NOTE ON
PAVEMENT AND SURFACING TECHNOLOGIES
FOR LOW-VOLUME ROADS

By

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Introduction

The SADC Guideline on LVSRs

1. The SADC Guideline on Low-volume Sealed Roads (LVSRs) challenges many aspects of the the traditional paradigms regarding the provision of LVSRs. Based on research carried out in the Southern African region over the past 25 years, it provides a wealth of information and guidance on alternative pavement and surfacing technologies that, when properly implemented, can provide significant benefits over the more traditional approaches. Much has been written on this topic since the production of the guideline in 2003. Nonetheless, *some discussion on the realities of maintaining unpaved roads as well as on developments in pavement and surfacing technologies is merited for comparison with how these important issues are dealt with in the RED model*.

The Gravel Road Conundrum

Sustainability of gravel roads

2. For many years gravelling has been the preferred option for surfacing when upgrading from earth roads. Natural gravel materials are usually excavated from borrow pits or quarries and hauled by trucks/tractors to be laid on the previously shaped formation or road surface to a thickness of typically 150 mm to 200 mm to form an "all-weather" running surface.

3. A gravel road surface can be appropriate and cost effective in certain specific circumstances. These include situations where:

- sufficient quantities of gravel are available that meet the required surfacing specifications;
- haul distances are relatively short;
- longitudinal road gradients are less than about 6%;
- rainfall is low or moderate;
- traffic is relatively low;
- dry season dust generation is not severe;
- finance and resources are going to be available for the necessary on-going periodic re-gravelling and routine maintenance.

4. However, increasingly, the above suitability criteria are often not met and the practice of managing more than 75% of a national road network as gravel roads is being seriously questioned. The major concerns to national governments, development agencies and rural roads agencies over the efficacy of rural road gravelling/re-gravelling may be summarised as follows:

5. *Financial and economic issues*

- Gravel is a sacrificial, “wasting” layer that is being rapidly depleted in a number of countries. Gravel loss rates per annum are typically of the order of 30-50 mm, depending on such factors as traffic, climate and terrain. Thus, the uppermost 30-50 mm wearing layer that overlies the 100-120 mm residual gravel support layer can be lost annually while, without regravelling, the entire layer can be lost within 3-5 years!

- The cost of periodic regravelling and routine maintenance of gravel roads can be very high. Regravelling costs are typically of the order of US$ 5,000 to US$ 30,000 per km per year depending on such factors as width and thickness of gravel layer, gravel quality, haulage distance, haul conditions, technology used, location, mineral fees, organisational arrangements, etc. In addition, routine maintenance costs related to grading/reshaping, patching and off-carriageway operations are typically of the order of US$ 2,000 to US$ 3,000 per km per year. Such costs are often beyond the financial capability of most governments in developing countries.

- Very often, spot improvement gravelling may be the optimum solution for unpaved road maintenance. However, because selective gravelling in practice is difficult to achieve, this results in wastage of finite resources.

- The technology of using graders for regravelling purposes is not sustainable in a number of countries where it would be preferable to employ alternative methods of maintaining unpaved roads involving local communities to a greater extent and utilizing using local resources and management more extensively. Moreover, in many countries, the number of graders required to maintain a large network of gravel roads in reasonable condition is simply not available

6. *Social and environmental issues*

- There is a continuous demand for the use of a non-renewable, natural resource which is being seriously depleted in many countries.

- Dust generation in dry weather causes adverse impacts in terms of being a health hazard for communities living adjacent to the road as well as causing pedestrian, animal and vehicle safety problems related to visibility and overtaking movements. In addition, dust emissions cause damage to crops and natural habitats.

- Gravel roads are often slippery and dangerous in wet weather, especially in steep terrain, causing access problems for communities.

Unpaved roads: dusty, health hazard, pedestrian/vehicle safety; crop, natural habitat and vehicle damage. **Is this socially sustainable? NO!**

Unpaved roads: Require continuous use of a non-renewable resource–gravel. This is inherently unsustainable and environmentally damaging. **Is this environmentally sustainable? NO!**

The case for low-cost sealed roads

7. For the various reasons cited above, gravel is often not an appropriate or sustainable solution for many road locations in developing countries. Fortunately, there is a range of surfacing and paving options that have been proven in various countries that could provide appropriate, economical and sustainable alternatives in many instances.

Pavement Design, Materials and Surfacing

Pavement design

8. Low-volume roads (LVRs) present a particular challenge to designers. This is largely because, until relatively recently, such roads were not specifically catered for and the step from a gravel road to a paved road was a large one. Moreover, in contrast to high volume roads, in which load-associated stresses dominate pavement performance, environmentally induced distress dominates the performance of LVRs. Very few pavement design methods cater for this mode of performance (Ref. Figure 1).

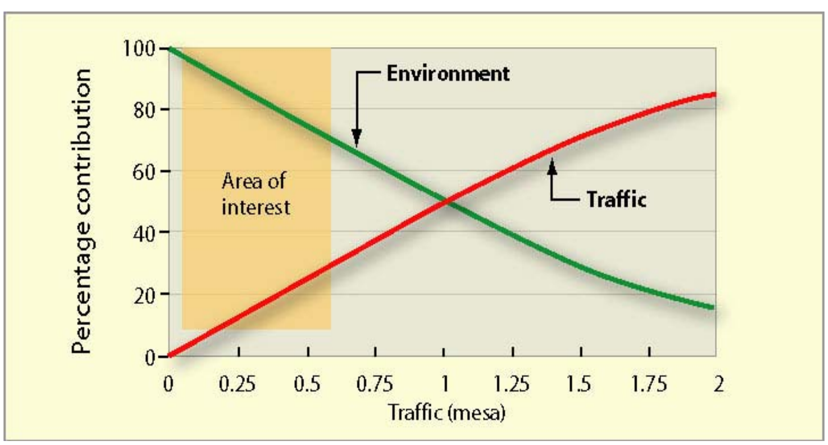


Fig. 1: Traffic loading versus dominant mode of distress

9. Successful cost-effective design calls for an imaginative 'systems' approach which can be applied in a flexible manner to cater for the characteristics of LVRs in relation to their particular environment. From recent research work carried out in the Southern Africa region [1] the following factors were found to be the most important for the design of LVRs:

- selection criteria for roadbase materials;
- subgrade strength or design class;
- crown height above drain level;
- sealed surface design and sealing of road shoulders;
- geo-climatic zone;
- traffic.

10. The results of the research were incorporated into a pavement design method that reflects the importance of local environmental factors and the wider use of locally available materials [1,2].

Materials

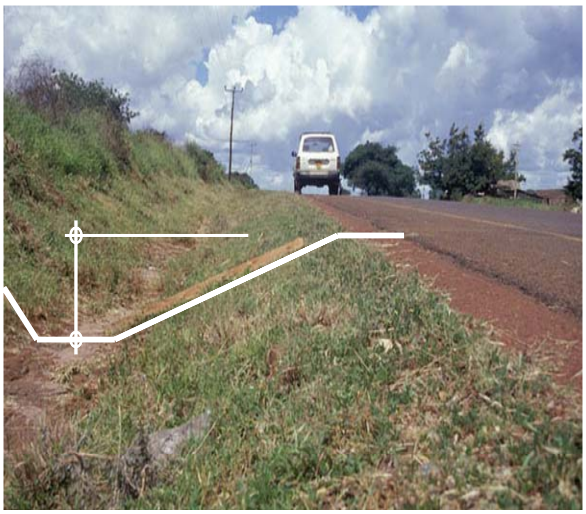
11. Materials make up 70% of the cost of a typical rural road. To reduce costs it is essential that as much use as possible is made of locally available 'low-cost' materials. However, until relatively recently, many of the design criteria for using naturally occurring materials have reflected specifications appropriate to temperate zones, with 'ideal' particle size distributions and low plasticity [3]. Application of such specifications often precludes the use of many local materials which do not meet these standards. However, research work carried out in the southern African region [4] has shown that many natural gravels have performed well as pavement materials and considerable use can therefore be made of them once appropriate specifications have been developed from suitable research studies.

Crushed limestone–a traditional, processed materials typically specified for the base layer of LVRs. Is this relatively costly material type necessary? NO!

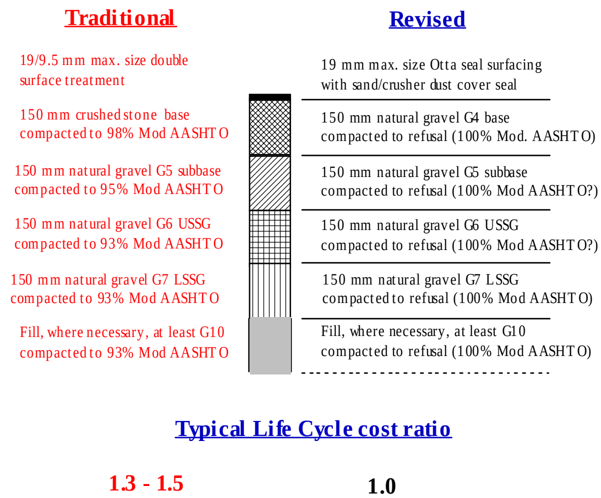
As-dug, nodular laterite. Can this be used as base for a LVR? Definitely, YES, when used in the right context (e.g. min. embankment height, sealed shoulders, compaction to refusal, etc. see photo. below)

12. A typical example of the application of the above principles is exemplified by a successfully trialled road project in Malawi in the 1980s that was supported by the World Bank and the African Development Bank [5]. The road (pictured below) was constructed with a natural gravel (laterite) base with the following properties.

- 4 day soaked CBR at 95% MDD BS Heavy Compaction: 40%
- Plasticity Index: ≤ 20
- Grading: ≤ 40%



Example of a well constructed LVR with a natural gravel (laterite) base with CBR << 80% and PI >> 6. Still performing extreme well after 15 years in service and having carried well in excess of 0.5 million ESAs.



Typical life cycle cost comparison between traditional and new pavement specifications for a typical LVR with a 10 – 15 year design life of 0.5 million ESAs.

13. The above example is by no means unique and is but one of many that, through back analysis, has provided much input into the guidance given in the SADC Guideline on LVSRs.

14. **Pavement Configuration:** Until relatively recently, the provision of sealed shoulders on low-volume roads would have been considered to be both expensive and unnecessary. However, there is a structural benefit from maintaining a drier environment under the running surface. The resulting high strengths derived from the relatively dry condition results in a stronger pavement. It also allows weaker materials to be used in the upper pavement layers in situations where materials, which satisfy conventional specifications, are unavailable. Recent studies [1] show quite clearly that there is a whole of life benefit from reduced maintenance alone, as well as a safety benefit from the sealing of shoulders.

Surfacing

15. For many years, the standard surfacing for LVRs in the SADC region has been surfacing dressing, although there have been a number of modifications to this technique including the Cape Seal used in South Africa. Whilst this type of seal still has wide application, there are alternatives available which are

often more appropriate, cost-effective and easier to apply than surface dressings. These include graded aggregate (Otta) seals [6], sand seals, slurry seals, hand-packed stone, stone setts and concrete blocks, many of which are especially suited to the labour-based construction techniques and construction plant used by small-scale contractors.

16. In view of the somewhat limited appreciation of the fundamental differences between the Otta Seal (category B surfacing) and the more traditional Chip seal (Category B surfacing), some information is provided below.

Mechanism of performance of Category A and Category B surfacings

Category A Surfacings: (Sand seal, Slurry seal, Otta seal)

These seal types rely to varying extents on a combination of mechanical particle interlock and the binding effect of bitumen for their strength, similar to a bituminous premix. Early trafficking and/or heavy rolling is necessary to ensure the coating of the fine particles with a relatively thick film of bitumen. Within this bitumen/aggregate admixture, the likelihood of stones becoming dislodged and whipped off the road by vehicles is relatively small.

Under trafficking, the seal acts as a stress-dispersing mat comprised of a bitumen/aggregate admixture - a mechanism of performance which is quite different to that of Category B surfacings.

Category B Surfacings: (Chip seal)

This seal type relies on the binder to "glue" the aggregate particles to the base, this being the primary objective of the binder. Where shoulder-to-shoulder contact between the stones occurs, some mechanical interlock is mobilized. Should the bitumen/aggregate bond be broken by traffic or poor adhesion, insufficient material strength, water ingress or numerous other causes, "whip off" of the aggregate by traffic is almost inevitable. Under trafficking, the aggregate is in direct contact with the tyre and requires relatively high resistance to crushing and abrasion to disperse the stresses without distress.

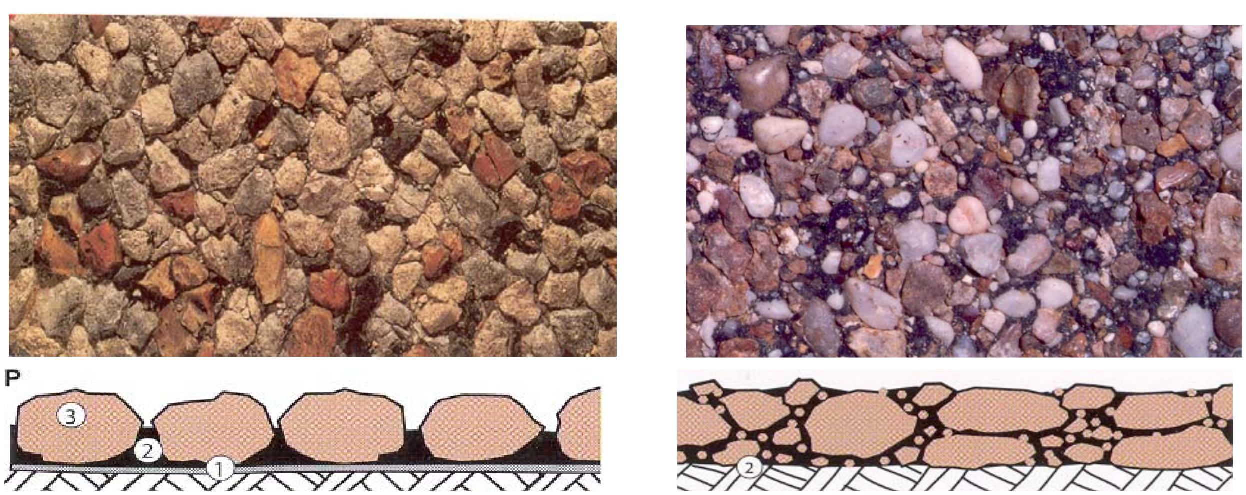


Figure 2 - Difference in make-up of single Chip seal and single Otta seal

Construction Issues

Levels of compaction

17. In many design manuals, the levels of compaction or density to be achieved during construction are set as a proportion of the maximum dry density in standard laboratory tests. However, it is widely accepted that, with many road building materials and modern plant, higher densities can be achieved with relatively few additional passes of the compaction equipment. Thus, "compaction to refusal" with the heaviest plant available will often provide a substantial benefit in terms of increased pavement stiffness which, as illustrated below, correlates directly with longer pavement life.

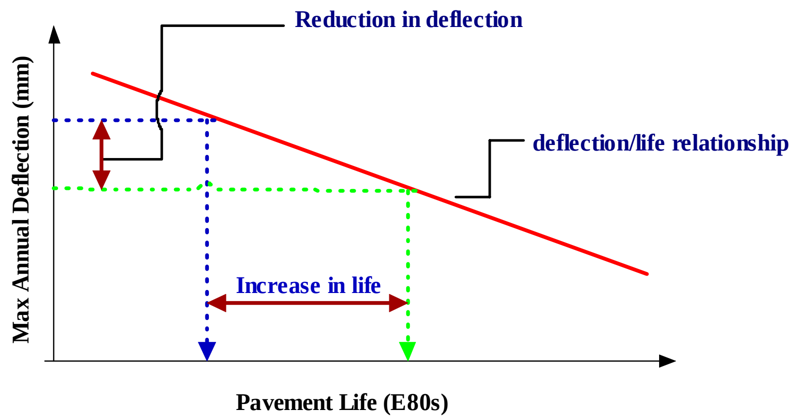


Figure 3 – Pavement life benefits of increased stiffness through "compaction to refusal"

Appraisal Methods

18. Using conventional LVR design and construction methods plus conventional cost benefit analysis and whole life costing principles (for example, those embodied in investment appraisal models such as HDM IV), traffic levels in excess of 200-250 vpd are often required to justify upgrading an unpaved road to a paved one. However, by using the technical solutions described in the SADC *Guideline on LVSRs*,, applying a sealed road surface becomes justifiable at considerably lower traffic levels, often below 100 vehicles per day [7]. What is more, traditional methods of investment appraisal rely on benefits arising from the reduced costs for motorised road users; such methods are not suitable for quantifying the multiple benefits of LVRs. This is because many of the benefits arising from the provision of LVRs are of a social rather than economic nature and the beneficiaries also include non-motorised traffic and pedestrians.

19. In view of the above, it is recommended that appraisal methods are used that are able to capture the non-economic benefits and, in so doing, integrate social, environmental and economic elements in project appraisal. When this is done, justification for providing a sealed road surface at much lower levels of traffic becomes possible (Figure 4).

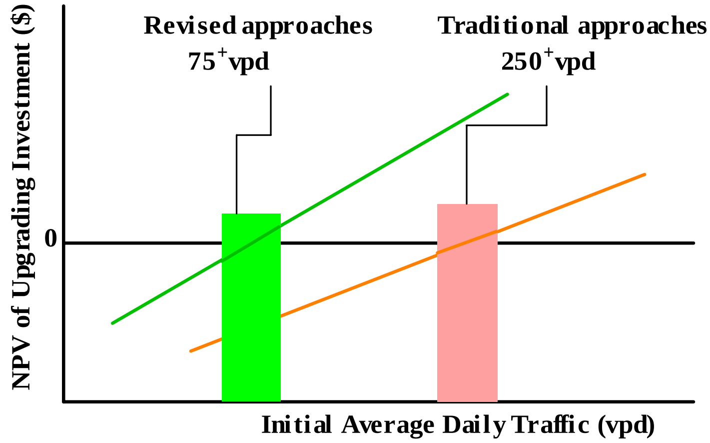


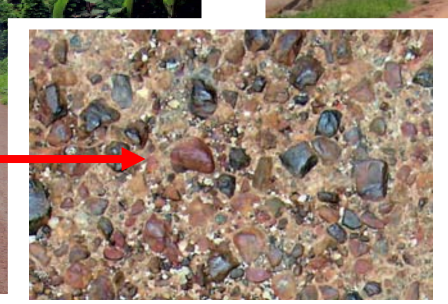
Figure 4 - Breakeven traffic levels for paving a gravel road - traditional versus revised approaches

20. The short-comings of the conventional methods of investment appraisal have been addressed, to some extent, by the development of such models as the Roads Economic Decision Model [7] and the SuperSurf model – Economic Warrants for Surfacing Unpaved Roads – that was developed in South Africa [8] The key question is – ***do these models accommodate sufficiently the developments in LVR technology described above?***

Summary

21. The above examples of developments in low-volume road technology that are based on research and practical experience distilled from many countries in the Southern African region provide important options for practitioners Unfortunately, lack of effective dissemination and uptake of these developments has suppressed their more wide-spread implementation – a key factor that triggered the need for developing the SADC Guideline on LVSRs. However, there is now increasing uptake of the recommendations presented in the SADC guideline which have now taken root in a number of countries as exemplified by a typical application on a rural feeder road in Ghana which is illustrated below.

Typical section of feeder road after regravelling and surfacing with an Otta seal



Otta seal surfacing using screened natural gravel

Typical condition of gravel feeder road within one year of construction.

The school children above expressed their delight in being able to walk to school on a "proper" road in contrast to the muddy conditions experienced during the rainy season.

Residents of the above village in the Cape Coast area were happy that they no longer suffered from dust generation in the dry season and muddy, slippery conditions in the wet season.

22. In light of the above examples, it is important that models such as RED take cognisance, to the maximum extent possible, of the developments in LVR technology and, in so doing, enhance their value as economic appraisal tools – an issue that is considered in subsequent sections of this report.