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Theme: **Training , Research and Development**

Title: **Implementation of the SADC Guideline for Low Volume Sealed Roads on Labour-based Projects in Limpopo Province, South Africa**

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Abstract:

The Roads Agency Limpopo (PTY) Ltd (RAL) with technical assistance from ILO, has implemented a successful 3-year pilot programme, Gundo Lashu, in labour-based road construction using emerging small scale contractors. The programme was originally conceived as a regravelling programme, but it was soon realised that pursuing the regravelling strategy would not be sustainable for many reasons, viz:

- Good quality wearing course gravel was largely unavailable;
- High traffic levels on most provincial roads, many carrying 200-500 vpd, and
- Using the available gravel sources on these roads would result in rapid deterioration, unacceptably high road user costs due to corrugation, high maintenance costs and levels of dust pollution, rapid depletion of the remaining gravel sources and environmental degradation.

RAL therefore decided to look into alternatives to the recurring regravelling cycle on the unpaved provincial road network and in conjunction with the CSIR developed improved construction techniques that would enable the inexperienced labour-based contractors to produce high quality pavements for low volume roads with bituminous seals.

Shifting the goal posts, although quite necessary, in the middle of the contractor development programme naturally caused additional problems and lower productivity than would otherwise have been expected. Nevertheless, a cost comparison study using data from Gundo Lashu and other comparable projects has concluded that labour-based methods (LBM) are financially on par with machine-based methods (MBM) of construction, even with the relatively high wage levels in South Africa compared with most other African countries. In economic terms Labour Based construction has about a 20 per cent advantage over MBM for these specific projects.

The continuation of the Gundo Lashu programme under the umbrella of the national Expanded Public Works Programme, which was launched in May 2004 and largely modelled on Gundo Lashu, coincides with the official launch of the SADC Guideline for Low Volume Sealed Roads (LVSR). With this guideline now available, the philosophies and recommendations will be applied in the design of 15 labour-based projects for the financial year 2005/06. In order to achieve the most appropriate and

economical designs, the Guideline was presented and discussed in a workshop conducted by the CSIR with the consulting engineering firms who have been trained under Gundo Lashu and acquired the much needed practical experience with LBM. A follow-up workshop after the field data had been collected, examined the preliminary pavement designs and exchanged ideas before the designs were finalised. A proactive approach by the client is needed to overcome the resistance from designers in the application of new philosophies that clash with accepted norms and standards and therefore are perceived as carrying a higher risk.

Trials with non-conventional soil stabilisers are being carried out in order to assess their potential for use in light pavement designs. With the huge task of improving the low volume rural road network in most African countries, use of such products is however not an issue that should be overlooked, especially because some of these products lend themselves to labour-based methods of construction by dilution of the product in the compaction water.

Different sealing techniques are also being tried and assessed. Some seals, although with relatively high labour content, require hot bitumen and spreading by a bitumen tanker. Hot bitumen poses a potential health hazard and the tanker a problem when it is delayed or has mechanical problems. For such seals to be economical, long stretches of base (1 to 1.5 km) must be prepared and risk being damaged by traffic and/or weather before the sealing operation can take place. Seal-as-you-go techniques using emulsions or cold-mix asphalt can therefore remove some of the headaches for a labour-based contractor and be technically and economically viable solutions.

The design alternatives based on the SADC Guidelines and experiences gained under Gundo Lashu, will be evaluated using a simple spreadsheet tool for economic evaluation of investment alternatives, SuperSurf. The risk, real or perceived, will thus be assessed against the potential benefits and contribute to the reduction or removal of the fear of failure, which is perhaps the biggest obstacle towards the adoption of new ideas by client bodies, politicians and engineers.

1. Introduction

a. Background

The Roads Agency Limpopo (Pty) Ltd (RAL) with technical assistance from ILO, has implemented a successful 3-year pilot programme, Gundo Lashu, in labour-based road construction using emerging small scale contractors. The programme was originally conceived as a regravelling programme, but it was soon realised that pursuing the regravelling strategy would not be sustainable for many reasons, viz:

- Good quality wearing course gravel was largely unavailable;
- High traffic levels on most provincial roads, many carrying 200-500 vpd, and
- Using the available gravel sources on these roads would result in rapid deterioration, unacceptably high road user costs due to corrugation, erosion and potholing, high maintenance costs and levels of dust pollution, rapid depletion of the remaining gravel sources and extensive environmental degradation.

RAL therefore decided to look into alternatives to the recurring regravelling cycle on the unpaved provincial road network and in conjunction with the CSIR developed improved construction techniques that would enable the inexperienced labour-based contractors to produce high quality pavements for low volume roads with bituminous seals.

The continuation of the Gundo Lashu programme under the umbrella of the national Expanded Public Works Programme, which was launched in May 2004 and largely modelled on Gundo Lashu, coincides with the official launch of the SADC Guideline for Low Volume Sealed Roads. With this guideline now available, the philosophies and recommendations are being applied in the design of 15 labour-based projects for the financial year 2005/06. In order to achieve the most appropriate and economical designs, the Guideline was presented and discussed in a workshop conducted by the CSIR with the consulting engineering firms who have been trained under Gundo Lashu and acquired the much needed practical experience with LBM. A follow-up workshop after the field data had been collected, examined the preliminary pavement designs and exchanged ideas before the designs were finalised. A proactive approach by the client is needed to overcome the resistance from designers in the application of new philosophies that clash with accepted norms and standards and therefore are perceived as carrying a higher risk.

b. Cost comparison of machine versus labour

Shifting the goal posts, although quite necessary, in the middle of the contractor development programme naturally caused additional problems and lower productivity than would otherwise have been expected. Nevertheless, a cost comparison study using data from Gundo Lashu and other comparable projects has concluded that labour-based methods (LBM) are financially on par with machine-based methods (MBM) of construction, even with the relatively high wage levels in South Africa compared with most other African countries.

The data in tables 1 to 3 below are based on two LBM contracts (restricted tender for training contracts) and one MBM contract (open tender) that were directly comparable with regard to scope, location and pavement design.

Together with a statistical analysis of data from other projects this indicates that LBM is about 25% cheaper in economic terms than MBM.

	Units	LBM	MBM
Average cost per kilometre with 14% VAT	ZAR/km	427,002	426,632
Average cost per kilometre without VAT	ZAR/km	374,563	374,239
Profit and overhead	%	12%	12%
Average cost per kilometre excl profit/o/h	ZAR/km	329,616	329,330
Unskilled lab.	%	45%	12%
Skilled lab.	%	9%	10%
Plant	%	10%	29%
Fuels	%	7%	20%
Materials	%	29%	29%
TOTAL	%	100%	100%
Profit and Overhead	ZAR/km	44,948	44,909
Unskilled lab.	ZAR/km	148,327	39,520
Skilled lab.	ZAR/km	29,665	39,520
Plant	ZAR/km	32,962	95,506
Fuels	ZAR/km	23073	65,866
Materials	ZAR/km	95,589	95,506

Table 1: Financial Cost per Resource per Kilometre (ZAR/km)

	Units	**LBM**	**MBM**
Financial cost of unskilled labour	ZAR/km	148,327	39,520
Cost of unskilled labour per person–day	ZAR/p-day	32.29	35.00
Unskilled labour person-days	p-days/km	4,594	1,129
Assumed Shadow Wage Rate	ZAR/day	10.00	10.00
Economic cost of unskilled labour	ZAR/km	45,936	11,291

Table 2: Calculation of the Economic Cost of Unskilled Labour

Resource	**LBM**	**%**	**MBM**	**%**	**MBM/LBM**
Unskilled lab	45,936	22.9%	11,291	5.0%	0.25
Skilled lab.	29,665	14.8%	32,933	13.2%	1.11
Plant	27,028	13.5%	78,315	31.3%	2.90
Fuels	15,290	7.9%	45,448	18.2%	2.85
Materials	82,206	40.9%	82,135	32.8%	1.00
TOTAL	**200,756**	**100.0%**	**250,121**	**100.0%**	**1.25**

Table 3: Economic Cost Comparison (ZAR/km)

c. Macro and Socio-economic Impacts

In the cost comparison study a model based on a Social Accounting Matrix of the South African economy was used to compare the impacts of LBM and MBM. The inputs to the model were expenditure patterns for LBM and MBM based on the data used for the financial and economic cost comparisons.

For the purposes of running the model, an annual investment of ZAR 3 billion was assumed. The results showed that there were only small differences between MBM and LBM in terms of overall impact on factors of production. However, LBM contributed 28% more than MBM directly and indirectly in terms of GDP, and increased employment sixfold. LBM also showed greater impact on the income of poor households, mainly due to the direct wage effects, providing recruitment was targeted at poorer groups.

Somewhat surprisingly, the generation of jobs elsewhere in the economy due to multiplier effects was similar for MBM and LBM. The reason for this was believed to be the relative small size of the investment compared to the whole South African economy combined with a low elasticity of demand for labour consequent on marginal changes in the demand for products. The conclusion was that much of the extra demand generated by the spending of wages could be met by increases in labour productivity and overtime working in the supplying industries.

There were other noteworthy differences between the use of LBM and MBM relating to socio-economic factors that were not captured by the economic or macro-economic analyses, and which should be considered in terms of justifying any cost premium involved in the use of LBM. These mainly related to the consequences of the employment created. LBM provides more wage income to poorer households than MBM, reducing the depth of poverty. Potentially, LBM may also encourage the setting up of small businesses, the generation of self-employment, increased social stability and lower levels of crime, and improvements in nutrition and education.

However, these impacts depend critically on sustained employment opportunities and complementary inputs (e.g. access to credit), as well as effective targeting of employment to the poor. Short term public works employment, however, has only a limited impact in terms of making a sustained impact on poverty or improving labour market performance.

2. Design and construction of light pavements for Low Volume Sealed Roads (LVSR)

a. Construction techniques

For construction of light pavements for sealed roads, and even for gravel wearing courses when the gravel conforms to wearing course specifications, construction techniques using a steel shutter system, have been adopted (see Annex 1).

The steel shutters, when set out and used correctly will ensure:

- Uniform thickness of the base layer, which is critical for light pavements for LVSR with relaxed specifications;
- A smooth vertical and horizontal alignment
- Correct camber or crossfall
- Excellent riding quality

Experience has shown that most materials, when mixed to OMC and placed loosely between the shutters by means of wheelbarrows and screeded off to the top of the shutters and/or bulking rails, have a bulking factor of 1.5. The shutters can therefore give a visual clue as to when adequate compaction has been achieved and thereby simplify quality control.

Compaction should in any case be done to refusal. Testing has shown that the pedestrian rollers most commonly in use can easily achieve compaction to 98% Mod

AASTHO provided the compaction is done at OMC. A method specification should however be used and simplified control testing be done by means of DPC.

3. Design approach (2005/06 projects)

The design approach recommended to the consultants assigned to the individual projects was to try and implement the SADC Guideline as far as possible in order to minimise the overall cost of the roads. The primary tenets to be followed was to use local materials as far as possible, to design the pavement appropriately for the current and predicted traffic making as much use as possible of the in situ materials and "pavement structure" as possible and to make use of appropriate bituminous seals instead of the less sustainable gravel wearing courses.

a. Workshops

A number of workshops were held. At the first session the relevant content of the SADC guidelines was highlighted, examples of past local experience were discussed and appropriate material and subgrade investigation requirements and techniques were introduced. The workshop attempted to concentrate on the deviations from conventional pavement design processes that were expected from the consultants. Aspects such as compaction to refusal instead of a fixed effort and the importance of good construction control, particularly with respect to layer thicknesses were emphasised.

The Consultants then carried out their field and laboratory investigations and a follow-up workshop was held. Each Consultant made a brief presentation on his investigation and proposed design. The CSIR staff then assessed this information and provided feedback relating to possible different approaches. These included:

- More attention to climatic regime and drainage
- Reduction in pavement thickness (omit selected layers and/or subbase where in situ materials have adequate strength
- Treat in situ materials where appropriate
- Avoid fixed pavement structure for entire road length – adapt structure to local conditions

The result of the last workshop was a redesign of the pavement structures with reduced layers optimising use of the existing pavement structure.

b. Materials investigations

At the time of the last workshop, few of the material test results were available. The use of the shapes of the compaction curves, strength/moisture/density sensitivity assessments (Paige-Green, 2004) was not being employed and recommendations to follow this route were made.

c. Design

Although the SADC Guideline document does not provide specific design options (e.g. catalogues), it provides a detailed section on the philosophies and decision processes necessary to achieve cost-effective and appropriate pavement designs without unnecessarily increasing the risk of failure of the pavement. An extensive list of references regarding specific design issues is provided in the document.

The general rule in the design of LVSR is not to relax more than one critical input parameter simultaneously. If lower quality materials are used for example, it is imperative to ensure that the drainage and construction quality are very good.

The road should be divided in sections that has more or less uniform features in terms of in situ / sub grade materials, traffic, climate and topography. For instance, the pavement on a section with a constant vertical and/or transverse grade can be designed very differently from another flat, low lying section were soaking of the pavement is a potential risk. On the former section only minimal shaping may be needed prior to sealing whereas in the latter lifting of the roads with two or more pavement layers may be required

i. Design philosophy

1. Pavement life

The pavement life should be tailored to the various design inputs, primarily the traffic. If there is doubt regarding the long-term prediction of the traffic on the road, a reduced design life (10 or 15 years) should be used in the design. Many of the roads assessed were based on such reduced lives.

2. Risks

The objective of low volume sealed roads is not to increase the risk of failure. Good engineering judgement is necessary and the factors that could lead to premature failure need to be identified and managed during the design and construction process. Where a higher risk is likely, it is important that this is clearly defined, that the client understands this risk and agrees to carry at least part of the risk in return for economic benefits of the lower cost option.

Even if a premature localised failure caused by variability in the in situ materials that was not picked up during the design, may occur, it will be more economical to the client to accept this “risk” and carry out local repairs as and when needed rather than raising the design standards for the whole project. Such instances should rather be regarded as a result of prudent use of public funds than failures of the client project managers and designers.

ii. Assessment of existing pavement (DCP vs lab CBR)

Experience has shown that an existing earth or gravel road develops an inherent strength under traffic over time. Frequently, this structure is disturbed or even totally lost during upgrading of the pavement as the in situ materials may be of inadequate quality in the laboratory and are thus reworked, treated or removed. In practice these materials are moulded under traffic to their optimum density, which can never be achieved using conventional compaction plant. Use was made of the Dynamic Cone Penetrometer (DCP) test to identify the in situ state of the existing imported materials and the in situ subgrade materials. This provides a strong basis for the identification of pavement cover requirements using an appropriate DCP design profile, of course taking the moisture content at the time of testing into account.

Table 4 illustrates the difference between in situ strength and laboratory 4-day soaked CBR values.

Position	DCP CBR	Soaked CBR at 95%	PI
0+100	30	-	9
0+350	249	3	13
0+700	165	33	20
1+500	792*	2	28
2+100	756*	7	18
2+600	1421*	-	-
3+000	512	10	13
3+600	162	2	21
4+000	1071*	21	17
4+400	373	7	13
4+850	477	18	16
5+500	161	9	12
6+600	-	10	11
7+500	-	7	17
8+200	-	7	13
9+100	138	33	SP
9+300	72	23	5
9+600	4073*	32	16
10+000	122	2	19
10+500	93	13	11

* Refusal on rock

Table 4: In situ strength vs. laboratory CBR (Contract RAL/GL/T384/2005 Mokwakwaila - Lebaka, Mosomo Consulting Civil Engineers)

The results illustrate that to base the design on soaked CBR values in many cases would result in an over design of the pavement structure especially where the drainage is adequately taken care of to ensure that the moisture in the pavement is retained at equilibrium, at which level the pavement strength is considerably higher than 4-days soaked CBR values.

iii. Features of an appropriate design

The most appropriate designs for the types of pavement being considered (ie, low volume sealed roads) optimise the use of the in situ materials (typically improving them through additional compaction) and then placing a single layer of selected local material as a base course. The design, however, needs to be appropriate to the traffic and environment, the latter being handled by a suitable side drainage system. This suitability is a function of the depth of the drains as well as the spacing of mitre drains to remove the water from the edge of the road without excessive scouring or any ponding. Where the local materials are of marginal quality, the first option is to look at improving them through mechanical or chemical stabilization, in order to minimise haulage costs. In addition, if the subgrades are poor, their quality needs to be raised to at least a CBR of 15 per cent (not necessarily a soaked CBR, depending on the topographic environment and climate). The thickness of the base course also needs to be controlled to ensure adequate protection of the subgrade, with a thicker layer where underlying materials are of inadequate strength and/or depth.

Conventional pavement design principles must not be neglected and it is recommended that simultaneous relaxation of more than one property, eg, subgrade strength, base quality, base thickness, drainage, etc, must not be permitted.

iv. Potential for cost savings

The efforts undertaken to arrive at optimum designs for the new projects have shown that cost savings up to 20% can be achieved by following the design philosophy of the SADC Guidelines compared to the common approach, i.e. using inappropriate specifications, one pavement design for the whole road without regard for local variations and the in-built strength of the existing “pavement” and relying on import of materials from borrow pits rather than optimising the use of in situ materials.

On a typical 5km contract costing around R600,000/km these savings could amount to around R500,000. The additional investment of, say, R50,000 for additional materials testing and inputs by the design engineer would thus give a return in the order of 10 times the investment, not bad in anyone’s view.

The twelve open tenders for the 2005/06 contracts for a total of 69,75km came in with an average cost/km of R573,575 for roads varying between 6.5 and 8.0m width. Most pavement designs include some form of stabilisation and full road markings for the wider roads. Considering that these contracts are based on an increased labour wage of R35/daily task as opposed to R30/task for the contracts analysed in the cost comparison study, the costs seemingly compare favourably to those used for the study.

v. Economic analysis using Supersurf

The costs and benefits of each project were determined using SuperSurf (Sabita 2005), with the existing unsealed road being the base case and the proposed design being the alternative. SuperSurf allows the inclusion of various economic influences such as shadow costs for labour (particularly relevant to labour based projects in rural areas with high unemployment), social benefits and environmental costs and benefits.

The results obtained form a SuperSurf analysis for a road with relatively high traffic (about 400 vpd) are summarised in Annex 2. It is seen that without any social benefits, the Internal Rate of return is about 19 per cent but including various nominal social benefits equivalent to about R3,000 /km/year the Internal rate f return increases to nearly 27 per cent. Additional discussion regarding the analyses is included in Annex 2.

4. Trial Sections

With the huge task of improving the low volume rural road network in most African countries, the use of proprietary soil stabilization products should not be overlooked, especially because some of these products lend themselves to labour-based methods of construction by dilution of the product in the compaction water.

During construction of one of the roads in the Waterberg district, the opportunity arose to include a number of short trial sections using various proprietary soil stabilizers. Unfortunately, many of these proprietary products, although seemingly presenting viable solutions and cost benefits, have not undergone rigorous independent testing and long term performance monitoring. These products were used to improve the local materials in preference to importing alternative materials.

During the design period, various suppliers of chemical stabilizers were approached with regard to supplying product for the trial sections. A number of suppliers indicated their willingness to provide chemical and supervise its application. Initially 4 prospective roads in different material, traffic and climatic environments were identified and appropriate chemicals for the situations were identified.

However, logistics of the project finally resulted in three chemicals (Permazyme, RBI Grade-81 and Ecobond) being applied at one experimental site. The trial sections include two control sections, one using the in situ material and the other cement. The trial sections consist of 100 mm of treated material (base course) over a compacted subgrade.

a. Trial section data

Testing of the local materials was carried out prior to construction and each of the chemical suppliers was required to determine the optimum application rate of their product based on the soil properties provided. The option was also given for them to carry out their own testing on the relevant soils to ensure that their products would in fact be suitable for the purpose. Samples were collected from each site during the first site visit by CSIR and provided the following test results (see Table 5).

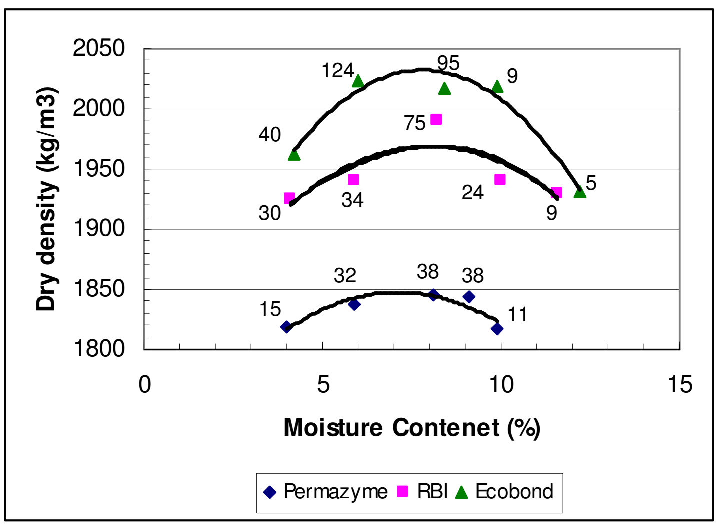

Table 5: Density and strengths of raw (untreated) materials from each trial section (labels at each point are <u>un-soaked</u> CBR values on each mould)

i. In situ material

The in situ material consists of transported and residual materials. These include fine wind-blown sands, nodules of ferricrete and residual/transported weathered granite/gneiss and arkosic sandstone. Samples from each test site were tested as described above. This same material was treated with the various stabilizers in the trial sections. It is, however, clear that despite the visual similarity and close proximity of the materials at the trial section sites, significant differences in density and strengths occur. The moisture and density susceptibility of the unsoaked CBR strengths of the materials is also clearly shown in by the labels in the figure.

ii. RBI

RBI Grade-81 is an environmentally friendly, inorganic, hydration activated powder-based stabilizer that reacts with soil particles to create layers that are interconnected through a complex inter-particle framework (Anyways Solutions Marketing CD). The product is provided as a powder that is mixed in with the soil as for conventional lime or cement stabilization.

iii. Permazyme

Permazyme has apparently been used extensively internationally but has had limited exposure in South Africa. Permazyme is a non-toxic formulation of enzyme-rich materials that is manufactured through a natural fermentation process using only 100% natural, organic compounds (Permazyme web site). When mixed with water and applied prior to compaction, Permazyme acts upon the soil's organic fines through a catalytic bonding process, producing a strong cementation effect. The product is marketed as a solution.

iv. Ecobond

Ecobond is a urea formaldehyde polymer bituminous resin that considerably hardens a very wide range of soils (even fine sand) and makes these water-resistant. This turns soil into a valuable new building material for the construction of roads, houses, ponds, etc. ("Ecobond Township and Rural Roads" marketing brochure). The trial sections were constructed in two layers with an application rate of 1.45 per cent in the lower compacted 66 mm and 2.2 per cent in the upper compacted 84 mm.

v. Cement

The trial section using cement has still to be constructed.

vi. Other products

There is a host of other products available on the market with potential to be of good use in certain soils, e.g. polymer based products and ionic soil stabilisers. Acrylate polymer based products tend to be quite expensive and their use must be carefully assessed for suitability and cost compared with the alternatives. Ionic soil stabilisers have been successfully used in clays and high PI materials and could be a viable solution due to their comparatively low cost.

b. Trial section test results

The test results from the trial sections available at the time of preparation of this paper are summarised in Table 6.

There are currently insufficient data to draw any conclusions but there is a trend of increasing strength with time. This needs to be assessed with consideration of the drying out of the layer with time, as none of the sections had been sealed at the time of the final testing. Visually most of the sections appeared hard but were overlain with a thin layer of wind-blown sand during the final inspection reported on 14 June 2005.

Product and date of testing	Mean test result		
	Moisture content (%)	In situ density (kg/m^3)	Approx in situ CBR (from DCP)
RBI Grade-81			
12/04/05	5.2	1914	87
29/04/05			93
17/05/05			110
01/06/05			95
14/06/05	4.4	1855	247
Permazyme			
12/04/05 (being constructed)	8.5		-
17/05/05			30
01/06/06			93
14/06/06	2.0	1955	300
Ecobond			
05/05/05 (being constructed)	13.9		-
17/05/05			62
01/06/06			110
14/06/06	3.0	1958	296

Table 6: Initial test results of treated bases in trial sections

5. Sealing Options

Different sealing techniques are also being tried and assessed in this programme. Some seals, although with relatively high labour content, require hot bitumen and spreading by a bitumen tanker. Hot bitumen poses a potential health hazard and the tanker a problem when it is delayed or has mechanical problems. For such seals to be economical long stretches of base (1 to 1.5 km) must be prepared and risk being damaged by traffic and/or weather before the sealing operation can take place. Seal-as-you-go techniques using emulsions or cold-mix asphalt can therefore remove most of the headaches for a labour-based contractor and be technically and economically viable solutions.

The use of appropriate sealing technology on this type of project thus has significant cost and practical benefits. These obviously have to be compared, however, with any costs associated with possible premature resealing or shorter surfacing lives. The major benefits are normally associated with the use of natural materials with minimal processing requirements. Sand- and Otta Seals fall into this category.

Both the costs and lives of the various surfacings depend on numerous factors. Costs are primarily affected by the project location (haulage of binder and aggregate), degree of competition amongst contractors, size of project, terrain, etc. The surfacing lives are affected primarily by climate (rain and temperature) but also by traffic, nature of the pavement structure (eg, deflection), presence of animals and steel wheeled vehicles, maintenance, etc. The need to repair base (and often the prime) prior to sealing as a result of trafficking of the completed sections of base and/or primed base can affect the contractors progress and time schedules significantly, be costly and usually results in a below par riding quality.

Seal type	Suitability for LBM (labour component)	Costs (relative to single seal)	Expected life (years)	Advantages	Disadvantages	Comments
Single chip	Marginal	1	4-6	Proven track record	Hot binder Costly aggregate	Requires good design and construction quality
Sand	Very good		1 - 4	Local aggregate	Needs second seal within 8 moths to one year	Insensitive to poor application
Slurry	Very good		2 - 4	Prepare on site	Grading critical Very thin	Needs very smooth base
Otta	Good		8 - 10	Local aggregate No prime required	Requires hot binder	Needs sand seal as well
Double Otta	Good		10 - 14	Local aggregate No prime required	Requires hot binder	Double mobilisation for second application
Grav seal	Good		8 – 10 ?		Use proprietary bitumen products, Processed aggregate Hot binder	Commercial product
Cape Seal	Good		8 - 10	Smooth finish	Processed aggregate Hot binder	Construction not as critical as chip seal alone
Otta/grav using emulsion	Very Good		8 – 10 ?	Cold binder	Processed aggregate	Specifications still to be established
Cold mix asphalt	Very Good		10+ ?	Cold binder, Self healing of minor cracks?	Use proprietary bitumen products, High cost	
Hot mix asphalt	Poor		15 - 20	Low maintenance	High cost	

Table 7: Comparison of different seals (SADC , 2005: Sabita, 1992; Botswana Road Department, 2002)

6. Maintenance

The maintenance related to the treated sections cannot be quantified at present. However, as these sections will all be surfaced, provided the in situ strength of the layers is the same as any other equivalent layer (natural or stabilized with conventionally materials), the maintenance needs should not differ from a conventional product. Typically the performance of the layers is primarily a function of the seal, which should be maintained following normal principles, ie, crack sealing, pothole patching and repair of damage resulting from accidents or flat wheels.

7. Conclusion

The Gundo Lashu programme has provided very good opportunities to implement recent research and developments in the low volume sealed roads arena.

For a successful implementation of the SADC Guidelines in project design it is vital to have informed clients as well as designers. The design period needs to be long enough to accommodate all the detailed site investigations needed to arrive at the most economical design. These projects have shown that a modest increase in money spent on the design may give huge returns in terms of savings on construction costs.

The implementation of the guidelines, however, probably requires more engineering judgement and understanding than required using a conventional catalogue-type pavement design.

8. References

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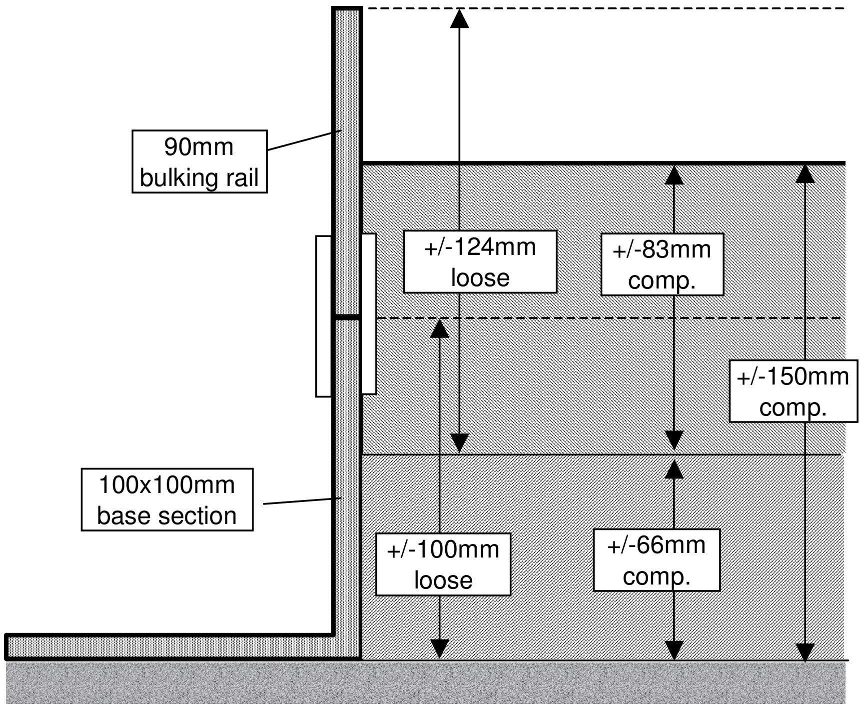
9. Acknowledgements

The assistance provided by Mr Abrie Cilliers of Mosomo Consulting Engineers Pty (Ltd) with actual costs and other data is gratefully acknowledged.

Annex 1: Illustration of use of shutter system and camber block



Construction of 150mm Base layer

The layer is too thick to b e compacted in one layer. Using the shutters and bulking rails the base is constructed in steps as follows:

1. Correct sub-base/subgrade to within+/-10mm from correct level
2. Moisten and scarify the surface of sub-base/subgrade to obtain bonding to the base
3. Mix base material to OMC, fill loose material and screed off to top of base section. Compact to refusal.This will give a first layer of +/- 66mm.
4. Scarify the surface to obtain bonding to the next layer.
5. Place 90mm bulking rail on top of the base section. Mix base material to OMC, fill loose material and screed off to top of bulking rail. Compact ot refusal. This will give a second layer of +/-83mm and a total thickness of the compacted base at +/- 150mm.

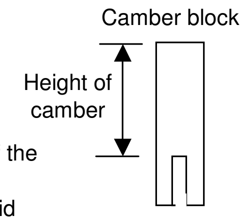
Construction of 120mm Base Layer

The layer is too thick to be compacted in one layer. Follow the steps above, but replace the 90mm bulking rail with the 50mm rail.

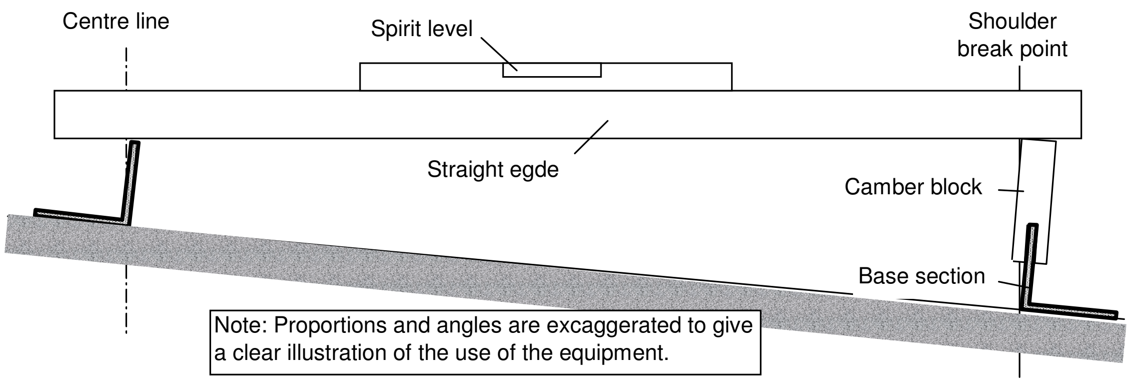
Construction of 100mm Base Layer

This can be done in one layer by following steps 1, 2 and 3 above except that the 50mm bulking rail is now placed on top of the base section before placing and screeding off the material. Compaction to refusal will give a resulting thickness of +/- 100mm.

Road width (m)	Camber %	Height of camber (mm)
8.0	3.5	0.14
6.3	3.5	0.11
5.5	3.5	0.10



Three standard camber block have been provided, one for each of the most commonly used cross sections. Be sure to mark them with a permanent marker and keep the ones not in use off the site to avoid mixing them up.

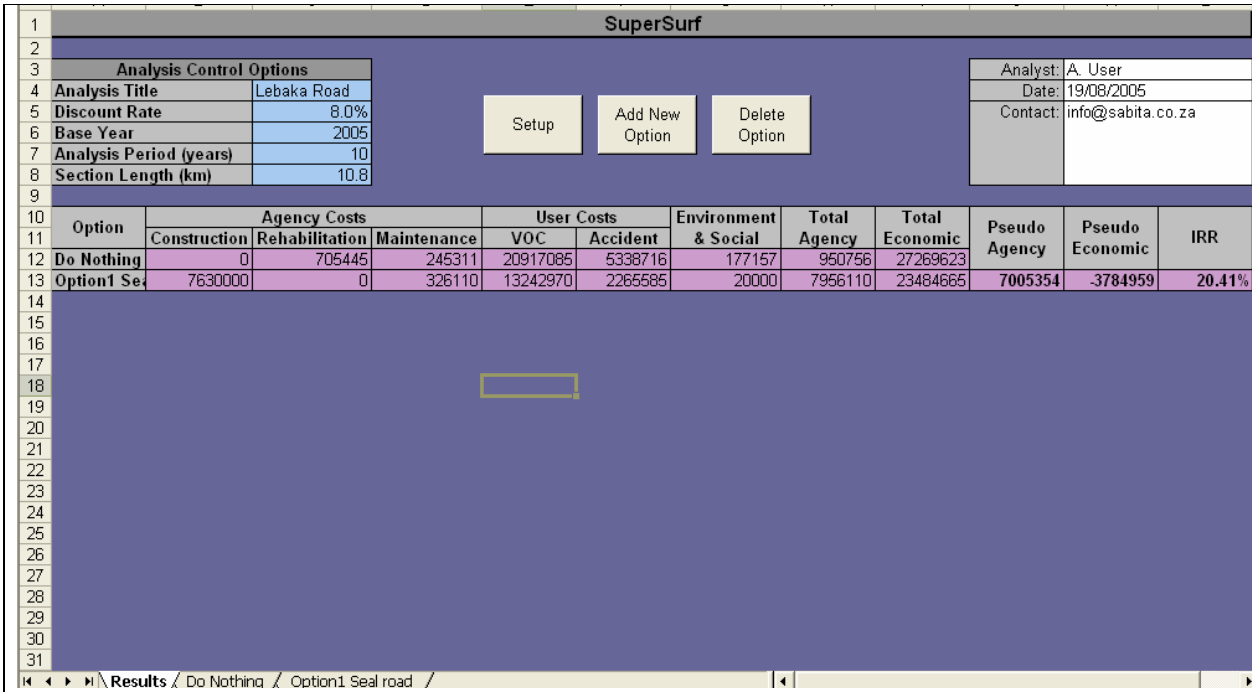


Setting out / checking for correct camber

1. Place the shutter base section in the correct position according to the road width, i.e. one at the centre line and the other at shoulder break point.
2. Put the correct camber block on top of the outer base section
3. Put the straight edge across from the camber block to the centre base section
4. Check with the spirit level if the straight edge is horizontal. If so, the camber is correct at 3.5%.

Annex 2: Results of SuperSurf analysis

SuperSurf analyses were carried out on the roads and the following is a typical example for an existing road currently carrying about 400 vpd.



SuperSurf

Analysis Control Options	
Analysis Title	Lebaka Road
Discount Rate	8.0%
Base Year	2005
Analysis Period (years)	10
Section Length (km)	10.8

Analyst:	A. User
Date:	19/08/2005
Contact:	info@sabita.co.za

Option	Agency Costs			User Costs		Environment	Total	Total	Pseudo Agency	Pseudo Economic	IRR
	Construction	Rehabilitation	Maintenance	VOC	Accident	& Social	Agency	Economic			
Do Nothing	0	705445	245311	20917085	5338716	177157	950756	27269623			
Option1 Sea	7630000	0	326110	13242970	2265585	20000	7956110	23484665	7005354	-3784959	20.41%

Figure A2.1: SuperSurf analysis excluding social benefits

The road currently needs regravelling and this is shown as a rehabilitation cost in the analysis (Figure A2.1). A small environmental cost related to the regravelling, blading and dustiness is included in the analysis. It is clear that the initial outlay for the construction is considerably higher than the gravel option and in fact the overall agency cost is considerably higher, the pseudo economic benefit over a period of 10 years has a net present value of in excess of three million rand or an Internal rate of return of just over 20 per cent.

In Figure A2.2, nominal social benefits relating to improved quality of life, opportunity costs and road safety amounting to about R30,000 per km/yr have been included. This results in an increase in the IRR to about 26 per cent. The environmental costs have been limited to the same environmental costs of gravel required for initial construction as those for regravelling the road.

SuperSurf

Analysis Control Options	
Analysis Title	Lebaka Road
Discount Rate	8.0%
Base Year	2005
Analysis Period (years)	10
Section Length (km)	10.8

Setup | Add New Option | Delete Option

Analyst:	A. User
Date:	19/08/2005
Contact:	info@sabita.co.za

Option	Agency Costs			User Costs		Environment & Social	Total Agency	Total Economic	Pseudo Agency	Pseudo Economic	IRR
	Construction	Rehabilitation	Maintenance	VOC	Accident						
Do Nothing	0	705445	245311	20917085	5338716	-185187	950756	26907279			
Option1 Sea	7630000	0	326110	13242970	2265585	-2154066	7956110	21310598	**7005354**	**-5596681**	**26.53%**

Results / Do Nothing / Option1 Seal road

Figure A2.2: SuperSurf analysis including social benefits