can result in less usage of specialized equipment which are expensive. Adopted strategies opens a gap for in-cooperating many newer entrants in the industry to gain experience and participate in the main stream of the Civil Engineering and Construction industry.

X. ACKNOWLEDGEMENT

We would like to acknowledge Aurecon South Africa for being part of this experimental project as Consulting Engineer’s and Design Engineer’s for the innovative strategies implemented. We also acknowledge Penny Farthing Engineering Contractors for implementing the strategies accordingly.

XI. BIBLIOGRAPHY

1. **Aurecon South Africa.** *R.58-010-2015/1 and R.58-010-2015/2 Final Design Report.* Cape Town : Aurecon South Africa, 2014.

2. **South African National Road Agency Soc Ltd.** *TRH3, Design and Construction of Surface Seal.* Pretoria, South Africa : SANRAL, 2007.

3. **Sabita.** *Best Practice for the Design and Construction of Slurry seals.* South Africa : Sabita, 2011.

4. **Aurecon South Africa.** *R.58-010-2015/1 and R.58-020-2015/1 F Contract Report.* Cape Town : Aurecon, 2017.