

Alternatives to Conventional Gravel Wearing Courses on Low Volume Roads

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Abstract

Gundo Lashu, the 'Labour Intensive Rural Roads Maintenance Programme' that is currently being implemented in Limpopo Province, South Africa has set out to train 24 emerging contractors in rehabilitation of rural gravel roads. All 24 contractors have gone through an extensive practical and theoretical training programme and are currently executing their first Trial Contracts, which forms the second step in their development programme.

Labour intensive programmes in South Africa have a chequered history, mostly having been implemented as short-term relief programmes. For this and other reasons, the concept has not gained the necessary acceptance by the engineering community nor among decision-makers at provincial or national level. The initiative taken by Limpopo Province and the province's long-term commitment to the programme has potential to buck this trend and lead the way in a currently conducive political climate towards a wider acceptance of labour-based methods as a sound technological approach and as a tool for alleviating poverty, unemployment and related social problems.

South African rural roads generally carry much more traffic than the rural road network in the rest of sub Saharan Africa with many gravel roads carrying up to 1000 vpd. At the lower end, there is a vast network (nobody really knows the exact extent) of district and community access roads carrying less than 100 vpd, which is largely unimproved and maintained only as bladed tracks. In addition, there are probably hundreds of thousands of kilometres of unimproved village roads and streets. The potential for large-scale application of labour-based road works is therefore enormous.

Delivery of a quality product is seen as key to the acceptance of labour-based road works. In Gundo Lashu it was realised early on that finding good quality wearing course gravel in itself constituted a major problem in many areas of the province and thus bringing the costs for a fully rehabilitated and gravelled 5.5m road to about R230,000 (~USD29,000 @ R8/1USD) in some instances. Aside from depleting an ever more scarce resource, construction and maintenance of conventional gravel roads would be very costly.

The Roads Agency Limpopo, which is implementing the Gundo Lashu programme, engaged CSIR to carry out a case study based on the second batch of Trial Contracts to be executed in areas where good wearing course gravel was scarce or non-existent. The aims of the study are to:

- *Assess different options to provision and maintenance of a good gravel wearing course, in financial and economic terms as well as suitability for labour-based operations;*
- *Carry out full scale trials of the recommended options;*
- *Establish best practice construction and maintenance techniques and development of guidelines and training material.*

Preliminary results of the study have shown that better use and/or improvement of in situ material by emulsion or chemical stabilisation in combination with provision of various low cost bituminous seals results in lower predicted life-cycle costs than the gravelling option for the roads in question. Sand-cushioning would also be a more favourable alternative where the specified gravels are scarce and traffic is low. Aside from the potential financial/economic benefit, the alternative solutions would have considerable intangible or non-quantifiable benefits such as elimination of dust pollution, reduced negative environmental impact and conservation of valuable resources in the form of gravel deposits.

All options under consideration are eminently suitable for labour-based techniques. Thus, if chosen, they would retain more or less the same employment potential but shift costs away from plant (graders, tippers, tractor/trailers) towards materials (bitumen, chemical stabiliser).

It is envisaged that labour-based contractors can use the techniques successfully on roads carrying up to 200-300 vpd and thus cover a large proportion of the rural road network. Aside from retaining the employment benefit, the potential savings in construction and maintenance costs may be used to construct more roads and thus provide a larger proportion of the rural population with good quality access roads of an appropriate standard and contribute to economic development of previously disadvantaged communities. The implementation of community-based maintenance programmes is an essential part of the works programme.

INTRODUCTION

Gundo Lashu, the 'Labour Intensive Rural Roads Maintenance Programme' which is currently being implemented in Limpopo Province, South Africa has set out, *inter alia*, to train 24 emerging contractors in rehabilitation of rural gravel roads. All 24 contractors have gone through an extensive practical and theoretical training programme and are currently executing their first Trial Contracts, which forms the second step in their development programme.

Labour intensive programmes in South Africa have a chequered history, mostly having been implemented as short-term relief programmes. For this and other reasons, the concept has not gained the necessary acceptance by the engineering community nor among decision-makers at provincial or national level. The initiative taken by Limpopo Province and the province's long-term commitment to the programme has potential to buck this trend and lead the way in a currently conducive political climate towards a wider acceptance of labour-based methods as a sound technological approach and as a tool for alleviating poverty, unemployment and related social problems.

The ruling party, African National Congress, resolved in December 2002 that government must make more use of labour-based public works programmes in an attempt to bring more people out of poverty and become part of the mainstream

economy. This has since been reiterated by the President, Thabo Mbeki and preparations for an Expanded Public Works Programme is currently underway. The programme will be vested in a special unit of the National Department of Public Works which will oversee and co-ordinate the implementation and support the various implementing agencies at provincial and municipal level.

POTENTIAL FOR LABOUR-BASED ROAD WORKS IN SOUTH AFRICA

South African rural roads generally carry much more traffic than the rural road network in the rest of Sub Saharan Africa with many gravel roads carrying up to 1000 vpd. A significant portion of the provincial roads carries traffic from 100 to 400 vpd. At the lower end, there is a vast network (nobody really knows the exact extent) of district and community access roads carrying less than 100 vpd, which are largely unimproved and maintained only as bladed tracks. In addition, there are hundreds of thousands of kilometres of unimproved village roads and streets (Table 1). The potential for large-scale application labour-based road works is therefore enormous and only limited by the funding available for the sector.

Table 1: Extent of functional road types in South Africa¹

Road Category	Length (km)	Per cent of total (%)
National	6 713	0.8
Provincial surfaced (rural)	56 464	7.1
Provincial gravel (rural)	300 954	38.1
Formal urban	168 058	21.3
Informal urban	36 908	4.7
Unproclaimed rural	221 092	28.0
<i>Local access roads and tracks</i>	136 589	
<i>Local distributor</i>	57 965	
<i>Access collector</i>	26 538	
Total	790 189	100.0

CONDITIONS FOR A BROAD ACCEPTANCE OF LABOUR-BASED TECHNOLOGY

Delivery of a quality product is seen as key to the acceptance of labour-based road works. In Gundo Lashu it was realised early on that finding good quality wearing course gravel in itself constituted a major problem in many areas of the province, thus bringing the costs for a fully rehabilitated and gravelled 5.5m wide road to about R230 000 (~USD29,000 @ R8/1USD) in some instances. Aside from depleting a scarce resource of potential material for sealed roads the cost of construction and maintenance of conventional gravel roads that will provide a generally poor quality wearing gravel course material is high.

A continuation of the (re)gravelling approach was therefore seen as a threat to the general acceptance of LBT even if the technology in itself could not be blamed for not producing roads that would stand up well over time and provide a reasonably safe and comfortable drive for the motorised road users. It should be noted in this regard that concern about the quality of the wearing course gravel to a large extent seemed to be non-existent among consulting engineers and project managers in the maintenance of

the gravel road network. Finding alternative solutions hence became a necessity for a successful continuation of the programme and key to the broad acceptance and establishment of the technology in the road sector.

The Roads Agency Limpopo, which is implementing the Gundo Lashu programme, therefore engaged CSIR to carry out a case study based on the second batch of Trial Contracts, which were to be executed in areas where good wearing course gravel was scarce or non-existent. In one of the areas, the in situ material consists predominantly of Kalahari-type sands whilst in the other area the in situ material is mostly low- or non-plastic weathered granite.

The main objectives of the study were to:

- Assess different alternatives to provision and maintenance of a good gravel wearing course, in financial and economic terms as well as suitability for labour-based operations;
- Carry out full scale trials of the recommended options;
- Establish best practice construction and maintenance techniques and development of guidelines and training material.

Preliminary results of the study (Table 2) showed that better use and/or improvement of in situ material by emulsion or chemical stabilisation in combination with low cost bituminous seals would in fact be cheaper than the gravelling option for the roads in question. Sand-cushioning would also be a more favourable alternative where the gravel specifications could not be met. Aside from the potential financial/economic benefit, the alternative solutions would have considerable intangible or non-quantifiable benefits such as elimination of dust pollution, reduced negative environmental impact and reduced use of valuable resources in form of gravel deposits.

Road	Action	Estimated Construction costs (R/km)	Total Life Cycle Costs (R/km) ^a	Recommended action	Trial sections
D3342 and D3348 Bochum	TRH 20	173 546	440 603	Pave in situ with double seal ^b Non TRH20 & extra maintenance	Chemical treatment Bitumen emulsion
	Non TRH20 + additional maint	92 600	409 858		
	Sand cushion	210 000	408 000		
	Paved TRH 20	228 000	460 201		
	Pave in situ	110 000	352 928		
	Pave local import	147 600	387 110		
	Pave treated in situ	195 000	411 090		
	Paved imported and treated	235 000	447 454		
D4263 and D4262 Km 12-24 Jane Furse (30 vpd)	TRH 20	196 333	436 583	Pave in situ with double seal ^b Non TRH20 & extra maintenance Sand cushioning	Chemical treatment Bitumen emulsion
	Non TRH20 + additional maint	92 600	389 194		
	Sand cushion	216 000	413 455		
	Paved TRH 20	247 000	427 946		
	Pave in situ	107 000	300 673		
	Pave local import	139 600	330 310		
	Pave treated in situ	167 600	386 181		
	Paved imported and treated	191 600	407 999		
D4263 and D4262 Km 0 - 12 Jane Furse (78 vpd)	TRH 20	221 222	847 400	Pave in situ with double seal ^b	Chemical treatment Bitumen emulsion Non TRH20 & extra maintenance
	Non TRH20 + additional maint	92 600	815 576		
	Sand cushion	231 222	772 795		
	Paved TRH 20	276 222	765 645		
	Pave in situ	107 000	611 807		
	Pave local import	139 600	641 444		
	Pave treated in situ	177 600	747 975		
	Paved imported and treated	221 600	787 975		
D4263 and D4262 Km 24 - 32 Jane Furse (145 vpd)	TRH 20	180 000	1 265 611	Pave in situ with double seal ^b	Chemical treatment Bitumen emulsion
	Non TRH20 + additional maint	92 600	Not practical		
	Sand cushion	231 222	Not practical		
	Paved TRH 20	247 000	1 122 461		
	Pave in situ	107 000	995 198		
	Pave local import	139 600	1 024 825		
	Pave treated in situ	195 000	1 187 713		
	Paved imported and treated	221 600	1 211 895		

a) Economic costs over a 20 year analysis period

b) The use of in situ base and a double seal should be the first choice in all cases. Where the in situ materials do not allow this (ie CBR < 45 per cent), locally imported material (haul < 2 km) should be assessed prior to treatment of local or imported material. For the low traffic roads, the use of Non-TRH 20 materials with extra maintenance or sand cushioning is the second choice.

All options under consideration are eminently suitable for labour-based techniques. Thus, if chosen, they would retain more or less the same employment potential but shift costs away from plant (tippers, tractor/trailers) over to materials (bitumen, chemical stabiliser).

It is envisaged that labour-based contractors can use the techniques successfully on roads carrying up to, say, 200-300 vpd and thus cover a large proportion of the rural road network. Aside from retaining the employment benefit, the potential savings in construction and maintenance costs may be used to construct more roads and thus reach a larger proportion of the rural population with good quality access roads of an appropriate standard and contribute to economic development of previously disadvantaged communities.

Constructing sealed roads, no matter the type of seal to be applied, required a slight review of the construction techniques traditionally applied for labour-based gravel roads and a more selective choice of in situ materials to be used for the layer works. By simple means, it is thus possible to construct high quality sealed roads to a lower overall cost than a dusty, corrugating gravel road.

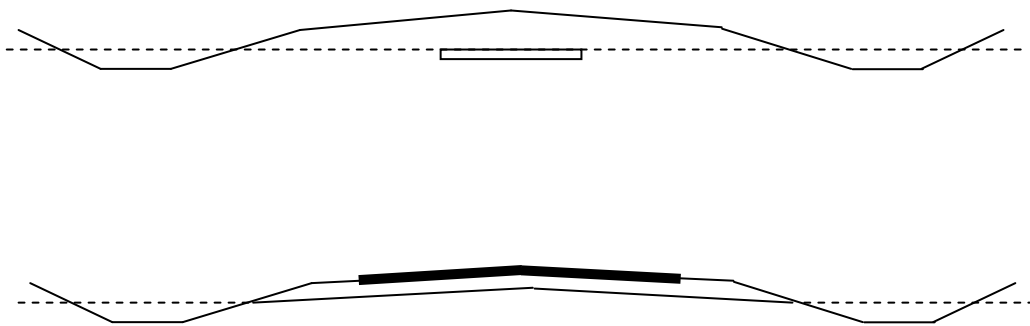


Figure 1: The old method (top) results in weak spots and biscuit layers in construction of the formation (subbase). The revised method (bottom) ensures controlled moisture content, optimum compaction of the layers and a uniform thickness of the base

Thus by broadening the scope for application of labour-based technology on a large scale and producing durable high quality assets which are seen to be an engineered product, embracement of the technology by a conservative engineering community should be forthcoming. Perhaps the LBT community for has been trapped in the “gravel road syndrome” too long? It is well known that rehabilitation of gravel roads is not regarded by many engineers as proper engineering, but merely as a maintenance function. Moving a step up to low cost sealing could therefore be the trick to finally ensure acceptance of the technology and the sustainability of labour-based road programmes beyond the ever-recurring pilot phase.

PREVIOUS EXPERIENCE WITH LOW-COST SURFACING

Significant experience has been built up in South Africa^{2,3} and elsewhere⁴ regarding the application of surface seals to existing gravel roads to provide appropriate low volume sealed roads. Provided the existing wearing course materials have an adequate strength (a soaked CBR of 45 per cent is adequate for most roads carrying less than about 50 vehicles per day and 60 per cent will suffice for roads carrying up to about 100 vpd), application of a suitable seal will provide a significantly better road than any unsealed equivalent.

Appropriate seals include double sand^{5,6} and grit seals and the Otta seal⁷, all of which are highly tolerant to low experience contractors and have significant benefits in that they make use of local materials (of substandard strength compared with normal requirements) requiring minimal processing. The majority of the material source is used, unlike conventional chip seals that make use of only a small proportion of the total source.

The successful use of this type of pavement design depends on attention to a number of construction practices:

- Drainage – It is essential that effective side-drains be constructed with invert levels at least 300 and preferably 450 mm below the pavement crown level.
- Materials – The materials must be as uniform as possible and meet the design requirements.
- Compaction – All gravel layers should be compacted to refusal for the plant available and not a specified density. It is necessary, however, that a minimum density is achieved in all cases, preferably 98 per cent of the modified AASHTO maximum dry density. It is thus essential that adequate compaction water is available and this is uniformly distributed through the material at as close to optimum moisture content as possible.
- Maintenance – A good maintenance capability, which is regularly implemented, is necessary. This must ensure that cracking, potholes and vehicle or animal damage to the surfacing are timeously repaired and all drainage structures are clean and effective. This should ensure a sustained community labour involvement.

DISCUSSION OF THE FINANCIAL/ECONOMIC ANALYSIS OF THE CASE STUDY

A summary of the economic analyses of the options was provided in Table 1. Details regarding specific aspects of the project are provided in Tables 3 and 4.

Table 3: Cost per kilometre of individual treatments for Bochum cluster roads

Alternative	Present Worth of Costs (R)		Net Present Value (R)	
	Financial	Economic	Financial	Economic
TRH20	186 945	440 603		
Non TRH20 + extra maintenance	139 479	409 858	47 466	30 745
Chemical/bitumen treatment & seal	245 956	411 090	-59 011	29 513
In situ	282 320	447 454	-95 375	-6 851
Imported < 2 km				
Sand Cushioning	194 233	408 000	- 7 288	32 603
Paved TRH20 material	275 956	460 201	- 89 011	-19 598
Paved local material				
In situ	168 683	352 928	18 262	87 675
Haul < 2 km	202 865	387 103	-15 920	53 500

Table 4: Cost comparisons per kilometer for Road D4264 (traffic 145 vpd)

Alternative	Present Worth of Costs (R)		Net Present Value (R)	
	Financial	Economic	Financial	Economic
TRH20	237 022	1 265 611		
Non TRH20 + extra maintenance	223 162	1 319 424	Not practical	
Chemical/bitumen treatment & seal	423 596	1 187 713	-186 594	77 898
In situ	447 778	1 211 895	-210 756	53 716
Imported < 2 km				
Sand Cushioning	214 763	1 174 191	Not practical	
Paved TRH20 material	369 524	1 122 461	-132 502	91 420
Paved local material				
In situ	242 301	995 198	-5 279	270 413
Haul < 2 km	271 938	1 024 825	-34 916	240 786

Table 3 summarises the Present Worth of Costs (PWoC) and Net Present Values (NPV) of a typical section of road carrying about 30 vehicles per day. The analyses are presented as both financial costs (ie, the cost to the road authority) and economic costs (the cost to the road authority and the road user) and shadow costs were used for all input costs. All analyses were carried out over a 20 year analysis period using a discount rate of 10 per cent. Construction and maintenance costs were based on the best

currently available estimates (the analyses will be reworked at the end of the projects using the actual costs determined during the projects).

Six basic alternatives were analysed:

- TRH 20⁸ – Conventional regravelling with materials complying with the South African gravel wearing course material standard.
- Non TRH 20 material with extra maintenance - This option would make use of the local materials, generally with inadequate plasticity to avoid corrugation and ravelling, with additional maintenance to ensure an acceptable riding quality.
- Chemical/bitumen treatment with a seal – This option assessed the costs of treating the in situ material with either bitumen emulsion or a proprietary soil chemical stabilizer. Included in this option was that of importing local material from adjacent to the road, where the in situ material could not be suitably treated.
- Sand cushioning – This is an option that makes use of a thin layer of sand to protect the gravel wearing course from vehicle wear. It requires good conventional gravel wearing course material and regular low-cost maintenance (sand replacement and dragging), but minimises the loss of the imported gravel wearing course.
- Paved TRH 20 material - The option of paving material imported for a conventional gravel wearing course was assessed. This is typically a poor alternative, as the gravel wearing course necessarily requires cohesion and is thus often excessively water sensitive to perform as a good base course under a bituminous seal.
- Paved local material – Inspection of the local materials indicated that many of them would probably perform successfully as a base course. The options of sealing them directly as well as importing local materials from adjacent to the road were analysed.

It was clear from the results that:

- In financial terms, only the use of non-TRH20 materials with additional maintenance and the sealing of in situ local materials have direct cost advantages.
- Sand cushioning has slight cost disadvantages in financial terms.
- The economic analyses indicate that all options except the sealing of TRH20 materials and the treatment and paving of imported materials are beneficial. Where the in situ materials are not suitable for sealing directly, the sealing of imported materials (< 2km haul) without treatment is the most cost-effective solution in all cases.
- The total savings (economic) generally exceed the difference between construction costs on any sections of the roads: the results thus indicate that for the roads analysed, the TRH 20 option is mostly the least cost effective.

For the low traffic prevailing on these roads, sand cushioning and the use of non TRH20 gravels with additional maintenance would result in the need and necessary development of sustainable local maintenance capabilities.

However, the options of sealing local materials (with or without treatment) are significantly more beneficial than the non-sustainable practice of replacing gravel lost through traffic and erosion associated with the unsealed road options (other than the sand-cushioning to a significant extent). The maintenance cost of the paved options was selected to be high, providing sustainable employment for a number of teams for the service life of the road, although it is anticipated that maintenance will be less and a higher proportion of the maintenance costs will be directed to materials. Other benefits such as dust reduction and an overall improved riding quality of the road (with a reduction in vehicle operating costs of about 23 per cent) would be obtained with the paved options. This type of saving in vehicle operating costs can be significant to a rural community such as this, where transportation is an important cost.

Similar findings were generally determined for Road 2464 (Table 4). The expected traffic on this section of the cluster, however, would make the use of non-TRH 20 type materials and sand cushioning impractical. The maintenance required would present a severe traffic disruption and safety hazard.

The expected cumulative E80s for this road will exceed the design E80s after about 8 years, where after rehabilitation will be required. A reseal and second rehabilitation would be required within the 20 year analysis period. The TRH20 design, on the other hand would require regravelling three times in this period necessitating the use of about 33 000 m³ of gravel and would require grading about once a month initially and more frequently for the last 7 years.

The financial net present values of the paved options are slightly worse than the TRH20 option, only marginally worse when the in situ material can be used. All options are economically beneficial, primarily as a result of the large savings in road user costs related to the better road surface provided by paving the road. Road user cost savings of up to 25 per cent would accrue to the community.

It is interesting to note that the use of chemical stabilizers or bitumen emulsion treatment is the least cost-effective of all options in financial terms but has significant benefits in economic terms. Where suitable base course quality materials cannot be sourced locally, improvement using chemical or bitumen emulsion stabilization should thus be considered. The use of these products generally has high construction costs but low overall life-cycle costs, provided they perform as expected. The maintenance needs and techniques for these are currently unknown.

TECHNICAL SOLUTIONS FOR THE PRACTICAL TRIALS

The technical solutions have mostly been discussed in the previous section. The final proposals, however, include a number of innovations.

In the granitic terrain, the in situ material has a CBR value well in excess of 80 per cent and can thus be used directly as a base course with a bituminous seal. It is proposed that the local sand would provide an appropriate sand seal (a double seal is required to minimise animal hoof damage). It is also proposed that the top 50 mm of the base will be enriched with a dilute emulsion to both permit traffic movement prior to sealing and to avoid the necessity for a prime. Assessment of the slope of the CBR density curve⁹ indicated that the strengths of the materials are density sensitive and a high degree of compaction is essential.

In the sand terrain, the in situ material has a CBR of about 30 per cent while the cleaner Kalahari type sands have strengths in excess of 45 per cent. The proposal is to treat the in situ materials and sand with a diluted emulsion and a nominal cement application (to assist with breaking of the emulsion) and surface the road with an Otta seal. The aggregate for the Otta seal can be obtained from an existing borrow pit some 10 km from the project, by ripping, gridding and scalping the plus 16 mm to provide a suitable aggregate for the Otta seal.

The possible use of proprietary chemical stabilizers will also be investigated on an experimental basis with the construction of various short trial sections making use of both sprayed on and mixed in processes. These sections will also be sealed.

The construction process will make use of premixing and shuttering to ensure uniformity of the material and to directly control the density and compaction.

SOCIAL IMPACTS

Employment Potential

The low cost sealing options have been shown to have an enormous potential for improvement and upgrading of the rural road network. It is anticipated that the general acceptance of the technology that is likely to be achieved will ensure sustainability of labour-based programmes beyond the pilot-phase and pave the way for large-scale implementation. The overall social impact is therefore also likely to be significantly higher than a programme limited to earth- and gravel road rehabilitation and maintenance. Perhaps only then can one have hope of any significant and lasting contribution to the alleviation of poverty and unemployment.

A detailed analysis of the required labour inputs for the low cost sealing options compared to the gravelling option will be carried out. It is anticipated that the analysis will show no significant difference between the two (sealing will require some more labour for the layer works but less for the wearing course). All in all the sealing options would at least retain the social impact of the programme as regards proportion of costs going to labour wages and slightly increase the impact in that a higher proportion of females are likely to be employed for a sustained period.

Gender

The Gundo Lashu programme is implemented as a Special Public Works Programme (SPWP) and as such is governed by the Code of Good Practice for SPWPs. This stipulates, *inter alia*, that:

- Wages can be negotiated, i.e. that one is not governed by the industry minimum wages. For Limpopo Province the industry minimum is currently about R50/day (~USD7.0). Based on research of acceptable wage rates in the province, a wage of R30/daily task (~USD4.0) was chosen. This rate was considered to be attractive to the poorer segment of the

population who would otherwise not find gainful employment, amongst these a majority of women.

- The stipulated employment targets are:
 - 60% female
 - 40% male
 - 20% youth (18-35years)
 - 2% disabled

These targets have been set as a reflection of the dominant demographic profiles of poor rural communities where a large proportion of the households are single female headed households.

To date the programme has employed about 54 per cent female and 46 per cent male. The target for youth has been well exceeded and 1 per cent disabled have been employed.

The shift away from gravelling to provision of low-cost bituminous seals will perhaps minimise the most arduous of tasks on labour-based projects, i.e. the excavation and loading of gravel. This is a task most often done exclusively by able-bodied men and to the extent female workers have been involved, being a cause for high worker turnover. Providing a bituminous seal could therefore contribute to a higher sustained proportion of female workers and thus reach the stipulated employment targets. Knowing that a higher proportion of the wages then will be spent on family needs, the social impact of the programme should increase accordingly.

HIV/AIDS

A recent Output to Purpose Review of the Gundo Lashu programme warned: “It should be noted that much more highly resourced and focussed interventions around HIV/AIDS have battled to be effective and unrealistic expectations should not be attached to this project.”

It is thus a question whether programmes of this nature are the right vehicles to deal with the HIV/AIDS issue. The programme is nevertheless offering awareness training to contractors and workers and a condom distribution programme on all construction sites. It is however too early to have any opinion on the possible impact of these initiatives, if any significant impact is to be measured at all.

Environment

The extraction of gravel and depletion of existing resources constitutes a significant but non-quantifiable impact on the environment in terms of visual degradation, danger of increased soil erosion and silting up and pollution of water sources. A more immediate impact on the adjacent communities is the horrendous dust pollution from most gravel roads, especially in dry climates and where the gravel does not conform to the ideal specifications.

It has been shown that provision of low cost bituminous seals in combination with stabilisation of marginal base course materials can significantly reduce these adverse effects on low volume rural roads.

Provision of sealed roads will also contribute to a general upliftment of poor rural communities and improved quality of life.

Use of dust palliatives can be an alternative in the short term for reduction of the dust pollution and the rate of gravel loss, but they cannot prevent the eventual need for replacement of the gravel wearing course.

STATUS OF PROJECT

At the time of preparation of this paper, the project was in progress. It was found that the labour-based technique being implemented had some shortfalls, resulting in poor densities being achieved and a thin feather wedge at the outer extremes of the formation (subbase). The formation, which in the gravelling option would form the subbase, but with the redesign would form the base course for the sealing options, was therefore corrected to ensure uniform and sufficient compaction in order to proceed with the sealing trials.

Instruction of the Contractors and their supervisors in the use of shuttering to prepare the base (ensuring the correct compaction and pavement structure) was being carried out. Labour-based application of the prime and construction of the sand seal was being demonstrated and a trial/demonstration section of Otta seal was being constructed.

CONCLUSIONS

The Gundo Lashu programme in the Limpopo Province of South Africa is a labour-based training programme involving the regravelling of a network of unsealed roads. Suitable wearing course gravels are, however, scarce in the area and in order to provide adequate wearing courses, blending or the haulage of material would be necessary. Economic analyses showed that it would be more cost-effective to pave the existing (in situ) materials with a low cost seal than to acquire materials for unsealed roads, which would need to be repeatedly regravelled in an unsustainable programme.

The use of the local contractors would continue, with a revised training programme. It would also be important to train these contractors in the maintenance of sealed roads, which requires only slightly greater skills than those necessary for unsealed roads.

The anticipated social impact of the programme is likely to be retained or potentially increased with provision of low cost sealed roads rather than gravel roads.

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