Local Government Note

NEW PERSPECTIVES OF UNSEALED ROADS IN SOUTH AFRICA

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Abstract

Like many countries, South Africa has a preponderance of unsealed roads in the road network. These are costly to maintain and have severe environmental repercussions. Recent work in which the specification of wearing course materials for unsealed roads developed in 1989 has been fully implemented, indicates that significant improvements in performance of the roads and reductions in gravel loss can be achieved. Mechanisms for reducing gravel loss are discussed and recent developments in the field of chemical stabilisation are highlighted.

INTRODUCTION

Unsealed roads still comprise the majority of low volume roads in most countries. In South Africa they make up more than 75 per cent of the total road network and probably 95 per cent of the low volume road network.

Unsealed roads come with various disadvantages over sealed roads, primarily the ongoing and continual maintenance as well as the accompanying environmental problems. The maintenance, whether grader blading to restore riding quality or replacing the gravel lost under traffic and environmental actions is both costly and disruptive to the normal traffic.

The environmental impacts associated with both the operation of the road as well as long term sustainability are also problematic. During operation of the road, fine material is lost as dust while the finer and coarser material is eroded from the road and usually finds its way into water courses, where together with detritus (oil, rubber, etc.) from the vehicles using the road it can result in siltation and pollution. The continual removal of material (essentially a non-renewable resource) from borrow pits is also not sustainable.

This paper discusses latest perspectives regarding the improvement of the performance of unsealed roads, particularly by reducing many of the current problems.

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BACKGROUND

The derivation of appropriate specifications (*Table 1* and *Figure 1*) for the selection of materials for unsealed roads has been described elsewhere (Paige-Green, 1989). These specifications were derived from the monitoring and performance assessment of a range of existing roads using a factorial design with traffic counts, climate, material group and geometry (curvature and grade) as the factors. At the same time, models for the prediction of gravel loss and roughness deterioration were also developed (Paige-Green, 1989).

Testing of the materials for the specification development followed the standard South African test methods (TMH 1: 1979 & 1986) which are predominantly based on American methods. In order to make the specifications more widely applicable, they have been modified to allow their use with test results based on British test methods (*Figure 2*: Paige-Green, 2007).

Following development of the South African specifications in 1989, their transfer into practice was slow and only partially implemented where used, ie, materials were selected for use and wearing course layers were constructed without particular attention being paid to oversize control and compaction of the layer in the field. This resulted in only slight improvement of the road performance. The deterioration models developed provided good predictions of the deterioration rates for use in Gravel Road Management Systems in South Africa.

FULL IMPLEMENTATION

With the increasing cost of constructing and maintaining unsealed roads, a Quality Management System applicable to all regravelling operations was implemented in the Western Cape Province in South Africa in 2001 (Van Zyl *et al*, 2005; 2007). Various sections of road have been carefully monitored since

Table 1
Recommended material specifications for unsealed rural roads

Maximum size (mm)	37.5
Maximum oversize index (I_o)	5 %
*Shrinkage product (S_p)	100 - 365 (max. of 240 preferable)
†Grading coefficient (G_c)	16 - 34>
‡ Soaked CBR (at 95 per cent Mod AASHTO compaction)	15 %
Treton impact value (%)	20 – 65

* I_o = Oversize index (per cent retained on 37.5 mm sieve)
† S_p = Linear shrinkage x per cent passing 0.425 mm sieve
‡ G_c = (Per cent passing 26.5 mm - per cent passing 2.0 mm) x per cent passing 4.75 mm)/100

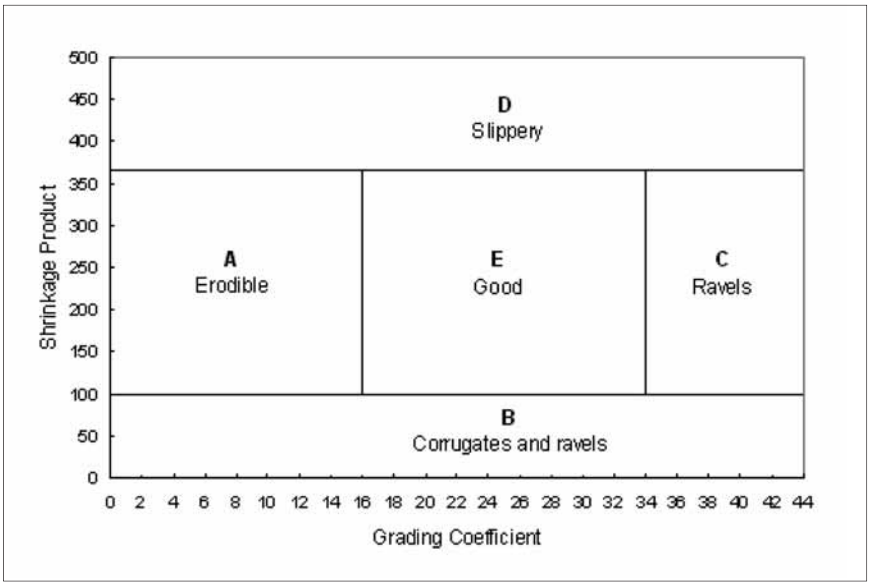

Figure 1
Diagrammatic indication of expected performance of wearing course gravels

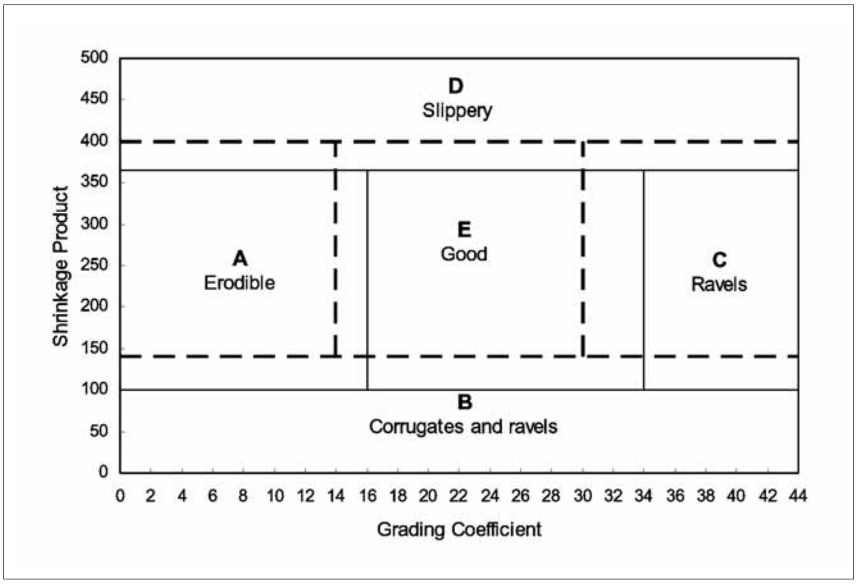

Figure 2
Revised performance prediction diagram using BS shrinkage test results and 20 mm sieve (broken lines – the original specification is shown by the solid lines)

2003 (Van Zyl *et al*, 2007). The roads are constructed with materials complying fully with the Grading Coefficient and Shrinkage Product requirements of *Table 1*, oversize material is meticulously controlled; all of the roads are compacted at optimum moisture content to at least 97% Mod AASHTO density or preferably refusal and it is ensured that the road has a good shape (crown and camber of 4–6 %). Monitoring includes roughness and gravel loss measurements and routine maintenance has been controlled at minimal levels.

The financial implications of the improved material selection and construction operations are an increase of about 30 per cent, 10 per cent in material selection and approval and 20 per cent in the construction process (removal of oversize and improved compaction).

It soon became apparent that the performance of the road sections was considerably better than predicted by the existing models and in fact, routine grader blading maintenance could be reduced to almost nil (*Figure 3* and *Figure 4*: from Van Zyl *et al*, 2007).

It can be clearly seen that for traffic less than 150 AADT, even after more than 3 years, the riding quality of the road deteriorated very little (Figure 3). For the road carrying up to 350 AADT, deterioration was very slow for the first 2 to 2.5 years after which it suddenly accelerated during the next 1.5 years (Figure 4). This is not surprising as 17% of the traffic using the road is classified as heavy (ie, 55 heavy vehicles per day).

Prediction of the gravel loss versus the measured gravel loss for Road MR276 (relatively high traffic 323 AADT) is shown in *Figure 5*. The loss under heavier traffic is considerably higher, but less than that predicted from the available models.

The performance prediction models generally overpredicted both the gravel loss and blading requirements significantly. This is of course not unexpected as the original models were developed on roads constructed to previous standards, which although using the best local material available (minimal testing was carried out) had little oversize material removed (only by graders during placing and shaping), and compaction was usually carried out with the application of a nominal number of passes of a grid roller at in situ or slightly elevated moisture conditions.

MAINTENANCE OPERATIONS

Monitoring of the performance of the trial sections has indicated that revised maintenance strategies need to accompany the re-invented construction process (Van Zyl *et al*, 2007). These include occasional light blading with periodic rip and recompact actions when the road roughness reaches a Quartercar Index (QI) of about 100 or an International Roughness Index (IRI) of about 8.

It has been shown that deterioration of the road surface, manifested by reduced riding quality is significantly decreased and in fact on roads carrying light traffic, no maintenance was required for more than 3 years.

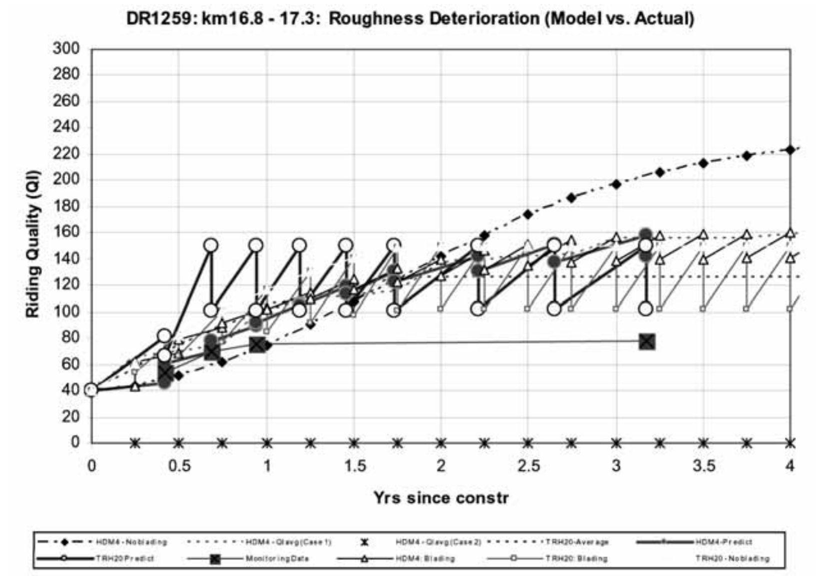

Figure 3
Comparison of actual versus predicted rate of deterioration (AADT<150) (after Van Zyl et al*, 2007)*

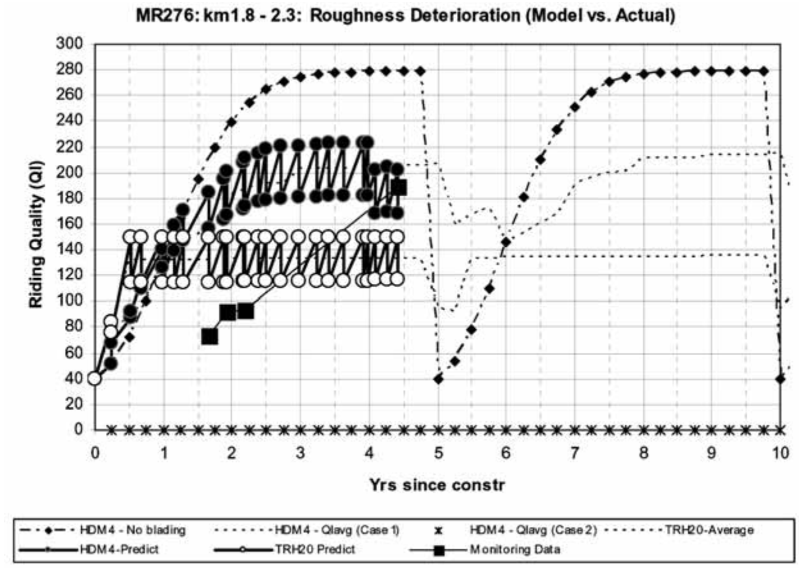

Figure 4
Comparison of actual versus predicted rate of deterioration (AADT<350) (after Van Zyl et al*, 2007)*

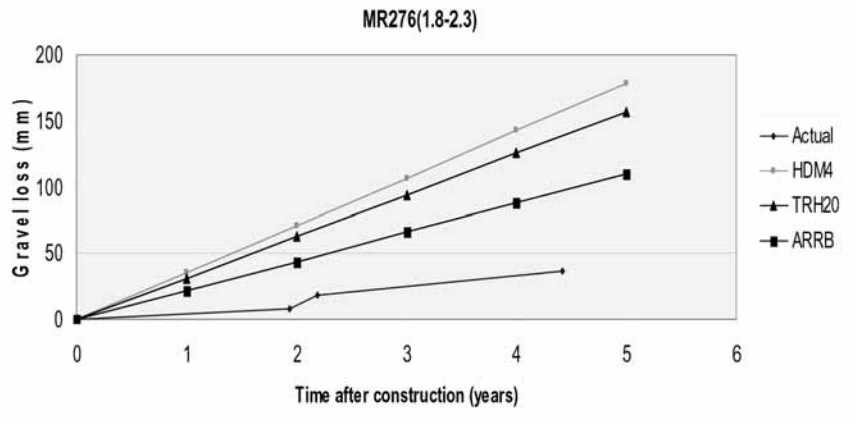

Figure 5
Comparison of actual versus predicted gravel loss (after Van Zyl et al*, 2007)*

Similarly, the gravel loss is reduced and the regravelling frequency can be decreased by up to about 75 per cent.

Continued monitoring of these sections is necessary to determine the actual adjustments to the prediction models that is required.

RECENT PROBLEMS

Despite the use of the new specifications, a number of problems have been reported where roads constructed to the new requirements have shown signs of ravelling soon after opening to traffic. In each case the Engineers have confirmed that the construction records indicate good material properties and that adequate densities were achieved.

Various possible causes including possible salt damage have been investigated without identifying any particular problem. The remedy, in each case, has been to rip and recompact the sections under the Engineer's direction and inevitably, the problem has been resolved. This indicates the absolute necessity for good compaction at properly controlled moisture contents.

On one of the problem roads, the causes were attributed to high variability of the material in the borrow pit (mixed hard and soft material). Compounding this, the road was slushed after compaction producing a very smooth clayey surface, which crumbled during the following very dry period. The improved road quality also attracted a significant amount of truck traffic (now 30 km shorter than the paved alternative) to exacerbate the problem.

GRAVEL CONSERVATION

As highlighted previously, the conservation of gravel is becoming an ever increasing problem, both from the decreasing availability of suitable construction materials and the legislative (mostly environmental) points of view. In order to develop a borrow pit in South Africa, the requirements of about 27 Parliamentary Acts currently need to be satisfied.

It is thus becoming increasingly important to try and reduce the use of gravel in unsealed roads, where significant quantities of material are lost each year under both environmental and traffic influences. Modelling of the losses indicate that typically about 20 to 25 mm of gravel is lost every year. Recent investigations in an important nature conservation area, where the unsealed roads typically carry between 20 and 50 vehicles per day indicated that between 1 and 2 mm of the annual gravel loss is traffic related and from 11 to 13 mm is environmentally induced.

The continual replacement of gravel in conservation areas is not environmentally sustainable and in these areas it is also not an option to seal the roads from an aesthetic or 'feeling of place' viewpoint.

Various techniques for reducing the required gravel replacement are thus being investigated. These include reducing the width of those roads wider than about 6 m, the implementation of better material selection and construction procedures and the possible treatment of certain roads with chemical stabilisers.

TREATMENT OF GRAVELS

The improvement of gravels by treatment with proprietary chemical stabilisers can potentially be a cost-effective solution. There is a plethora of these products on the open market but the performance of few of these has been adequately proven in practice. The performance of the majority of these products is highly sensitive to material type and application rate and these need to be carefully controlled for their effective use.

However, the use of such chemicals should only be carried out once their effectiveness has been proven in the laboratory and under strict supervision and control testing regimes during construction. Experience has shown that the performance of the products is related to their composition and the mode of stabilisation related to the materials being treated. For example, sulphonated oils (SPPs) will only be effective if the material being treated has a suitable clay component, including sufficient quantity as well as preferably clays of the smectite group.

Thus before a sulphonated oil is selected for use, it must be ensured that the material has sufficient plasticity and the correct clay mineralogy. A suitable percentage of the material should be finer than 75 µm (typically between 15 and 55 %) and the chemical should improve the soaked CBR in the standard laboratory test.

Normally, a number of laboratory CBR tests with different products and application rates would be carried out and if the required CBR is obtained, then the material should be effective in the field.

An example of the variable effect on the CBR of five residual gravel materials using a variety of SPPs is summarised in *Table 2*.

It is clear that the diabase (a material with a high percentage of smectite clays) was affected strongly by all the chemicals used. The black clay and ferricrete were not affected at all (possibly negatively in the ferricrete as a result of lubrication by the surfactant chemicals), while Product C had a significant effect on the chert and shale as well. None of the other products had a positive effect on the chert but Product A also affected the shale positively.

It is interesting to note that thermo-gravimetric analysis (TGA) of the diabase and chert treated with Product C showed distinct changes in the traces at temperatures above about 650°C indicating that the theoretical effect of the chemical of reducing the adsorbed water had probably occurred (*Figure 6*).

Many other chemical treatment techniques are available and these can be investigated for specific purposes. These include cement based materials (more appropriate for less plastic sandy type materials), very effective hygroscopic dust palliatives, lignosulphonate dust palliatives and a diverse range of other chemical products. Each of these needs to be tested with the materials proposed or available for any project and their technical effectiveness confirmed. Once this has been found to be positive, the cost-effectiveness in terms of the life-cycle costs of the products must be confirmed. This is often difficult as the effective service lives of few of the products have been scientifically proven. Many of the products are expensive and thus not cost effective in comparison with the provision of a paved road with a light pavement structure that is suitable for many low volume roads.

CONCLUSIONS

There is no doubt that, despite the environmental consequences, unsealed roads will be in use for many years to come. However, it is clear that with appropriate material selection and construction procedures, the

Table 2
Effects of treatment with various SPPs on five different materials

Material treatment	Diabase	Black clay	Ferricrete	Chert	Shale
None	32	2	181	59	33
Product A	*76*	2	137	39	*42*
Product B	*65*	2	144	41	37
Product C	*72*	-	-	*85*	*45*
Product D	*69*	-	-	46	38

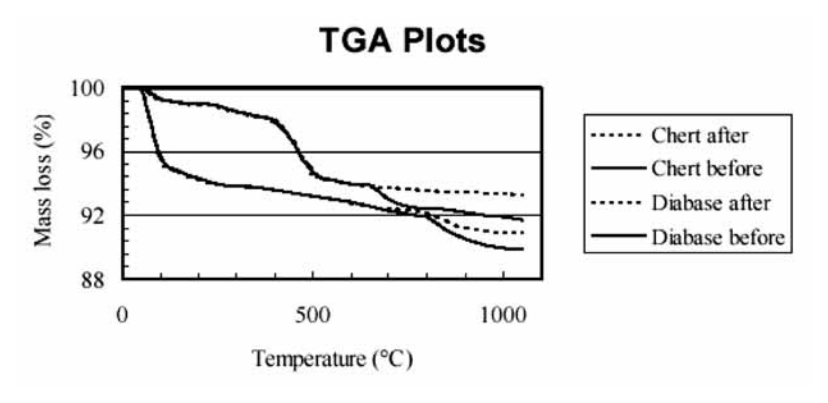

Figure 6
Thermo-gravimetric plots of chert and diabase before and after treatment with SPP Product C

performance of the roads can be improved and the consequent negative environmental effects can be significantly reduced. Recent developments have indicated that the use of the best available materials with oversize material removed and that are well compacted at optimum moisture content reduces both the grader blading maintenance needs significantly and also reduces the gravel loss.

The use of chemical stabilisation to improve the performance of many materials can be investigated but the life-cycle cost effectiveness needs always to be proved.

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