THE REHABILITATION OF A NATIONAL ROAD BASED ON A PRODUCT PERFORMANCE GUARANTEE SYSTEM

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ABSTRACT

The present vision of the South African National Roads Agency Limited (SANRAL) is to encourage innovative technology and appropriate solutions in as transparent a procurement manner as possible. A particular roads rehabilitation contract was considered an ideal project to implement this innovative rehabilitation strategy on a guarantee system. When tenders were called for, the contractors were provided with information detailing the pretreatment works considered necessary for structural repairs to the existing asphalt base and surfacing. The contractors had, however, the option to indicate their own pretreatment and methodology for these repairs. The integrity of these repairs had to be monitored on the basis of predefined minimal functional parameters assessed visually and by instrument, that must be met after a period of two, four, and six years. To ensure that SANRAL is covered for non-conformance during these periods a system of reducing bank guarantees was prescribed as an integral part of the contract.

KEY WORDS

PPGS, GUARANTEES, INNOVATION, ULTRA THIN ASPHALT SURFACINGS, ROAD REHABILITATION.

1. INTRODUCTION

The present scenario for road pavement rehabilitation in South Africa involves the usual pavement assessment and remedial recommendations. Repairs may vary from major pavement reconstruction to surface overlays. As such, the pavement upgrading is fixed, tenders are called for based on a fixed schedule of quantities with prescribed mix recipes and properties.

Although this process works well, it does not readily lend itself to innovation and the use of proprietary products which cannot under normal circumstances be specified. In this regard, the use of ultra thin surfacings defined by Corté (Corté, 2002) as being in the 10mm - 20mm thickness range are new to South Africa, and to date there are no generic specifications for these types of layers. The selection of these layers is therefore difficult considering that they are proprietary products, making procurement on an open tender basis difficult.

With this background, and a need to make allowance for innovation and the introduction of "brand names" it was decided that this tender would be called for employing an end user programme property specification system. Prior to proceeding with this decision, interviews were held with contractors experienced in asphalt construction to gauge their views on the applicability of undertaking the work based on a Project Performance Guarantee System (PPGS). PPGS is defined by Verhaeghe (Verhaeghe et al. 1999) as a system which entails the formal management of product performance guarantees, including the contractual, institutional and risk sharing management of the road building industry, where:

- Product is the result of an activity or process, either tangible or intangible;
- Performance is the agreed requirements and service over the desired period; and
- Guarantee is defined as the product performance undertaking or warranty.

2. THE PROJECT

The road concerned consists of 8,4 km of the existing multi-lane dual carriageway of the heavily trafficked National Route 3 Section 1 from Candella Road to Pinetown, near Durban, which forms part of the main arterial route from Durban to Johannesburg. It was opened to traffic in 1974 with the following pavement design:

40mm	Semi-gap graded asphalt surfacing with pre-coated chips
125mm	Continuously graded asphalt base
150mm	Cemented upper subbase natural gravel
150mm	Cemented lower subbase natural gravel
100mm	Natural gravel selected subgrade

A 40mm semi-gap graded asphalt surfacing was added in 1985. Since then, no major repairs to the existing pavement were carried out apart from routine repair work in the form of crack sealing and patching.

At the time of opening the daily traffic volume was in the region of 30 000 vehicles per day (two way), of which heavy vehicles comprised around 7%. From 1974 to 2000 the past traffic has been calculated to be of the order of 26 x 10^6 E80's. The cumulative equivalent traffic for a 15 year design period, assuming 4% growth, from January 2000 is reported in Table 1 for each lane.

Table 1- Cumulative E80's For Each Lane

Northbound						Southbound			
Length (km)	E80's/Lane x 10^6					Length (km)	E80's/Lane x 10^6		
	8	7	6	5	4		3	2	1
9,0 - 10,6	0,87	8,71	30,97						
10,6 -	0,87	2,90	10,16	11,61	15,48	9,0 - 17,4	1,98	9,8	34,84

Northbound						Southbound			
Length (km)	E80's/Lane x 10^6					Length (km)	E80's/Lane x 10^6		
	8	7	6	5	4		3	2	1
11,5									
11,5 - 13,8	0,87	5,81	12,19	23,22					
13,8 - 17,4	0,87	8,21	30,97						

Fast lane traffic is represented by lanes 3, 7, and 8.

Pavement distress in 2000 was mainly in the form of rutting and cracking, with the total length of ruts in both carriageways being recorded as:

5 - 10mm	rut depth	-	8280 m
11 - 20mm	rut depth	-	9700 m
>20mm	rut depth	-	3275 m

The total length of cracks of width 3mm and more was measured as 25466 m.

3. PAVEMENT INVESTIGATION

SANRAL appointed consultants to do the normal investigation and design for a maintenance project.

The investigation involved a traffic analysis; detailed visual inspection (carried out under special contract with lane closures due to the high traffic volumes); the excavation of test pits involving the taking of asphalt cores, and sampling of materials from the pavement layers for laboratory test analysis. The results obtained from this investigation, coupled with deflection readings carried out in the fast and slow lanes, were used to evaluate the remaining pavement life.

The investigation revealed the pavement to be still serviceable structurally for another 15 years provided repairs were carried out. These repairs were limited to the asphalt layers to rectify severe rutting and cracking which had developed in the slow lanes, and middle and fast lanes respectively. Although transverse and longitudinal cracks recorded in the middle and fast lanes categorised as severe (>3mm in width), they did not appear to have major influence on the strength of the pavement. There were also areas where the voids in the asphalt layers were low (< 2%) which required attention by milling and replacement. None of the repairs extended to the subbase layers.

On completion of the deeper asphalt repairs, resurfacing measures were necessary to reinstate functional properties. Due to the high traffic volumes and loading, a normal surface dressing/chip seal was not appropriate as a wearing course because of rutting, or embedment, which could develop in the slow lanes, and the effects of noise in the fast lanes in an urban environment.

In summary, the consultant's recommendations for reinstatement were for milling out areas where rutting had occurred, replacing the milled-out areas with asphalt base, crack-sealing where necessary in other areas, followed by a 35mm continuously graded asphalt overlay. It was also recommended that construction activities should take place at night between 19:30 and 06:00 in order to minimise disruption to traffic and for safety reasons.

4. TENDER REQUIREMENTS

4.1. General

Tenders were called for on a PPGS basis, but to provide a datum for evaluation, a benchmark for tender assessment based on the consultant's recommendations detailed above was established. The recommendations allowed for a 15-year structural design life after the maintenance repairs had been completed.

The total duration of the PPGS period was six years commencing on the official completion date of the contract. This covered work relating to the base and surfacing repairs, and functional condition of the surfacing in terms of a Product Performance Guarantee, including repair methodology, types of distress, field measurements, acceptance criteria, remedial work, and payment items related to the Product Performance Guarantee. Surface distress clearly attributable to subgrade conditions was not the contractor's liability.

4.2. Repair Methodology

The general repair methodology for the repair work to be undertaken for the various items of distress occurring in the surfacing and pavement layers is detailed in Table 2.

Table 2 - Repair Methodology

Types of distress	Treatment of defects
Longitudinal and transverse cracks $\geq$ 3 mm	Crack sealing
Crocodile cracks (base layer still intact and deformation < 6 mm)	Mill and replace
Structural failure (cracked and deformed or rutting due to base failure)	Mill and replace
Rutting $\geq$ 6 mm (crocodile cracks and deformation of surfacing layers)	Mill and replace
Rutting < 6 mm	Overlay
Coarse textured surface	No pre-treatment required
Longitudinal and transverse cracks < 3 mm	No pre-treatment required

It was up to the contractor to make his own assessment of the extent and method of repairs and base his tender accordingly, the extent of which could differ considerably from that of the consultant. At tender evaluation stage these could be compared with the benchmark.

4.3. Functional Performance Assessments

Functional performance assessments are to be made immediately after completion, and then in years 2, 4, and 6. The parameters to be assessed are listed in Table 3 for both visually and instrumentally assessed parameters.

Table 3 - Functional Performance Parameters

Visually Assessed Parameters	Instrumentally Assessed Parameters
1. Deformation (Shoving)	1. Roughness (Riding quality)
2. Surface Failure	2. Surface Friction (Skid Resistance)
3. Surface Cracking	3. Rut Depth
4. Surface Ravelling (Aggregate loss)	4. Surface Macrotexture
5. Bleeding	

4.4. Visually Assessed Parameters

The visual assessment of the pavement surfacing during the Guarantee Period shall be undertaken by a Visual Assessment Panel comprising representatives from SANRAL, the contractor, and consultant as follows:

- Employer 2 representatives
- Contractor 2 representatives
- Consulting Engineer or suitably qualified external assessor 2 representatives

The acceptance criteria are listed in Table 4.

Table 4 - Criteria For Visually Assessed Distress

Type of Distress	Time [1] (Years)	Maximum Allowable	
		Degree[2]	CIV[3]
Deformation (shoving) of Asphalt	2	2	0.0
	4	3	0.2
	6	3	0.6
Surface Failure	2	2	0.1
	4	3	0.2
	6	3	0.6
Surface Cracking	2	2	3.0
	4	3	8.0
	6	3	15.0
Surface Ravelling	2	2	3.0
	4	3	8.0
	6	3	15.0
Bleeding	2	2	3.0
	4	3	8.0
	6	3	15.0

Notes:
1..../ Time in years after the issuing of Completion Certificate.
2..../ The degree of a visually assessed parameter as specified in TMH 9 (1992) “Pavement Management System: Standard Visual Assessment Manual for Flexible Pavements”, issued by the Committee of Land Transport Officials (COLTO).
3.../ Combined Index Value (CIV) per one kilometer length of lane or shoulder.

The Combined Index Value (CIV) for each visually assessed parameter will be processed as follows:

$$\text{Combined Index Value (CIV)} = \sum_{\text{Degree}=1}^{5} \text{Degree} \times \frac{(\text{Length}_{\text{Degree}})}{10}$$

4.5. Instrument Assessed Parameters

4.5.1. Roughness

Road roughness is defined as the deviations of a road pavement from a true planar surface, which deviations affect vehicle dynamics and riding quality. The acceptance criteria are presented in Table 5.

Table 5 - Acceptance Criteria For Roughness

Time[1] (Years)	Limit Value (Average 100m IRI)[2]	Maximum (%) of 1 Km Segment With Roughness Worse Than Limit Value
2	1.60	20%
	1.90	5%
	2.30	0%
4	1.90	20%
	2.10	5%
	2.60	0%
6	2.10	20%
	2.40	5%
	3.10	0%

Notes:
1.../ Time in years after the issuing of Completion Certificate)
2.../ Average 100m IRI = $\dfrac{(100mIRI_{\text{Left Wheel Path}} + 100mIRI_{\text{Right Wheel Path}})}{2}$

4.5.2. Surface Friction

Surface friction is defined as the ratio of the force to the normal load on the wheel of a SCRIM (Sideway Force Coefficient Routine Investigation Machine), or equivalent approved, under wet surface conditions. This ratio is termed the Sideway-Force Coefficient of Friction (SFC). The unit of measurement is SFC_{50}, which is the value at 50 km/hr and 20°C.

On this contract the applicable SFC_{50} limits were 0,35 for the main carriageway, and 0,4 where the on and off ramps tie in to the main carriageway. If the SFC_{50} values at any particular location fall below these limits, further investigations must be carried out to establish the likelihood of associated unsafe situations requiring remedial action.

4.5.3. Rut Depth

The rut depth is defined as the maximum vertical distance (mm) in the wheel path measured between the road surface and the bottom of a two metre straight edge placed transversely across a wheel path. The acceptance criteria are detailed in Table 6.

Table 6 - Acceptance Criteria For Rut Depth

Time (Years)	Limit Value (Average 10m Rut Depth (mm)	Maximum (%) of 1 Km Segment With Average 10m Rut Depth Value Worse Than Limit Value
2	3.0	20%
	4.0	5%
	6.0	0%
4	5.0	20%
	6.0	5%
	10.0	0%
6	8.0	20%
	10.0	5%
	15.0	0%

4.5.4. Surface Macrotexture

Surface macrotexture is the deviation of a pavement surface from a true planar surface with the characteristic dimensions along the surface of 0.5 - 50 mm. The acceptance criteria are given in Table 7.

Table 7 - Acceptance Criteria For Surface Macrotexture

Time (Years)	Limit Value (Mean Profile Depth (mm))	Maximum (%) of 1 Km Segment With Surface Macrotexture Value Worse Than Limit Value
2	1.0	20%
	0.7	5%
	0.5	0%
4	0.8	20%
	0.6	5%
	0.4	0%
6	0.6	20%
	0.5	5%
	0.3	0%

4.6. Evaluation And Final Acceptance

The contractor was required to provide a guarantee in terms of the Product Performance Guarantee System.

This guarantee is not intended to cover the full cost of the repair work, but rather intended to be of an acceptable order for functional repairs which the contractor can handle, taking into account that the contractor has other works as well which require guarantees to be furnished. The order of magnitude of the guarantee was determined according to the extent of high-risk areas, such as slow lanes and steep gradients, with particular attention to rutting.

The contractor is also obliged to work with professional partners who carry out his quality audits as well as assessments of remedial work required in the event of non-conformance, and who propose designs for the pre-treatment work required during the contract.

An assessment was carried out at the end of the completion of the works, at which time all defects were remedied. Further assessments will be carried out at the end of years 2, 4, and 6, and when all parameters meet the full acceptance criteria, either initially or on repair, the sum tendered for the guarantee will be repaid in three installments:

- 50% of the lump sum will be repaid at the end of year 2 + release of 1/3 guarantee;
- 30% of the lump sum will be repaid at the end of year 4 + release of 1/3 guarantee;
- 20% of the lump sum will be repaid at the end of year 6 + release of 1/3 guarantee.

5. TENDER EVALUATION

Out of eight tender documents drawn, four tenders were submitted on a PPGS basis. Two contractors submitted three tenders on a non-PPGS basis, one of which was based exactly on the recommended design requirements and defined benchmark quantities, and the other which complied very closely to the benchmark. This gave a very good indication of the premium being paid for adopting the PPGS approach.

Of particular interest was the conformance of each PPGS tender to the benchmark. To ensure prudent assessment the pre-treatment works proposed by each tenderer was compared with the design proposals to give an idea of the possible risks SANRAL were exposed to structurally. Although the PPGS period was for six years, the benchmark design was for fifteen years structural life, and the higher the residual life at the end of six years then the greater the confidence factor for the pavement behaviour over the following nine years.

The proposed repair measures and surfacing layers of the three lowest tenders submitted are compared with the benchmark values and reported in Table 8.

Table 8 - Comparison Of Contractor's Asphalt Repair Proposals (PPGS)

Repairs To Asphalt Mill & Replace (mm)	Benchmark	Tender No. 1	Tender No. 2	Tender No. 3
0 - 45	66600 m^2	46400 m^2 (70%)	29960 m^2 (45%)	73260 m^2 (110%)
45 - 85	12300 m^2	10800 m^2 (88%)	Nil	14880 m^2 (110%)
85 +	1200 m^2	Nil	Nil	Nil
Surfacing	35 mm Asphalt	18 m Novachip	25 mm SMA	35 mm Asphalt

From a structural repair viewpoint Tender No. 3 was the most acceptable, but did not compare financially.

The asphalt repair work proposed in Tender No. 2 was considerably less than that of Tender No. 1, and is not considered to be acceptable technically, although the use of a stone mastic asphalt surfacing would have provided the necessary noise reduction.

Tender No. 1 was close to the benchmark. This tender also introduced the ultra-thin Novachip on a PPGS basis. This is a proprietary product and fulfills the requirements for innovation. It has the desired effect of noise reduction.

As a comparison, details of the three alternative tenders are reported in Table 9.

Table 9 - Comparison Of Alternative (Non PPGS) Tenders

Repairs To Asphalt Mill & Replace (mm)	Benchmark	Alt. Tender No. 1	Alt. Tender No. 2	Alt. Tender No. 3
0 - 45	66600 m^2	73260 m^2 (110%)	46400 m^2 (70%)	666000 m^2
45 - 85	12300 m^2	14880 m^2 (110%)	10800 m^2 (88%)	12300 m^2
85 +	1200 m^2	Nil	Nil	1200 m^2
Surfacing	35 mm Asphalt	35 mm Asphalt	Novachip	35 mm Asphalt

Alternative Tender No. 1 is the same as Tender No. 3, except that the guarantee is reduced from 6 years to 2 years.

Alternative Tender No. 2 is exactly the same as Tender No. 1 except that it is not PPGS based.

Alternative Tender No. 3 is based on the repair methodology quantities of the benchmark.

6. COST OF PROJECT

A cost comparison of the three tenders provides interesting reading, as there is not a wide variation in value.

Tender No. 1 is 2,83% below the estimate
Tender No. 2 is 0,78% below the estimate
Tender No. 3 is 3,06% above the estimate, and 6,06% above Tender No. 1.

Alternative Tender No. 2, which is exactly the same as Tender No. 1 except that it is not PPGS based is 3,74% less than Tender No. 1, indicating that this is the premium paid for going the PPGS route.

Taking into account the high remaining life of Tender No. 1 at the end of the 6 years this is a small price to pay for not having to maintain the road over this period, with the possibility that maintenance measures over the following 9 years (in line with the original 15 year design period) will be no more than would have been anticipated had the work been undertaken under normal tender procedures.

These comments would not, however, be applicable had Tender No. 2 been accepted which is more of a functional repair for the guarantee period and unlikely to enhance the life of the existing pavement beyond 6 years, possibly resulting in extensive repairs over the remaining 9 year period.

7. PROJECT EXECUTION AND SUPERVISION

Normal supervision costs are in the range 9% - 13% of contract value, with a full quality control testing laboratory being provided on site. Minimum staff requirements of this nature would normally allow for an experienced resident engineer, an experienced clerk of works and an experienced materials technician with laboratory assistants.

Being run on a PPGS basis the materials testing was the contractor's responsibility and the materials laboratory and staff were not therefore required. Some off-site testing was necessary for audit purposes, and as a record for future disputes that may arise.

An experienced resident engineer was employed from the consultant's staff to oversee the running of the contract, assisted by a trainee technician who was fully employed on accommodation of traffic. A large amount of the resident engineer's time was spent monitoring the quality of work and the repair methodology compliance with the contactor's proposed repair methodology.

The supervision fees on this contract were 5,77%.

During a contract of this nature the contractor has to guarantee his work only for the guarantee period and may vary his repair work as the contract proceeds. In this case we had a contractor who was committed to the philosophy, and increased the quantity of work originally proposed on his own initiative and concern.

Detailed Quality Assurance Plans were submitted by the contractor and by his suppliers (of asphalt and of modified tack). The quality-control and reporting of the manufactured products was generally of a very high standard and there were few (minor) non-conformances, although 15 tonnes of new asphalt base (1 shift's work) and 100 tonnes of Novachip (2 shifts' work) was milled out and replaced because of incorrect binder contents caused by an undetected mechanical problem at the mixing plant.

All paving was carried out at night (under lights), under heavy traffic, and in restricted areas (limited construction zones of up to 3 km in length by 2 lanes in width) and the thin high-stone-content surfacing mix was fairly susceptible to low temperatures. On completion of the work, joint inspections were carried out (including driving over the job a few times) and some 70 transverse joints had to be repaired to improve riding quality.

In addition, 3 sections of lane width (of up to 200m in length each) were milled out and replaced because of "corrugations" caused by faulty sensors on the paver.

8. CURRENT STATUS

PPGS contracts are still in an embryonic phase in South Africa, but are gaining in acceptance.

There are grey areas which still have to be addressed.

Overloading of heavy vehicles is a serious problem, which has not been corrected on a national scale by overload control, and this could have an effect on the performance guarantee.

With the introduction of ultra-thin surfacing layers there is the concern that acceptable riding quality values will be obtained, and their possible effect on the structural integrity of the pavement in the longer term. What will the future of these layers be at the end of the guarantee period? Will they have an extended life? Will they have to be milled off? Can they be overlaid?

On this contract the contractor increased his original commitment. Should the contractor, on the other hand, decide to reduce that commitment how far should this be tolerated?

9. FUTURE TRENDS

Development of the use of the PPGS will undoubtedly continue to absolve the client from any undue risk of non-conformance or premature distress. In doing so attention will have to be given to selecting the most appropriate guarantee period. On this contract was the six year period realistic and commensurate with the type of repairs envisaged? Should longer periods be selected closer to the structural design period, possibly with some inclusion for future maintenance?

Of particular concern is the extent of pre-treatment works the contractor may carry out. Should a tender, based on functional requirements only, be penalised because the residual life of the pavement at the end of the guarantee period might be close to zero? Should it be made clear to contractors at tender stage that a higher-priced tender may be accepted against a lower one on the grounds of enhanced structural life? On this contract had Tender No. 2 won the day the maintenance requirements at the end of the guarantee period would have been much more of a concern.

On a worldwide scale South African contractors are relatively small. Accordingly, guarantees are structured in order to set them a low as possible, but still adequate to minimise the risk to the client.

Premature failure is always likely to be much more of a risk in the slow lanes. This must be considered in the selection of surface types.

10. CONCLUSION

There is always a demarcation line where the risk factor to the contractor is such that the premium paid may exceed the benefits of adopting this guarantee system. Taking into account the tender prices received for this contract, the cost premium has been more than compensated for by transferring the obligation for quality to the contractor. In addition a propriety product has successfully, and transparently, been incorporated into the works.

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