

COMPARISON OF ACCELERATED PAVEMENT TEST RESULTS WITH LONG TERM PAVEMENT BEHAVIOUR AND PERFORMANCE

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Abstract. A comparison was made of pavement behaviour and performance as measured during an accelerated pavement test conducted by the Heavy Vehicle Simulator (HVS) in 1980, and actual behaviour and performance of the same pavement section measured in 1996. Behavioural aspects such as deflection, Dynamic Cone Penetrometer shear strength, moisture and density were found to correlate reasonably well with measurements made during the accelerated pavement test 16 years earlier. Rutting measured in 1996 compared well with rut depths measured during the accelerated pavement test at a similar number of equivalent standard axles. Rut development as measured during the accelerated pavement test also compared well with predictions made with the World Bank's Highway Design and Maintenance Program (HDM). Results obtained indicate that, for the pavement section studied, environmental effects did not significantly change the behaviour and performance of the pavement.

Keywords. Accelerated Testing, Long Term Pavement Performance., Heavy Vehicle Simulator, HVS, Rutting

INTRODUCTION

Aim. The aim of this study was to investigate the following: (i) how accelerated pavement testing (APT) predictions compare with actual road behaviour and performance; (ii) the relative influences of load and environmental factors on pavement deterioration, and (iii) how well predictions made with the World Bank's Highway Design and Maintenance (HDM) program compare with rutting curves obtained with accelerated tests.

The results reported in this paper form part of a longer term study to investigate the abovementioned issues. The results reported here are presented in the form of a case study which was conducted as a pilot study for the longer term project. The purpose of this pilot study was to investigate the feasibility of using Heavy Vehicle Simulator (HVS) test data to predict aspects of long term pavement performance, and to serve as a guide for the future collection of data for comparison of APT results with actual pavement behaviour. Thus the analysis conducted during the pilot study was somewhat more detailed than that which will be performed on other sections and, in addition to performance related aspects, included a comparison of some behavioural aspects.

Background. Over the past 20 years, Heavy Vehicle Simulator (HVS) testing has played a major role in the development of the South African mechanistic design method and pavement design catalogue (Theyse et al., 1996; TRH 4, 1996; Horak et al., 1992). South African APT data exist for a variety of pavement structures. These data normally contain information on the development of rutting and cracking as well as on changes in various structural indicators such as deflections (in-depth and surface), backcalculated moduli and shear strength as indicated by the Dynamic Cone Penetrometer (DCP) (Kleyn, 1984; De Beer et al., 1988). As such, APT data provides a "window" of pavement performance which can possibly be used to predict how the pavement will perform under real traffic. Thus the broad objective of this study was to determine the viability of using APT data to predict long term pavement performance and behaviour as well as compare HVS rutting curves with HDM rutting

prediction curves.

APT Predictions Compared With Actual Behaviour and Performance. The results of an accelerated pavement test are mostly indicative of pavement behaviour under simulated (and thus known) traffic conditions. The accelerated nature of the test precludes the study of long term environmental effects on the performance of the pavement. Although environmental effects such as ageing of binder and ingress of water have been simulated during more recent HVS tests (De Beer, 1990), all HVS test data used during this study include only load-related effects (this is apart from the addition of water towards the end of the test). Thus the influence of the environment on long term pavement performance remained uncertain for the HVS tests studied here.

In order to address this uncertainty, an attempt has been made to compare actual pavement performance with pavement performance indicators which can be measured during an HVS test. In the past, the only indicators measured during HVS testing which could be directly related to pavement performance were rutting and development of cracks, the latter of which is difficult to quantify for comparative purposes. Thus, as far as performance is concerned, from the outset this study was largely confined to a comparison of rutting prediction as measured under the HVS with that measured under real trafficking.

In addition to the measurement of performance indicators, a comparison was made of the behaviour of a pavement section as measured under the HVS with that measured after sixteen years of actual trafficking. The objective of this analysis was to determine whether the mechanism of deterioration as predicted by HVS testing is the same as that which develops under real traffic and environmental conditions.

HDM Calibrated Performance Curves for Gauteng Province. The Gauteng province in South Africa uses version III of the World Bank's Highway Design and Maintenance program (HDM III) (Watanatada, 1987; Paterson, 1987). This program uses performance curves for, amongst others, rutting and cracking, by means of which changes in riding quality as well as general pavement deterioration can be predicted. The HDM III performance curves were calibrated for the Gautrans province of South Africa by means of actual pavement performance data for various classes of pavements (Africon, 1994).

Because an HVS test allows a complete rutting curve to be developed with increasing load repetitions, it is hoped that HVS rutting results will be comparable to the HDM III predictive relationship for rutting. However, since HDM III predictive curves include environmental as well as load effects, it can be expected that these would differ from predictions made on the basis of HVS test results which include loading effects only. The magnitude of this difference may offer some

indication of the importance of the role of environmental effects for the rutting behaviour of the pavement studied. Thus an additional aim of this study was to compare predictions made using HDM III with those made on the basis of HVS testing. Both these predictions were then compared with actual pavement performance.

APPROACH AND DATA COLLECTION FOR PILOT STUDY

Choice of Pavement Section to be Used in Pilot Study. The pavement section selected for the pilot study was road P157-1, a four lane dual carriageway which connects Pretoria with Johannesburg International Airport. The road may be regarded as a major arterial and currently carries in excess of 15,000 vehicles per direction per day. The selection was based on the following:

- i) availability and detail of HVS test data;
- ii) availability of traffic information;
- iii) availability of past rehabilitation and maintenance data, and
- iv) pavement age and amount of traffic carried since HVS testing.

Of the candidate pavements considered, road P157-1 offered optimal satisfaction of the above criteria since excellent data collection and reporting was conducted during the HVS test (Maree et al., 1980). More importantly, the reports and most of the raw data were readily available. Availability of past data and information was found to be a crucial issue since some HVS tests had been conducted as far back as 1979 and not all tests were reported with the same amount of detail.

Because of the excellent performance of road P157-1, the only major maintenance action since its original construction was the application of a 13 mm surface seal in 1985. As the slow and fast lanes have carried significantly different amounts of traffic, this road also offered the opportunity to study differences in the structural responses measured in each lane.

Follow-up data collection in 1996 was aimed at ensuring that direct comparisons could be made with data from the 1980 HVS test. Thus, amongst other measurements, rut depth, Road Surface Deflectometer (RSD) (Basson, 1985), Dynamic Cone Penetrometer (DCP) (Kleyn, 1984, and De Beer et al. 1988) and Multi Depth Deflectometer (MDD) (De Beer, 1988) data were collected and, where possible, directly compared with measurements made during the HVS test in 1980. These measurements were broadly divided into behavioural and performance measures for comparative purposes.

Construction History of P157-1. Road P157-1 is a dual carriageway which was constructed during 1971 and 1972. The pavement structure is shown in Figure

1. It consists of a thin asphalt surface, a high quality crushed stone base (South African G1 standard) (TRH 14, 1985) and a weakly cemented subbase. This basic structure is underlain by a selected layer consisting of natural gravel. Lower selected layers and subgrade materials are of relatively good quality and were found to have an in-situ California Bearing Ratio (CBR) above ten percent during the HVS test conducted in 1980.

Apart from routine maintenance, the section on which HVS testing was conducted only received a 13 mm single seal during 1985. No other large scale rehabilitation or maintenance measures were undertaken since construction, which means that the structural condition of the road remained essentially unchanged since construction.

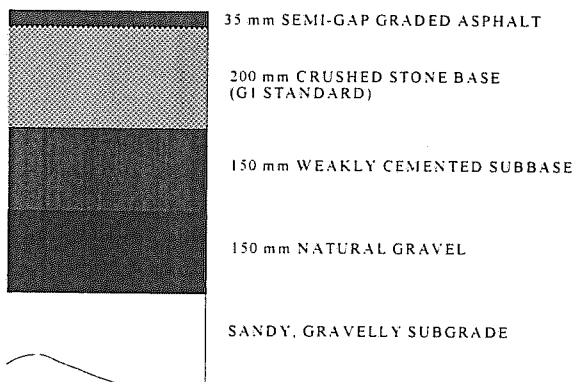


Figure 1. Pavement Structure of P157-1

HVS testing, 1980. An HVS test was carried out at km 18.2 on P157-1 from April to August of 1980. The test was conducted in the outer wheel path (near-side, or kerb-side) of the slow lane. The test site was chosen to represent the weaker 5 to 15 percent of the road, as indicated by DCP measurements and Lacroix deflections taken over the whole length of the road (Maree et al., 1980).

Instrumentation of the HVS test site consisted of Multi Depth Deflectometers (MDDs) and thermocouples. During the test various material and structural responses were monitored. These included RSD surface deflections, MDD deflections, moisture and density measurements, and rut depths. A detailed photographic record was also kept so that the development of cracks during the test could be monitored.

In order to accelerate the effects of traffic, a 70 kN dual wheel load was used during the greater part of the test. This wheel load is greater than the standard dual wheel load of 40 kN (or standard 80 kN axle) and thus had to be converted by means of the load equivalence formula:

$$F = \left(\frac{P}{40}\right)^n \dots \dots \dots \text{Equation (1)}$$

Where: F = Load equivalency factor
P = Actual dual wheel load
n = Relative damage exponent

The value of n is typically taken as approximately 4. However, in South Africa HVS tests have shown that relatively thin, stiff structures (known as "shallow" structures) may have higher n-values, indicating that the pavement is susceptible to overloading (TRH4, 1996). Conversely, well balanced thicker structures may have lower n-values. Since the choice of n-value may have an important effect on the estimated traffic applied by the 1980 HVS test, the influence of changes in the n-value were also investigated during this study. However, for the greater part of this study n was assumed to have a value of 4 unless otherwise stated.

The pavement performed very well during the HVS test. In Figure 2 the rut depth development during different stages of the test is summarized. No fatigue cracks developed during 1.5 million 70 kN dual wheel load repetitions (approximately 14 million equivalent standard axle loads, or ESALs) and the rut depth increased by only 3 mm to a total of 5 mm. It should be noted that during the test longitudinal cracks developed on the edges of the test section. These cracks are typical of HVS testing and first appeared at 750,000 repetitions (7 million ESALs). These cracks were not regarded as normal fatigue cracks and were thus ignored for evaluation purposes. However, the cracks did aid penetration of water into the pavement during the application of water to the pavement surface at a later stage of the test (Maree et al., 1980).

After the initial 1.5 million 70 kN load applications the load was increased to 100 kN. After a further 280,000 repetitions of this higher load very little change could be observed and the rut depth increased by only 1 mm, with no visible fatigue cracking. Only after an amount of water equivalent to 10 mm of rain had been sprayed onto the section every six hours and after a further 350,000 repetitions of the 100 kN load did some fatigue cracks develop. Rut depth changed significantly and rapidly during this final stage, as shown in Figure 2. This behaviour is typical of HVS-observed distress after

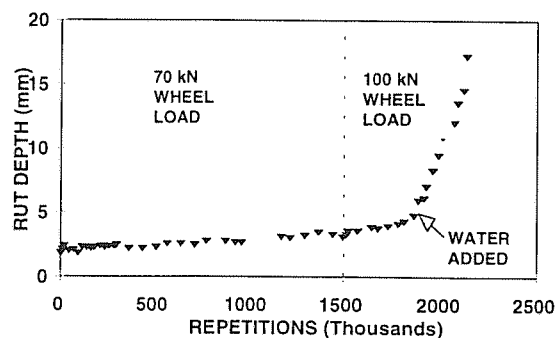


Figure 2. Average Rut Depth Development on P157-1 During HVS Testing

the ingress of water into the pavement structure (Maree, 1982).

Traffic History and Conversion of Traffic Data from HVS Tests. During an HVS test, performance and behavioural indicators are expressed as a function of number of loads applied. Actual pavement performance, on the other hand, is normally expressed as a function of time, or years passed since construction. In order to convert the HVS data so that rutting development during an HVS test can be readily compared to rutting under real traffic, it is necessary to (i) take account of past traffic up to the time of the HVS test, (ii) convert the number of axles to equivalent standard 80 kN axle loads (ESALs) by means of equation 1, and (iii) express the age of the pavement in terms of ESALs for comparison with HVS predictions. While point (ii) above is a straightforward calculation in which n is the only uncertain variable, points (i) and (iii) require more detailed consideration of traffic data.

Taking account of the uncertainties involved in determining the real traffic on any road, the cumulative traffic estimated during this study was not expressed as a single figure but as a confidence interval. This confidence interval was obtained by fitting a regression line through all traffic data points which were available from traffic counts since opening of the road in 1972. Figure 3 shows the regression line and the actual counts taken since 1972. Of the traffic counts shown, that taken in 1979 and both counts taken in 1996 are Weigh-in-Motion (WIM) counts and may be regarded as fairly accurate (Basson and Rust, 1990).

Since the number of heavy vehicles on the fast lane is significantly lower than that on the slow lane, the fast lane traffic can be used to represent a different point on the HVS rut prediction curve. The ratio of fast lane ESALs to slow lane ESALs was measured as 60: 700 in 1979. In the absence of more recent, specific data, this ratio was thus used to assign a daily E80 traffic to the fast lane. These data were then used to obtain cumulative traffic figures for both the slow and fast lanes, as shown in Figure 4. In order to take account of variability and uncertainty in the traffic information, the regression data shown in Figure 3 was used to construct

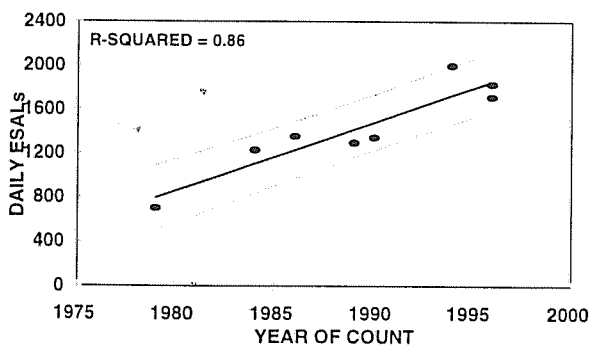


Figure 3. Traffic Counts, Average Regression Line and 80th Percentile Regression Lines on P157-1

a confidence interval for the cumulative traffic.

Processing of HVS traffic data consisted of conversion of 70 kN wheel loads to number of ESALs, and adding to this the cumulative traffic which had

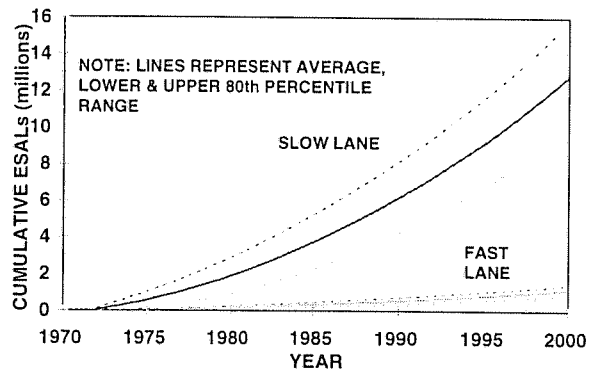


Figure 4. Cumulative Traffic on Slow and Fast Lanes on P157-1

occurred up to 1980, before the HVS test. Traffic data finally used in the comparison are summarized in Table 1.

Table 1. Estimate of Traffic Loading On P157-1

Lane	Year	Cumulative ESALs (millions)		
		Lower 80th Perc.	Average	Upper 80th Perc.
Slow	1980	0.89	1.89	2.88
	1996	7.37	9.90	12.43
Fast	1980	0.08	0.17	0.26
	1996	0.66	0.89	1.12

Data Collection on P157-1, 1996. As much as possible of the same type of information previously gathered during the HVS test in 1980 was collected during this study. Measurements consisted of the following:

- i) RSD Deflections;
- ii) MDD deflections;
- iii) Falling Weight Deflectometer (FWD) deflections;
- iv) Moisture and Density;
- v) DCP penetration;
- vi) Rut depth, and
- vii) Visual surveys

All data were collected during May 1996, which falls within the seasonal period during which the HVS test was conducted 16 years earlier. Although data were collected over a 300 m section, the analysis was concentrated around a section which lay 50 m to either

side of the 1980 HVS test section. Figures 5 and 6 show a typical variation in deflection measurements over part of the section of interest.

As can be seen from Figures 5 and 6, there is a relatively high variation in the measured deflections. This highlights an important facet of this type of comparison. A specific HVS test is conducted over only 8 m of the total road section. Although there is some

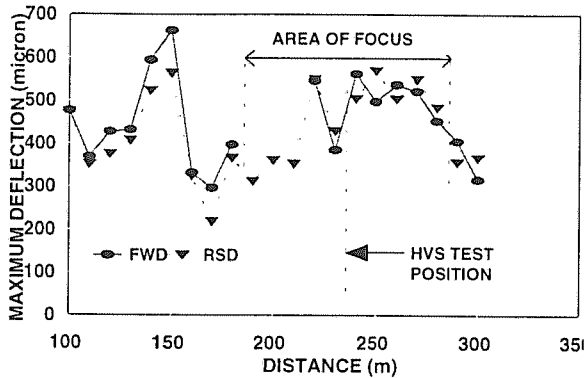


Figure 5. Deflections on P157-1, Slow Lane, 1996

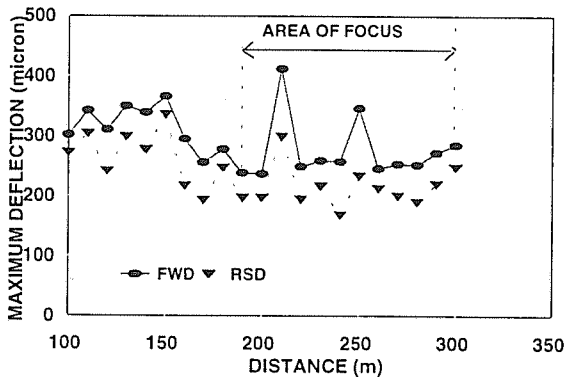


Figure 6. Deflections on P157-1, Fast Lane, 1996

variation in measured parameters even within this 8 m section, a specific HVS test essentially represents a point measurement. This point measurement now has to be compared with a deflection or rut depth value measured at a later time, and at a different position, or positions. However, there is a natural variation which has to be taken into account in the comparison. The point value represented by the HVS test should therefore not be compared with a single value (which may or may not be similar simply because of the natural variation in the measured parameter over a section of pavement) but with a range of possible values.

The problem thus arises of how to take account of the natural variation of deflections or rut depths over the section of interest. In this study, this was accomplished by constructing a confidence interval which was obtained based on the statistical information obtained over a 100 m section (50 m on either side of the HVS test section).

The confidence interval which is based on the parameter in question (i.e. rut depth, deflection etc.),

together with the confidence interval based on variations in cumulative traffic, results in a confidence window which provides a range of values which can be compared with the HVS test data, as discussed in the following section.

COMPARISON OF BEHAVIOURAL ASPECTS

A comparison was made of some of the behavioural aspects of the pavement as measured under the HVS with those measured under real traffic and environmental conditions. These behavioural aspects included a DCP comparison, a comparison of densities and moisture contents, and RSD deflections.

DCP Measurements. The behaviour of P157-1 as measured with the DCP during HVS testing is summarized in Figure 7. Figure 7 shows the rate of penetration versus depth, both before and at the end of testing (i.e. after water had been added, as shown in Figure 2).

The lines plotted in Figure 7 represent the average DCP curve measured on the HVS section. It should be noted that a lower rate of penetration indicates a higher shear strength (De Beer et al., 1988). Bearing this in mind, Figure 7 clearly shows the mechanism of failure. It is clear that, as a result of the HVS test, the shear strength at the bottom of the base decreased significantly, while the upper part of the base had actually strengthened slightly. A possible reason for this may be de-densification at the bottom of the base resulting from the tendency to develop tensile stresses

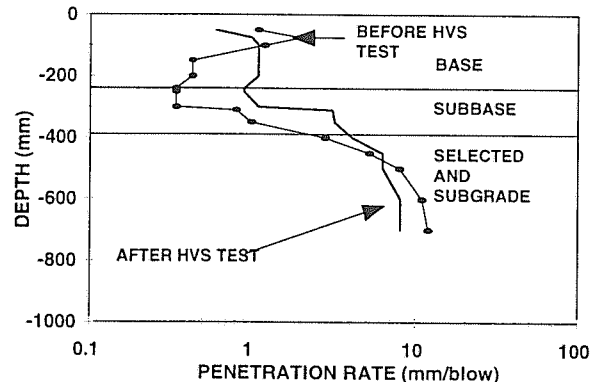


Figure 7. DCP Penetration Curves Before and After HVS Testing in 1980

at the bottom of this layer. The subbase had also experienced a significant loss in strength while the selected layers and subgrade had actually improved slightly during the test.

Figure 8 shows the maximum and minimum DCP curves taken *before* the HVS test started in 1980, together with the DCP data obtained in 1996. It is clear from this comparison that since 1980 the shear strength characteristics have remained virtually unchanged under

the action of traffic. In all cases the base and subbase layers were so dense that, during the measurements taken in 1996, some parts of these layers had to be drilled through in order to complete the test. The only DCP hole which did not require drilling was that taken within the old HVS section. Figure 9 shows the penetration curve for this point plotted with the average curve taken after failure of the HVS section in 1980. Once again there is a fairly good comparison between the HVS curve and the curve taken after real trafficking.

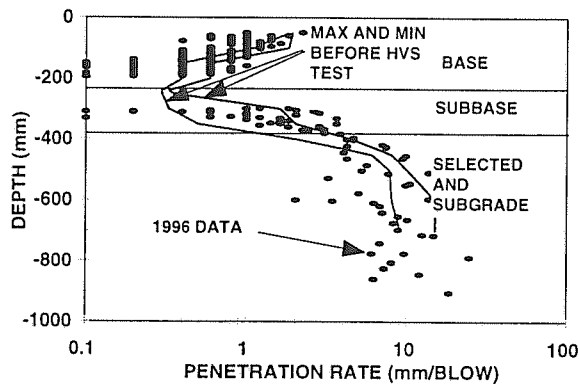


Figure 8. Comparison of DCP Penetration Curves Measured in 1980 and 1996

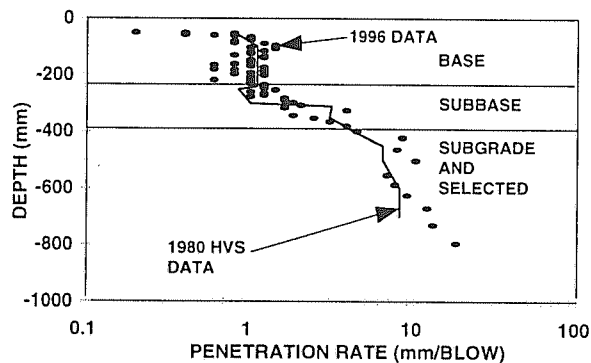


Figure 9. Comparison of DCP Penetration Curves Measured on the HVS Test Site in 1980 and 1996

It is thus clear from the figure that, even on this section which had experienced severe deformation changes under the HVS test, the subsequent action of traffic had not significantly changed the shear strength characteristics of the pavement.

Moisture and Density. The moisture and density characteristics of the different pavement layers were measured at several points within the slow lane, fast lane and shoulder in 1996. A nuclear gauge was used for all these measurements. Nuclear gauge measurements were also taken before and after the HVS test in 1980. Unfortunately only moisture measurements are available for the period during testing in 1980. The only density measurements reported were those taken after the test. Density measurements do however exist

for points adjacent to the test section. These densities are therefore assumed to represent densities prior to HVS trafficking in 1980. Changes in moisture content during the HVS test were very minor before the addition of water towards the end of the test. It was noted that the moisture contents measured after testing were not representative of a saturated condition.

Table 2 shows the average densities and moisture contents measured at two points during the HVS test and those collected during 1996. To present the data in a compact format, the averages of two sampling points are reported in Table 2. However, it should be noted that the variations in densities and moisture contents were quite large between the sampling points. Even within the relatively small HVS section, differences of as much as 136 kg/m^3 (approximately 6 percent) between the densities sampled at two points were recorded. Such a high natural variation limits the amount of confidence one can have in drawing conclusions from these data.

Table 2: Average Densities and Moisture Contents Measured in the Vicinity of the HVS Test Section in 1980 and 1996

Layer	Time of Measurement	Dry Density (kg/m^3)	Moist. Content (%)
Base	1980, No HVS Traffic	2262	2.7
	1980, After HVS Traffic	2326	3.4
	1996	2281	3.8
Subbase	1980, No HVS Traffic	2124	8.6
	1980, After HVS Traffic	2118	8.5
	1996	2306	7.8
Selected Layer	1980, No HVS Traffic	2084	10.2
	1980, After HVS Traffic	2058	8.4
	1996	2223	11.7

However, it can be seen that in all cases the densities and moisture contents measured during 1996 are similar to those measured during 1980. With the amount of data available it cannot be established whether any differences in density can be ascribed to the natural variation in material density and compaction or to the differences between HVS and actual

trafficking.

Deflection Measurements. During the HVS test in 1980, RSD measurements were taken under a 40 kN dual wheel load. RSD Deflections measured under the same load in 1996 were shown for the slow and fast lane in Figures 5 and 6, together with the FWD deflections.

Table 3 summarizes the deflections measured in 1996 on the outer wheel paths for each lane. These values, together with the confidence interval for the cumulative traffic summarized in Table 1, were used to construct a set of coordinates which can be compared to the measurements taken during the HVS test. This comparison is shown in Figure 10.

It is clear from Figure 10 that the HVS predicted deflections compare well with the deflections after the road had been trafficked for 16 years.

Table 3. Summary of Deflections on P157-1

Lane and Wheel Path	RSD Deflections (micron)		
	Low. 80th Percentile	Average	Upp. 80th Percentile
Slow Lane, OWP	339	457	575
Fast Lane, OWP	180	269	358

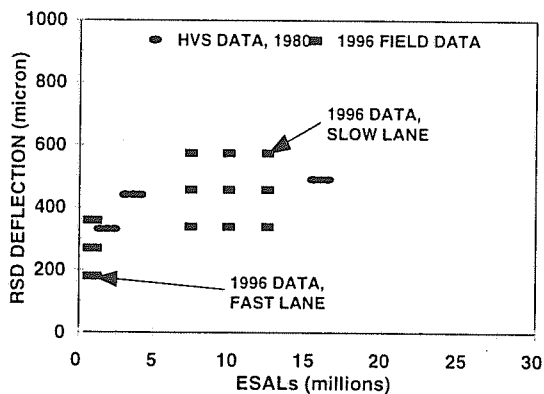


Figure 10. RSD Deflections Measured During HVS Testing Compared with Field Measurements Taken in 1996

COMPARISON OF PERFORMANCE RELATED ASPECTS (RUTTING)

In the previous section a comparison was made of some behavioural aspects as measured under the HVS and after 16 years of real trafficking. In this section a similar comparison is made of rutting measurements. Rutting and cracking are the only performance measures which were monitored under the HVS in the past. Of

these, rutting is at this stage the only parameter which can be directly used in this type of comparison. Crack development is closely monitored during an HVS test. However, this is a difficult measure to compare in a quantitative manner because of the often subjective nature of measurement and definition of cracks.

The general trend of rut formation with increasing HVS traffic was shown in Figure 2. As can be seen in Figure 2 the rate of rutting was very low. Only after the wheel load was increased to 100 kN and the addition of water to the pavement did the rutting increase significantly and dramatically.

During the data collection in May 1996, rutting was measured in both wheel paths of the slow and fast lanes. Straight-edge and High Speed Profilometer (HSP) readings were taken. During the measurement of rut depths with the straight-edge, it was noted that there was a slight ridge between the fast and slow lanes. This ridge was probably due to overlapping of the surface seal which had been placed during 1985. Although very slight, this ridge resulted in higher rut measurements in the inner wheel paths. As these higher rut measurements are not considered to be a true reflection of the rutting performance of the pavement, only the outer wheel path measurements were used in the comparison with rut depths measured under the HVS.

The rut depths measured by means of the straight-edge and the HSP are plotted in Figures 11 and 12 for the outer wheel paths of the slow and fast lanes, respectively. The average rut depths in all wheel paths in all lanes are summarized in Table 4. It should be noted that the averages shown in Table 4 represent only those data points lying within a 50 m distance of the HVS test site (i.e. only those points lying between 200 and 300 m in Figures 11 and 12 were used to obtain the averages in Table 4).

The differences between the rut depths measured in the inner wheel path and those measured in the outer wheel path can clearly be seen in Table 4. These differences are more marked in the case of the straight-edge measurements. In order to make the numbers more meaningful in real terms, all HSP measured values were rounded to the nearest mm.

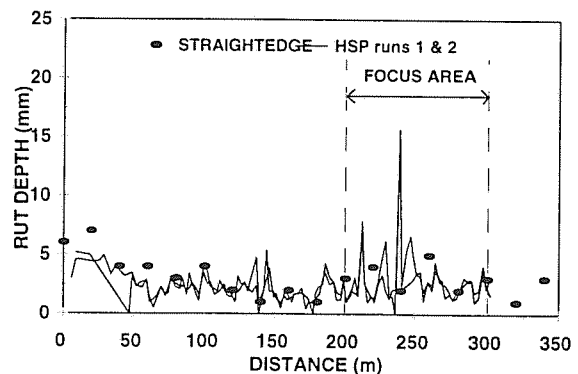


Figure 11. Rut Depths on Slow Lane, Outer Wheel Path

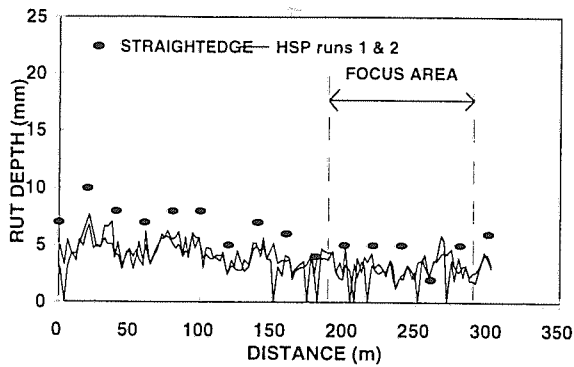


Figure 12. Rut Depths on Fast Lane, Outer Wheel Path

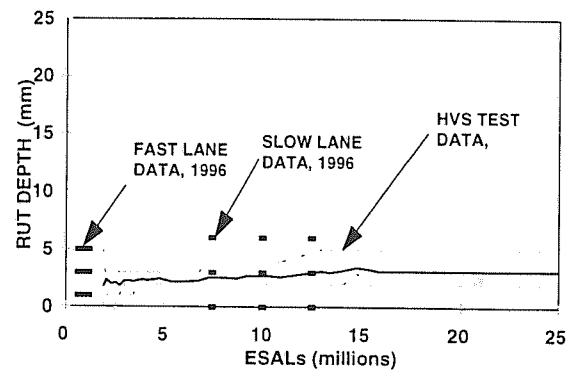


Figure 13. Comparison of HVS Rut Depth Measurements Taken During HVS Testing and Measurements Taken During 1996

Table 4. Rut Depth Measurements (in mm)

Lane	Instrument	Outer Wheel Path	Inner Wheel Path
Slow	Straight-edge	3	10
	HSP	3	9
Fast	Straight-edge	5	7
	HSP	3	3

Based on the HSP measurements, the standard deviation of rut depth measurements was 2.5 mm for the slow lane and 1.3 mm for the fast lane. The HSP measurements were used to obtain these standard deviations since a much larger number of data points were measured with the HSP than with the straight-edge.

As before, the rut depth data were used to construct a confidence interval for rut depth. Table 5 summarizes the confidence intervals for the slow and fast lanes. In view of the close similarity of the HSP and straight-edge measurements it was decided to use only the HSP averages and standard deviations to construct the confidence interval.

Figure 13 shows the confidence interval measured in 1996 plotted with the average, maximum and minimum rut depths measured during the HVS test. These values were obtained by sampling at a variety of test points along the 8 m HVS test section while the test was performed.

Table 5. Confidence Interval for Rut Depth (in mm)

Lane	Lower 80th Percentile	Average	Upper 80th Percentile
Slow	0	3	6
Fast	1	3	5

As before, the estimated traffic was used to obtain an estimate of the cumulative traffic on the road since 1980. It is clear from Figure 13 that the HVS rut curve compares well with the rut depth measured after a similar amount of actual traffic and after 16 years of changes in environmental conditions. However, since the rut depths are in all cases very low, the strength of the conclusions that can be drawn from the above comparison are naturally somewhat limited. What can be concluded, however, is that for road P157-1 the environmental influences which were not included in the HVS testing did not cause significant changes in rut depth formation and that the rut depths which developed during HVS testing are very similar in magnitude and variation to those which were measured after a significant period of trafficking and seasonal changes in environmental conditions.

EFFECT OF EQUIVALENCY FACTOR (n-VALUE)

It was noted earlier that the equivalency factor used in equation 1 can significantly affect the amount of ESALs estimated to have been applied by the HVS. After completion of the HVS test in 1980, a mechanistic analysis was performed to estimate possible n-values for this pavement. These values were based on backcalculated moduli values which were used in a mechanistic analysis to predict remaining life under different wheel loads. Since the moduli of the different layers changed during the HVS test, the n-values resulting from the analysis also changed, depending on the moisture conditions and stage of testing. The final n-values ranged from approximately 3 to 5. In the preceding sections, an n-value of 4 was assumed. The effects of using a different n-value to calculate equivalent ESALs from HVS trafficking is illustrated in Figures 14 to 17.

Figures 14 to 17 indicate that, in the case of P157-1, the choice of n-value does not significantly affect the comparison between HVS predicted performance and actual performance and behaviour at this stage.

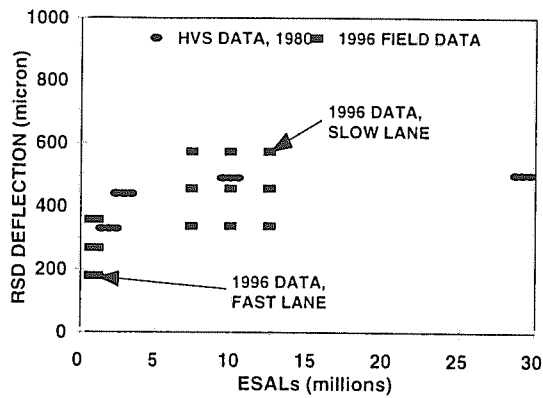


Figure 14. RSD Deflections Measured During HVS Testing Compared with 1996 Field Measurements for n=3

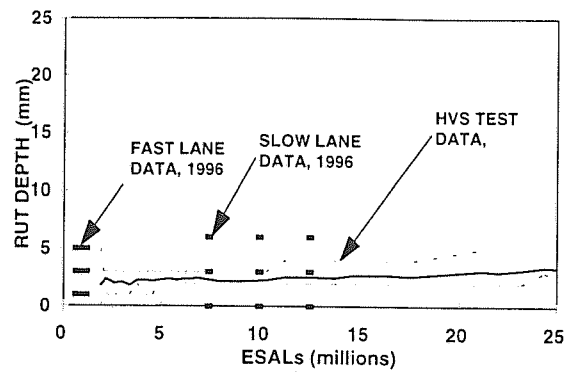


Figure 17. Rut Depth Measurements Using n=5 During HVS Testing, Compared with 1996 Field Measurements

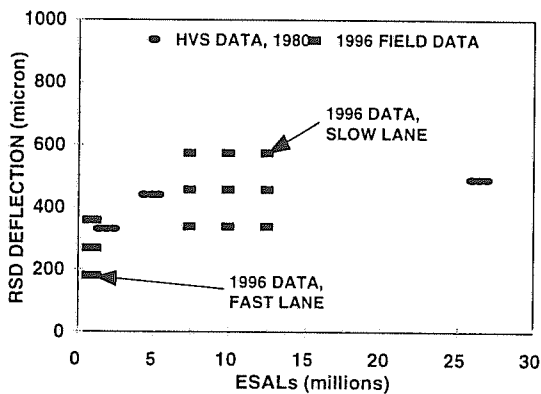


Figure 15. RSD Deflections Measured During HVS Testing Compared with 1996 Field Measurements for n=5

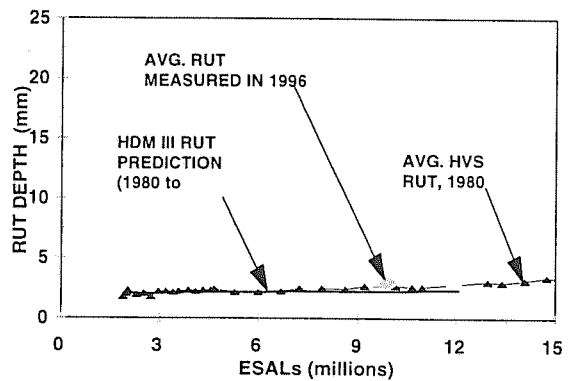


Figure 18. Comparison of HDM III Rut Prediction with Rut Depths Measured During HVS Testing in 1980, and Rut Depths Measured in 1996

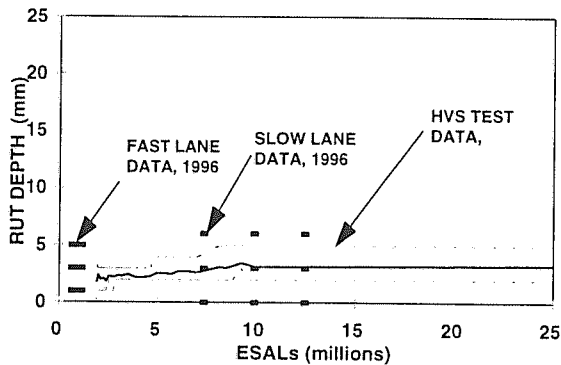


Figure 16. Rut Depth Measurements Using n = 3 During HVS Testing, Compared With 1996 Field Measurements

COMPARISON OF HVS DATA AND HDM III RUTTING MODEL PREDICTION

Figure 18 shows the rut depth predicted by the regionally calibrated HDM III, plotted with the average rut depth measured during the 1980 HVS test as well as the average rut depth measured in 1996. For the HDM III calculations, 1980 was used as a base year and rut

depth predictions were made over the next 20 years.

The traffic used as input for HDM III was the average estimate of daily ESALs as shown in Figure 3. This traffic estimate was also used to assign a cumulative traffic figure to each year so that a direct comparison with rutting measured under the HVS could be made. In order to obtain the HDM III rutting prediction, the pavement structural number (SN) as it was in 1980 had to be estimated. This was achieved by using the CBR values as indicated by the DCP tests conducted during 1980. This method of estimating SN was shown to be less accurate than methods based on backcalculated moduli or deflection bowl parameters (Rohde, 1994; Africon, 1996). However, in the absence of more detailed test data, it was hoped that the chosen method would provide a reasonable estimate of SN. Other inputs for HDM III included the rut depth and standard deviation of rut depth as measured at the start of the HVS test in 1980.

Figure 18 indicates that, in the case of P157-1, the rutting prediction of the regionally calibrated HDM III correlates well with both the HVS test measurements and the actual rut depth measured in 1996. As before, the strength of the conclusions that can be drawn from Figure 18 is limited because of the very low rut depth.

The figure does indicate, however, that the environmental effects included in the regionally calibrated HDM III did not play a significant role in the case of road P157-1. This observation agrees with earlier findings by Kannemeyer (1994) and others (Africon, 1994), which indicates that the influence of the environment on pavement deterioration observed on the former Transvaal road network is much lower than that predicted by the uncalibrated HDM III performance model.

SUMMARY AND CONCLUSIONS

The study reported here was concerned with the differences between pavement behaviour and performance as measured during an accelerated pavement test, and that measured under actual traffic and environmental conditions. As this comparison was limited to a single pavement section, the observations cannot be seen as conclusive. However, several interesting and useful observations followed from the study. These observations are summarised and discussed in the following.

Comparison of Accelerated Pavement Test Data with Actual Long Term Pavement Performance. The following observations were made regarding the comparison of accelerated pavement test data with actual behaviour and performance of road P157-1:

- The shear strength characteristics of the various pavement layers determined in 1996 were very similar to those measured at the start of the HVS test in 1980. This may indicate that the action of traffic has not changed the shear strength characteristics of the pavement up to this stage. This observation was echoed by the HVS testing which showed minimal rutting and cracking up to the point where water was added to the pavement structure after approximately 70 million ESALs.
- Deflections measured on two lanes which carried different amounts of traffic were significantly different. In both cases the deflections measured after 16 years of trafficking and environmental influences were similar to those measured under the HVS at similar amounts of trafficking.
- Rut depth measurements taken during the HVS testing compared well with measurements taken after an equivalent amount of actual trafficking had taken place. Although the amount of rutting was very low in both cases, the amount of variation as well as the average rut depth values compared well.

The results obtained during this pilot study indicate that a comparison of accelerated pavement test data with actual long term pavement performance is feasible.

In future, such comparisons may possibly be used to calibrate or formulate predictive curves for certain types of distress. However, this study also indicates that the relatively high natural variation of some performance measures and uncertainty with regard to traffic limit the amount of precision that can be hoped for in (or should be designed into) such a long term predictive model.

The measurement of more performance related measures (such as roughness) during accelerated pavement testing will greatly enhance the usefulness of such tests for long term pavement performance prediction.

Relative Influences of Traffic Loading and Environment in Pavement Deterioration. It was stated earlier that one of the aims of this study was to investigate the influences of environmental effects on long term pavement performance. Since the HVS test performed on P157-1 only included load effects it would seem from the above observations that, in the case of P157-1, environmental effects did not affect the behaviour and performance as measured by the HVS in any significant manner.

Factors which definitely contributed to the limitation of environmental influences were the impervious and flexible surfacing and the timely placement of a 13 mm surface seal. This seal limited the possible detrimental effects of rainfall and also helped to keep the surface flexible. If this surface seal had not been constructed, the environmental effects might have caused larger deviations from the behaviour observed during HVS testing. If an hypothesis had been put forward that the HVS could accurately predict long term pavement performance, then this hypothesis was not disproved by this study. However, because of the high strength of the pavement and the fact that only one pavement section was studied, it also cannot be said that the hypothesis was proven with a high degree of confidence.

Intuitively, and based on observations made during this study, it becomes clear that the relative influence of environmental factors would vary, depending on pavement type and utility. Thus the behaviour and performance of heavy, well balanced, relatively highly trafficked and well maintained pavements are likely to be predominantly influenced by traffic related factors. Conversely, the environmental influence is likely to be far greater on lighter, low traffic pavements, and especially where maintenance operations are neglected.

Measured parameters such as rut depth and deflection show relatively high variations over the length of pavement investigated. Since the HVS test was conducted over a much shorter section, there are differences in variability between the two measurements. This difference, together with seasonal effects, makes it difficult to directly compare measurements obtained in the field with those obtained during a single accelerated pavement test performed at an earlier stage. In some cases the high natural variation

of a measured parameter may make a direct comparison with earlier accelerated pavement test data meaningless. In such cases it becomes impossible to distinguish between variations resulting from seasonal changes and those resulting from differences between accelerated test data and actual long term pavement performance.

This situation may be improved by collecting data (both during accelerated pavement testing and later field testing) in such a manner that a proper statistical and engineering analysis of results can be performed. Data should include key indicators such as moisture at time of testing and measured variability of the parameter in question.

Comparison of Rutting Predicted by Accelerated Pavement Testing and HDM III. Rutting Predictions made by the regionally calibrated HDM III performance model compared well with measurements made during the HVS test performed during 1980, and with the average rut depth measured after 16 years of trafficking and environmental influences.

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