THE USE OF MICROSURFACING AS A COST EFFECTIVE REMEDIAL ACTION FOR SURFACE RUTTING

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ABSTRACT

Microsurfacing can be applied as a rut filling material and/or as an overlay in thicknesses varying between 5mm and 20 mm to an existing surfacing. This paper reports on the use of a proprietary Microsurfacing product called Colrut™ as a cost effective remedial action to overcome extensive surface rutting problems on provincial roads in KwaZulu Natal. Due to the excessive number of heavy vehicles using these secondary routes, rutting in the wheel paths to depths in excess of 20 mm had developed to such a point where it presented a major safety problem for motorists in wet weather. The KwaZulu Natal Department of Transport evaluated various rehabilitation options and in light of their economic constraints, decided to fill the ruts with a proprietary microsurfacing product. The paper provides insight to the development of the rutting problem and reports on the remedial action taken which has resulted in some 60 km of provincial roads being rut filled with microsurfacing since August 2000. The subsequent performance and cost effectiveness of this remedial action is evaluated and reported on.

1. BACKGROUND

The use of slurry seals for resealing existing bituminous surfaces is fairly common practice throughout the world.

However slurry does have certain limitations in that:

- It is dependant on the local weather conditions for setting which is usually between 2 and 4 hours
- Cannot be applied in a single layer with a thickness greater than 1.5 times the maximum aggregate size
- Contains no polymers which assist in maintaining a good surface texture in the long term.

During the late 1960's German scientists began experimenting with emulsion/aggregate mixes to find a way to use stable, thicker applications which could be applied in narrow courses to fill wheel ruts, without destroying expensive road marking lines on the autobahns. They found that if carefully selected coarser graded aggregates were combined with an emulsion containing special polymers, the resulting mix remained stable and resisted deformation, even when applied in a layer with a thickness greater than 1.5 times the maximum aggregate size. The result was the development of Microsurfacing.

Microsurfacing has undergone many developments since its inception. Although originally formulated as a rut filling system, it is now commonly used as a surfacing system to solve a variety of road surface problems throughout the world. Microsurfacing was introduced in South Africa in 1982 when Petrocol obtained the license from Raschig in Germany to produce and lay the Ralumac Microsurfacing system in Southern Africa. With the take over of Colas Southern

Africa by Colas France during early 2000, Colmat™ and Colrut™ replaced Ralumac as the proprietary microsurfacing surfacing overlay and rutfilling products respectively.

This paper reviews the application of microsurfacing as a cost effective rutfilling material in the rehabilitation of sections of Provincial Roads, which formed the main arterial links between the agriculturally rich region of Ixopo and the towns of the KwaZulu Natal South Coast, to primarily overcome safety problems.

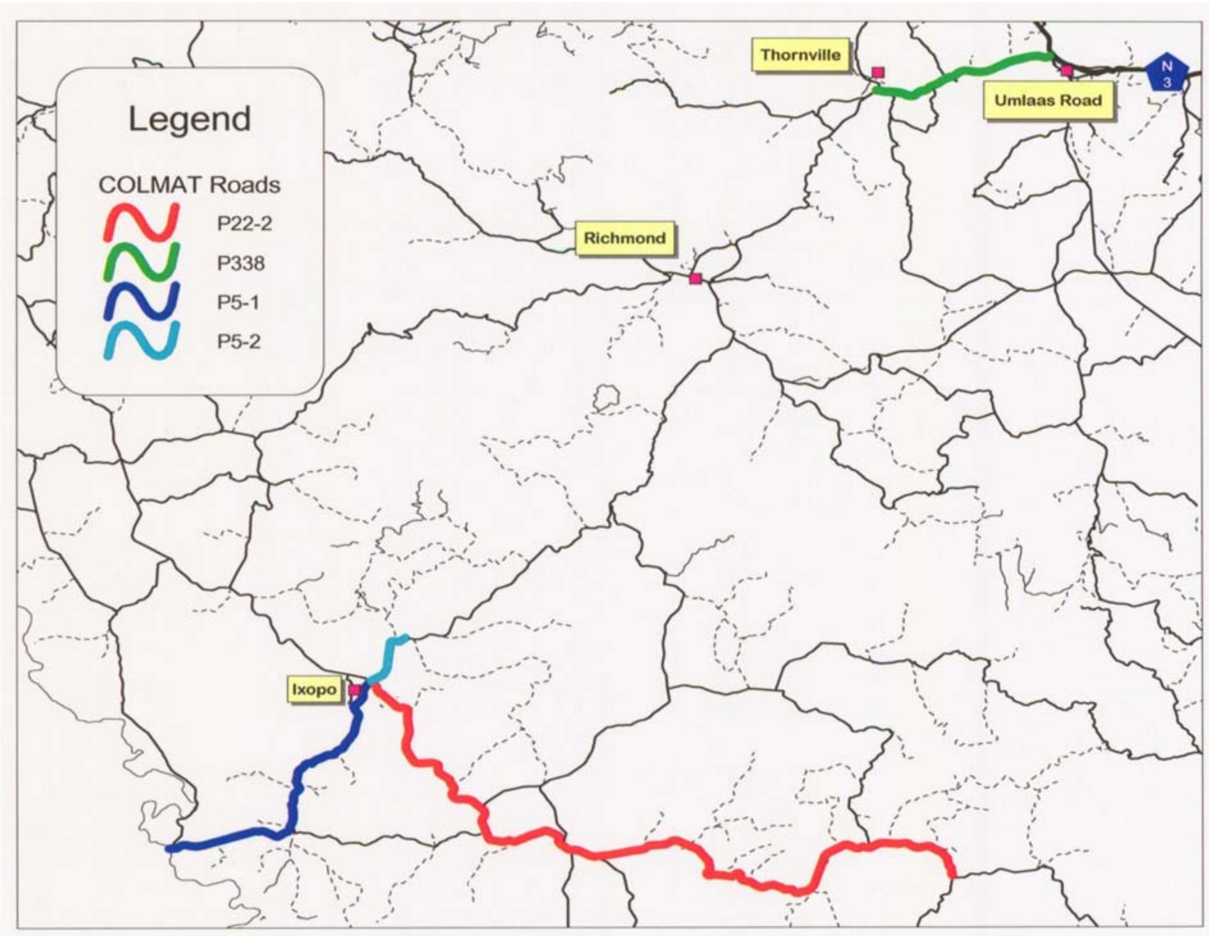


Figure 1. Locality sketch.

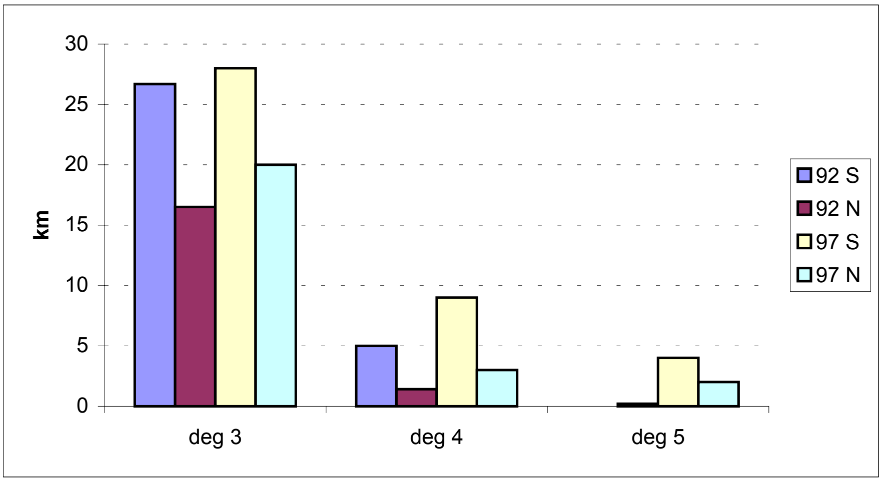
2. RUTTING PROBLEM

Due to the excessive number of heavy vehicles using these routes, signs of rutting in the wheel paths of the existing asphalt surfaces were first detected back in 1992. Following a further investigation in 1997, rutting in excess of a depth of 20 mm had developed to such a point where it presented a major safety problem for motorists in wet weather.

Rutting in the wheel paths had created unsafe conditions for vehicular traffic:

- As water collected in the ruts caused excessive spray behind trucks and increased the risk of aquaplaning for passenger cars.
- Due to inadequate skid resistance caused by flushing of binder in the wheel paths.

Figure 2 shows the increased deterioration in rut development from 1992 to 1997 as measured on P22/2 (2).



Degree 3: 10 – 15 mm   Degree 4: 15 – 30 mm   Degree 5: > 30 mm

Figure 2. Rut deterioration P22/2.

A further detailed investigation showed that shoving of the asphalt-wearing course generally caused rutting.

The Pavement Management System of the KwaZulu Natal's Department of Transport identified the roads shown in Table 1 from this area for rehabilitation. The Pietermaritzburg Regional office of the KwaZulu Natal Department of Transport evaluated various rehabilitation options and in light of their economic constraints, decided to fill the ruts > 10mm with a proprietary microsurfacing product called Colrut which complied to the properties described in this paper.

Table 1. Extent of rut filling works executed.

Provincial Road #	Traffic Volumes	Location	Stake values	m^3 of rutfilling	Date executed
P22/2	1860 elv/d (02) 18 % HV	Ixopo to Highflats	15.3 – 51.7 km	950	Aug 00 to Nov 00
P 5/1	3000 elv/d (02) 20% HV	Umzimkulu to Ixopo	0 –20.0 km	1570	Aug 01 to Dec 02
P5/2	1402 elv/d (02) 34% HV	Ixopo to Catholic Mission	0 – 5.0 km	338	Jan 03 to Mar 03
P 338	3519 elv/d (02) 21 % HV	Thornville to Umlaas Road	0 – 11.5 km	986	Nov 01 to Feb 02

3. RUTFILLING MATERIAL COMPONENTS

A microsurfacing system consists of a quickset cationic modified bitumen emulsion mixed with selected continuously graded crushed mineral aggregate, ordinary Portland cement and water. In exceptional cases additional mineral filler may be required to adapt the grading or improve the reactivity of the aggregate towards the emulsion.

It is essential to select a bitumen emulsion and aggregate system which performs well together given the local prevailing climatic conditions. The economics favour a variation of the emulsifier formulation rather than changing the bitumen or aggregate source. The preference is to stick to well known sources of bitumen and aggregates and try avoiding constant formulation changes. Problems had been experienced in KwaZulu Natal with local aggregates, and only after an extensive survey and investigation [(1)] was a suitable local source and blend of aggregates found.

3.1 Bitumen Emulsion Properties

The type of bitumen used has an influence on the mixing and setting properties of the emulsion made from it. The key performance characteristics are the penetration and acid value of the bitumen. For rut filling purposes a 60/70-penetration grade bitumen was used in place of a 80/100-penetration bitumen which is normally used for overlay purposes. The base bitumen was derived from Middle East crude which has low acid values. An elastomeric SBR polymer was incorporated into the emulsion to improve the consistency and cohesion of the microsurfacing and ultimately the durability of the surfacing. For optimum emulsion quality the synthetic rubber latex was introduced via the water phase prior to milling during the emulsion processing. The emulsion was specially formulated to provide the desired breaking time and to ensure sufficient setting properties of the mix during placing. Table 2 shows a comparison of the binder properties for conventional slurries vis-à-vis microsurfacings and rut filling.

Table 2. Comparison of binder properties for microsurfacings.

Property	Slurry	Microsurfacing	Rutfilling	Test Method
Base bitumen	80/100	80/100	**60/70**	SABS 307
Binder content, %m/m of emulsion	60 – 62	62 – 65	**62 - 65**	ASTM D244
SBR polymer content, % net mass of binder	Nil	3	**3**	Quantitative
Emulsion residue softening point, ° C	42 - 46	min 53	**min 56**	ASTM D36
Emulsion volume per m³ aggregate, litre	230 - 260	180 – 200	**180**	Quantitative
Curing time, hours	> 4	< 1	**< 1.5**	Heel test (4)

3.2 Aggregate Properties

The first requirement is to ensure that the candidate aggregate can be reliably supplied to the specified grading. The 'reactivity' of the aggregate influences the emulsifier type and concentration required to give an adequate mixing time. The methylene blue and sand equivalence tests were used to investigate aggregate 'activity'. A blend of washed and unwashed crusher dust sourced from Alpha Stone's Pietermaritzburg quarry was selected. Crusher dust conforming to the 0/8 grading and meeting the requirements in Table 3 were used as opposed to the 0/6 grading which is used for overlays.

Table 3. Aggregate properties.

Property	Limits		Test method
Grading	0/6	0/8 (ISSA Type III) (4)	
Sieve size mm	Cum % passing	**Cum % passing**	
9.5	100	**100**	TMH 1 Method B4
4.75	90 - 100	**70 – 90**	
2.36	65 - 90	**45 – 75**	
1.18	45 - 70	**28 – 50**	
0.600	30 - 50	**19 – 34**	
0.300	18 - 30	**12 – 25**	
0.150	10 - 21	**7 – 18**	
0.075	5 - 15	**5 - 15**	
Sand equivalent	65 min		ASTM D2419
Methylene Blue	< 8		Colas QMM

3.3 Filler

Ordinary Portland Cement was used to minimise the risk of segregation, to adjust the grading curve and as a setting agent. The type and amount needed was determined by a laboratory mix design. The amount used equated to 2 % by mass of dry aggregate.

3.4 Water

Potable water (approximately 140 litres per m³ dry aggregate) from local sources was added as a wetting agent and to improve workability of the mix.

4. PROPERTIES OF MICROSURFACING

4.1 Material Characteristics

A well-formulated microsurfacing system will allow a mixing time of between 90 to 120 seconds and after placing, set up rapidly during normal weather conditions allowing:

- pedestrian traffic within 10 – 15 minutes and
- vehicular traffic within one-hour of placement.

Due to a thicker layer (of up to 40 mm) being placed in the wheel rut, the curing time increased to 1.5 hours before being opened to traffic. Whereas conventional slurry relies on the evaporation of the water phase for the mixture to cure, microsurfacings derive their superior performance properties mainly due to the chemical reaction which takes place between the positive charged bitumen droplets in the emulsion (and latex if used) and the free negatively charged ions of the aggregate. See Figure 4 below for a schematic of the chemical attraction. The product sets and develops cohesion through a complex electrostatic/chemical reaction between the aggregate, cement and polymer modified emulsion. The bond between the aggregate and the binder is irreversible. Once early setting has occurred, the product is unaffected by unexpected rain. Its performance is further enhanced when the emulsion is modified with SBR latex. The latter results in an improvement of the temperature susceptibility of the binder, improved adhesion of the aggregate which reduces the loss of aggregate especially in the early life of the seal.

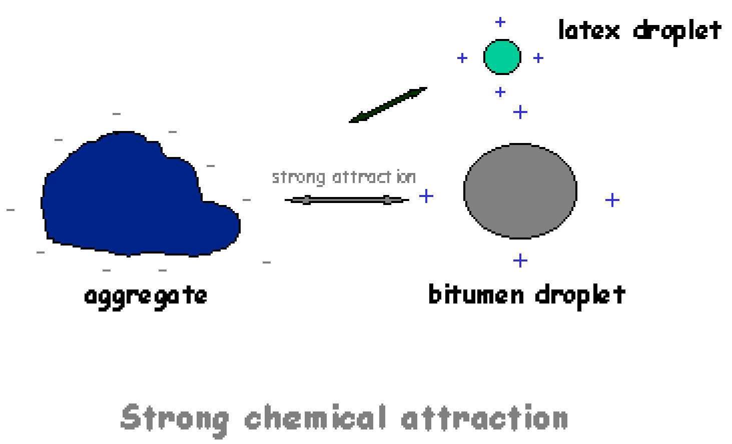


Figure 4. Chemical attraction of cationic SBR latex modified bitumen emulsion and aggregate.

4.2 Functional Properties

The aggregate gradings used in microsurfacing result in enhanced surface roughness and micro skid resistance characteristics. The overlaying of an existing bituminous surfacing with microsurfacing will also limit further deterioration of the pavement by preventing:

- The ingress of water into the underlying layers by filling the voids and cracks in the existing surfacing,
- Further oxidation of the aged binder in the existing surfacing.

Microsurfacing, due to its fluid nature, can be used as a preventative maintenance to fill surface irregularities such as wheel ruts to improve the road profile and thus improve the surface drainage. Microsurfacing can effectively fill surface ruts up to 15 mm in a single pass. Ruts up to 40 mm can be filled by a two-pass application. As some of the ruts were deeper than 20mm and given the nature of the heavy traffic on these road, an aggregate with a coarser grading and a binder with a lower penetration grade bitumen modified with SBR was used to improve the rut resistance of the mix.

It must be noted that the SBR latex in the microsurfacing does however not prevent cracks from reappearing and neither does it add structural strength to the pavement. Localised areas of fatigue cracking had to be repaired prior to placing of microsurfacing.

5. MIX DESIGN

Once a suitable emulsion dope and aggregate system had been developed, which mixed and set as required, then the performance of the cured microsurfacing was evaluated. To ensure optimum performance of the microsurfacing system for rutfilling purposes, all the components were evaluated in the laboratory before full-scale production commenced.

The following tests were performed on the components:

- Aggregate - grading, sand equivalent and methylene blue value
- Emulsion - binder content and residue on sieving

As the material was mixed and applied at ambient temperature, the Marshall Hot Mix design method is not suitable for determining the optimum binder content of the mix. The binder content range within which the mix would be functional was determined by using the following methods:

(a) The minimum binder content was determined by using the Wet Track Abrasion Test according to the ISSA TB-100 method. Samples of the mix were prepared at various binder contents on circular discs of roofing felt. After a curing and soaking period, the samples were abraded with a rubber hose for five minutes. The mass loss of the samples was determined after drying the sample to constant mass. The binder content level at which the abrasion loss stabilised was recorded as the minimum binder content.

(b) The maximum binder content was determined by placing the microsurfacing mixes, prepared at various binder contents, in a Marshall compaction mould. After a curing period the mixes were compacted at a temperature of 60ºC at 150 blows per side. The compacted samples were then inspected for signs of richness or bleeding. A clear indication was obtained at the binder content where the material had a tendency to bleed. Very good results have been obtained in the field to date using this simple approach. Figure 5 below shows the effects of the variation in binder content obtained on the above laboratory tests.

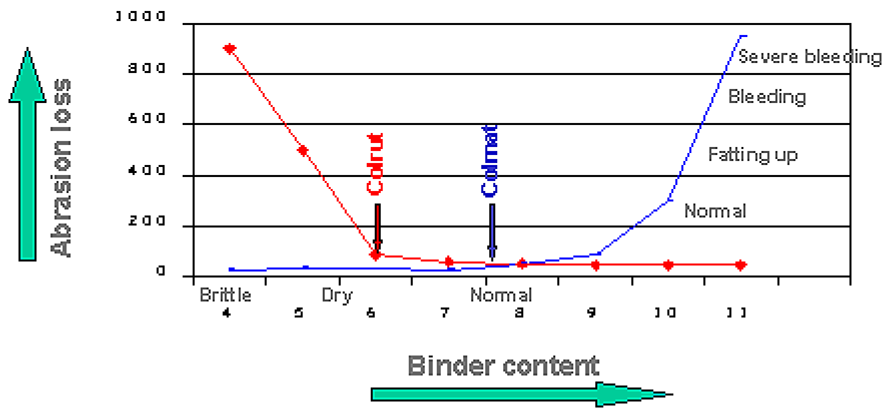


Figure 5. Determination of optimum binder content.

To avoid any possibility of bleeding under the heavy traffic conditions, the binder content selected was 6.1 % by mass of aggregate ie 180 litres of Microsurfacing bitumen emulsion per cubic metre of dry aggregate (180 litre * 64/100 bc / 1888 kg/m). The Marshall stability of a sample prepared at a binder content of 6.1 % was found to be 6 kN with a flow value of 4 mm @ 60ºC.

6. APPLICATION OF THE RUTFILLING MATERIAL

Microsurfacing is produced and placed by a purpose-designed machine, which carries all the material components. The machine accurately proportions these components on a continuous basis and applies it onto the road surface through an agitated spreader box.

6.1 Contract Awarded

In 2000 a R1.1 million contract was awarded to Jabulani Road Contractors under the KwaZulu Natal Provincial annual supply tender for the supply and lay of a proprietary microsurfacing product for rut filling. The contract was undertaken as a joint venture between Jabulani, an emerging contractor, and Colas South Africa as the emulsion and application equipment specialist supplier. In subsequent years the contract continued to be undertaken on a similar basis.

6.2 Pre-Treatment Work

Due to shoving of the asphalt surfacing in some of the ruts, the raised portions had to be cold milled to restore the road profile for surface water drainage purposes. This failure mechanism is illustrated in Figure 5. Other pre-treatment work included localised patching where base failure had occurred.

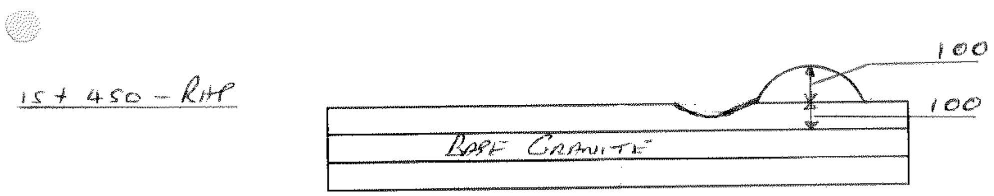


Figure 5. Profile of a surface failure.

6.3 Machine Application

Due to its rapid setting characteristics, the microsurfacing system has a limited mixing time of around 2 minutes, before the mix starts setting up. The Microsurfacing application machine is equipped with special mixers and spreader boxes that are continuously agitated to prevent material from prematurely setting up before application on the road. The setting rate can be further controlled by the addition of a chemical additive to the mix, via the additive tank, to accommodate an increase in the road surface temperatures. The spreader box is mounted on long skids that "ride" over imperfections on the road surfaces, resulting in improved rideability of surfaced layers.

6.4 Rut Filling Box

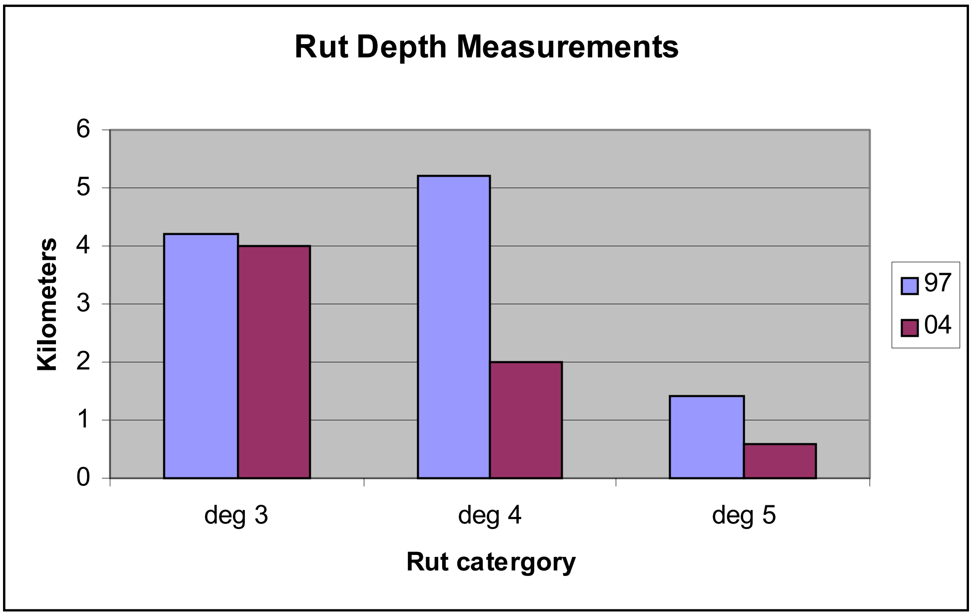
For the rut filling application a special narrow, agitated box was used that concentrated the coarser parts of the mix in the centre of the rut, whilst it augured the finer parts of the mix towards the edges of the box to ensure a thin feathered edge. The box is also capable of placing the mix with a slight camber to compensate for compaction under traffic. The rut filling box width varied from 1.5 to 1.8 metres.

Figure 6. Rutfilling on P22/2 Ixopo to Highflats.

7. COST EFFECTIVENESS AND PERFORMANCE

The application of Microsurfacing as a rut filling material does not increase the structural capacity of the pavement, however it does help restore the function performance of the road surface by restoring its skid resistance and surface drainage profile. Rut filling will only be successful if the rut is caused by mechanical compaction of the pavement structure. Since the existing pavement had been in service for more than 20 years it was felt that filling the rut with microsurfacing would provide the desired transverse profile for a reasonable period.

Whilst the real cause of the rutting in the wheel tracks could be related to the closing up of the voids in the existing asphalt mix, plastic deformation would however continue in the existing asphalt even after rut filling. To this end rut measurements were taken in 2004 on road P22/2 after being rut filled in 2000 and compared with the original survey done in 1997 to determine if there was an improvement. The results are shown in Figure 7. It should be noted that the rut depths measured in 1997 would have deteriorated further prior to rut filling in 2000 and would thus have been much deeper at the time of actual filling.



Degree 3: 10 – 15 mm Degree 4: 15 – 30 mm Degree 5: > 30 mm

Figure 7. Comparison of rut depths before and after rut filling.

7.1 Life Cycle Costs

The decision to fill the ruts with Microsurfacing was considered a short-term holding action whilst the longer-term measure would have been to mill out the ruts and fill with hotmix asphalt. The average cost for the supply, including materials, mix and lay of the microsurfacing was R1, 158.00 per m3 (October 2000). The cost of applying this product as a rutfilling material equated to R69.60 per running metre for a 9.2 metre wide road. If one makes the assumption that each of the ruts are milled out to a width of 1.5 m and filled with 80 mm hotmix asphalt and a lifecycle cost comparison (as shown in Table 4) is done between the two options, the rut filling option becomes more cost effective than to mill and replace with hotmix asphalt if the material remains in-service for longer than 2.5 years.

The costs for overlaying the rut filling as a stage construction are also included in Table 4. Although the strategy was initially to overlay the rut filling with a seal or slurry after one year, this has yet to materialise as a result of the good overall performance of the product.

Table 4. Life cycle cost comparison.

Remedial option	Cost per running metre	Expected life	Cost/year (R/year)
Rutfilling	R69.60	5 years	R13.92
Mill & replace with 80 mm HMA	R422.40	12 years	R35.2
Overlay options	**Cost per running metre**	**Expected life**	**Cost/year (R/year)**
13 mm modified binder reseal	R124.80	7 years	R17.83
10 mm slurry overlay	R69.00	5 years	R13.80

Information was obtained from KZN – DOT, T² Accident Management system on the number of vehicular accidents which occurred during wet weather conditions on the sections of road before and after rut filling to ascertain whether there was an improvement in the road safety. Although the results in Table 5 are not conclusive in that they show that there was only a reduction in the number of accidents reported on 2 of the 3 roads, the general consensus was that there was a marked improvement in visibility during wet weather conditions.

Table 5. Incidents of road accidents reported prior and after rut filling.[5]

Provincial Road #	Location	Stake values	Date completed	# Accidents 1 year prior	# Accidents 2003
P22/2	Ixopo to Highflats	15.3 – 51.7 km	Dec 00	8	12
P 5/1	Umzimkulu to Ixopo	0 –20.0 km	Dec 02	12	9
P 338	Thornville to Umlaas Road	0 – 11.5 km	Mar 02	5	0

8. CONCLUSION AND RECOMMENDATION

Microsurfacings are a cost effective remedial solution for improving the profile and skid resistance of an existing road. With the developments in microsurfacings it has become possible to apply thicker layers to accommodate higher traffic densities and due to its fluid nature to fill surface irregularities, such as wheel ruts. Microsurfacings are designed to be opened to traffic in one hour, whereas slurries however are weather dependant making them slow curing.

Microsurfacings, when compared to other surfacings types have further advantages in that they are more environmentally friendly, namely:

- Low tyre noise of the final surfacing
- No harmful emissions during application
- Improved worker safety due to cold product application

And the disruption to traffic during construction is minimal in that there is:

- No lifting of kerbs and manholes required
- No tack coat required
- Minimal construction plant required on-site
- Workable under a wider range of weather conditions vis-à-vis slurry and chip seals.

The decision to fill the ruts with a microsurfacing product rather than to mill out the existing surface and replace with hotmix asphalt was sought as the most cost effective option at the time in light of the limited funds available. A comparison of the relative life cycle costs between rut filling with microsurfacing or milling and replacing with hotmix asphalt shows that the former only has to provide an in-service life in excess of 2.5 years to be more cost effective than the latter option. Furthermore an overall reduction in the surface rut depths was achieved when the measurements are compared over a 7-year period. The impact of the improved skid resistance and transverse road profile can be attributed to a reduction in the number of road accidents.

Lastly the execution of these contracts can also be seen as a good example of how a partnership can work between the Client, contractor and supplier to provide a cost effective solution to sort out a severe road safety problem within the confines of a limited budget for road maintenance.

9. ACKNOWLEDGEMENTS

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10. REFERENCES

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