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Overview of the strategy for the HVS testing of LIC bases on Road 2388 near Cullinan

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Abstract: The five year strategic plan for the Gautrans Heavy Vehicle Simulator (HVS) programme is briefly reviewed. The strategy for testing the trial sections constructed on Road 2388 near Cullinan is discussed in relation to the five year strategy. The investigation conducted at Cullinan utilised a holistic approach to obtaining the required results and therefore includes an assessment of construction issues, comprehensive laboratory testing of materials, mechanistic analyses of the pavement structures and the monitoring of the performance of the trial sections in the long term in addition to the usual HVS testing. The Cullinan trial sections consist of 9 sections with Labour-Intensively Constructed (LIC) bases using various materials, including coarse clinker ash, Waterbound Macadam, Composite Macadam and natural gravel emulsion treated material at various thicknesses. The behaviour of these bases relative to a conventionally- constructed G2 base will be evaluated. An overview of the detailed planning for the HVS testing of these sections is given.

Keywords: Gautrans HVS, HVS testing, planning report, Emulsion-Treated Base, (ETB), Waterbound Macadam (WM), Composite Macadam (CM), G2, Coarse clinker ash, Labour-Intensive Construction

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None

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The views and opinions expressed in this document are those of the author and do not represent the policy of the Division of Roads and Transport Technology of the CSIR or the Gauteng Department of Transport and Public Works.

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SUMMARY

The Gauteng Department of Transport and Public Works (Gautrans) has been operating a Heavy Vehicle Simulator (HVS) since 1978 on roads in the former Transvaal Province. Currently, the Gautrans HVS, which originally was one of a fleet of three HVSs operated by the CSIR, is the only machine still in operation in South Africa. The current political and expected socio-economic changes in South Africa call for a strategic re-evaluation of the objectives of the Gautrans HVS project.

Until recently, Gautrans was the only provincial road authority in the world with an accelerated pavement testing facility. The fleet of four HVSs (prototype and three HVSs) has been used over the past 17 years to conduct research and investigations. In this process more than 400 test sections were evaluated with the HVS which resulted in a database containing more than 4 Gigabyte of raw data, reports and graphics. Currently, this database is being reworked in modern software to allow improved utilisation of historic data.

In many respects the HVS testing programme formed the kernel for developing and enhancing South African pavement engineering technology, the quality of which is currently recognised internationally. The HVS's reputation has resulted in significant international usage of the technology such as in the current Californian Department of Transport (Caltrans) project and the Cold Regions Research and Engineering Laboratory of the US Army Corps of Engineers project. It has contributed significantly to technological development in a number of areas, such as materials design, pavement structural design, materials test methods and several innovative testing devices. In the process the HVS programme contributed to the development of several design codes (eg TRH series), manuals and specifications. The HVS also played a major role in developing human capacity in the road engineering field in South Africa.

The ability of the HVS to deliver results in a relatively short period of time has not only made a major contribution to the development of pavement engineering in South Africa, but has also saved the road authorities and the tax payer significant amounts. It has been reported that the HVS programme yielded a benefit/cost ratio of 12,8.

In view of the current changes in South Africa, with the accompanying new challenges, and in view of the international developments around HVS technology, the fact that the Gautrans HVS is the only remaining one in South Africa becomes of significant importance. It is therefore vital that this technology be preserved for South Africa and that it continues to address issues of strategic importance to Gautrans as well as to South Africa. However, this calls for an in depth re-evaluation of the strategic objectives of and the activities of the programme.

This document reviews the Gautrans HVS five year strategy and indicates the detail planning for the period April 1997 to March 1999. The work for this period will include the evaluation of ten trial sections constructed labour-intensively and consisting of bases of various materials placed on similar support conditions. The project is approached in a holistic manner and therefore, in addition to the usual HVS testing, the project will include the evaluation of construction issues, determination of the relative engineering properties of the materials used, the mechanistic analysis of all pavement structures and of the relative structural behaviour of the various pavement sections under HVS trafficking (in relation to a conventionally-constructed G2 base) as well as the monitoring of the long term performance of the trial sections under normal traffic.

1 INTRODUCTION

The Gauteng Department of Public Works and Transport (Gautrans), has been operating a Heavy Vehicle Simulator (HVS) since 1978. In this period the HVS has been used to investigate the behaviour and performance of roads in what used to be the Transvaal Province which is now divided into the Provinces of Gauteng, North West, Northern Province and Mpumalanga. Over the last seven years, the main focus has been on roads with granular layers and/or cemented layers such as those typically found in the area. The work conducted with the HVS has had a significant impact on the roads industry in South Africa. Currently, the Gautrans HVS, which originally was one of a fleet of three HVSs operated by the CSIR, is the only machine still in operation in South Africa.

In 1995 a new strategy for the Gautrans HVS programme was developed (Rust *et al* [1]). The Gautrans HVS Strategy document has been presented to the HVS Steering Committee and to the Deputy Director General of Gautrans, Mr Jack van der Merwe. Their comments have been included in the document. This strategy is briefly reviewed here and the detailed planning for the HVS testing at Road 2388 near Cullinan is discussed in the light of this strategy. The project is approached in a holistic manner and therefore, in addition to the usual HVS testing, the project will include the evaluation of construction issues, determination of the relative engineering properties of the materials used, the mechanistic analysis of all pavement structures and of the relative structural behaviour of the various pavement sections under HVS trafficking (in relation to a conventionally-constructed G2 base) as well as the monitoring of the long term performance of the trial sections under normal traffic.

2 BACKGROUND

The HVS of the Gauteng Provincial Administration, Department of Public Transport and Roads (Gautrans), was commissioned in 1978 by the former Roads Department of the Transvaal Provincial Administration (TPA). The acquisition of the machine was planned in co-operation with the former National Institute of Transport and Road Research (NITRR) of the CSIR following on the successful service evaluation of the prototype “blue machine” built and used by the NITRR. The TPA machine was one of three Mark III HVS machines acquired - the other two going to the National Department of Transport and the NITRR. Until recently, Gautrans was the only provincial road authority in the world with an accelerated pavement testing facility. The Mark III HVS can apply up to 17 000 repetitions of a wheel load (up to 175 kN) per day. This equates to 6 million standard axles per day indicating that, under specific conditions, the HVS can fail a heavy duty pavement in a matter of weeks, although normally lower wheel loads are used in order to improve the understanding of the pavement’s mechanisms of failure.

The fleet of four HVSs (prototype and three Mark III’s) were used over the past 17 years to conduct research and investigations into the behaviour of and performance of road pavements in a number of areas in the country. In this process more than 400 test sections were evaluated with the HVS, and more than 150 x 10^6 wheel load repetitions were applied with single and dual wheel loads up to 200 kN using normal truck tyres and an aircraft wheel. This equals more than 1400 x 10^6 standard 80 kN axles or the life span of more than 100 E4 road pavements (E12 according to the new TRH4). In this process an information and results database of more than 4 Gigabyte was created which contains raw data, reports and graphics. Currently, this database is being reworked in modern software to allow improved utilisation of historic data.

The Gautrans HVS was used to address road building problems specifically experienced in the old Transvaal Province. Figure 1 shows the broad categories of road evaluated with the Gautrans HVS.

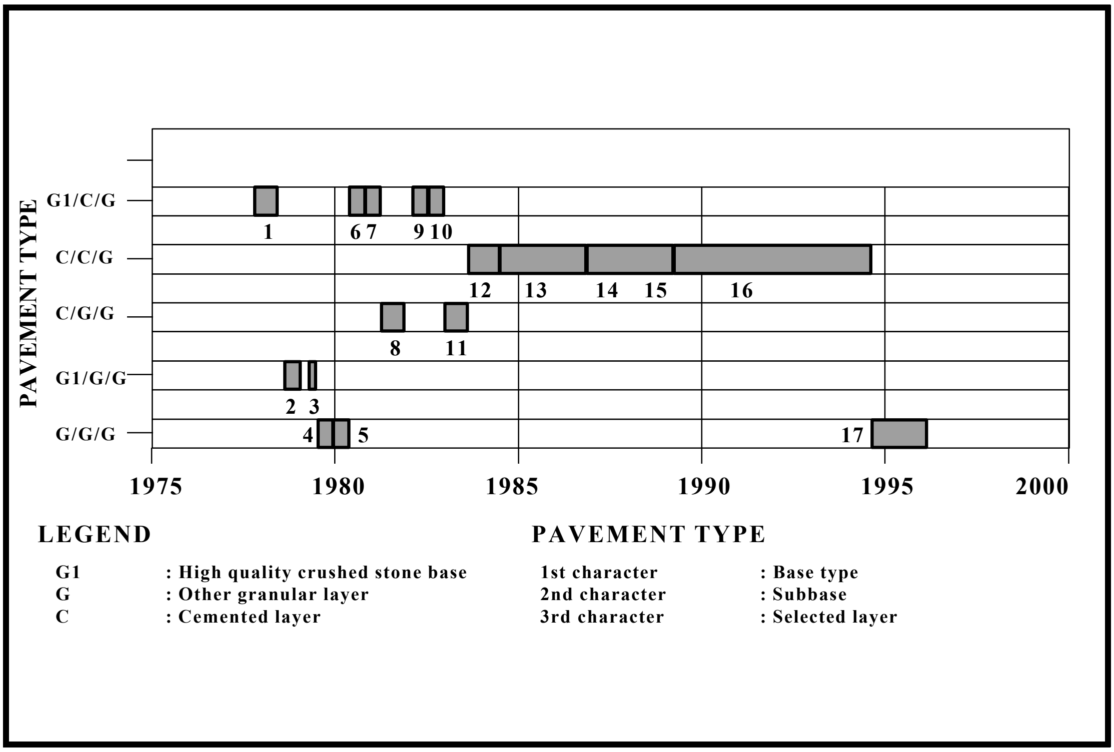

Figure 1 : The TPA Heavy Vehicle Simulator programme

In many respects the HVS testing programme formed the core of development and enhancement of South African pavement engineering technology, the quality of which is currently recognised internationally. It has contributed, and is still contributing, significantly to technological development in a number of areas such as materials design, pavement structural design, pavement rehabilitation and maintenance, materials test methods and investigations into the effect of environmental changes on pavement behaviour.

The HVS has also played a significant role in the reduction of pavement construction costs in South Africa. Initial materials and construction costs of South African pavements are in the order of 40 per cent less than those in the areas of the United States with similar climatic conditions to that of South Africa. This is largely due to the fact that pavement innovations could be rapidly evaluated using the HVS.

As reported by Horak *et al* [2] at the 7th International Conference on Asphalt Pavements in 1992, the HVS testing programme compares favourably (in terms of return on investment) with the well-known AASHO road test. Horak states :

"In total the quantifiable benefits obtained from HVS testing expressed as an annual benefit that should continue year after year are about US$ 17 million per year (Exchange rate R 2,65/US$ and 15% inflation rate). If the present total cost per year of running the HVS fleet of US$ 1,358,490 is used, the benefit cost ratio is 12,8. This is obviously only a rough guide, but clearly indicates the extent of the benefits possible from the application of HVS research technology."

Rust *et al* [3] reported some individual cases of financial benefit from HVS testing. In a recent (1992) HVS test on an emulsion-stabilised base, the HVS test results indicated that a decomposed dolerite (of a quality not suitable for use in a base) could be upgraded to base standard by the addition of lime and bitumen emulsion. This would lead to a potential saving of approximately R30 000 per km in the base layer. For the province of the Free State alone this technology could be used in 2000 km of road which indicates a potential saving of R60 million. The HVS testing on six test sections cost approximately R600 000.

Similarly, the development of the Large Aggregate Mixes for Bases (LAMBS) technology, in which the HVS played a major role, has led to major savings on the N2 North Coast project. The LAMBS technology allows for a reduction of up to 40 per cent in binder content if larger aggregates (26 mm to 53 mm) are used. In the N2 project where 75 000 tonnes of LAMBS were placed, this technology led to significant savings.

The ability of the HVS to deliver results in a relatively short period of time has not only made a major contribution to the development of pavement engineering in South Africa, but has also saved the road authorities and the tax payer significant amounts of money.

The HVS's reputation has resulted in significant international usage of the technology. The Californian Department of Transport (Caltrans), has recently acquired two HVSs and is funding a five year technology transfer project with the involvement of the CSIR, the University of California at Berkeley and Dynatest Consulting Inc. The Cold Regions Research and Engineering Laboratory of the US Army Corps of Engineers (USACE) and VTT in Finland are both using HVS Mk IV's. A new machine is also being constructed for the Waterways Experiment Station of the USACE.

In view of the current changes in South Africa, with the accompanying new challenges, and in view of the international developments around HVS technology, the fact that the Gautrans HVS is the only one remaining in South Africa becomes of significant importance. It is therefore vital that this technology be preserved for South Africa and that it continues to address issues of strategic importance firstly to Gautrans and secondly to South Africa. However, this calls for an in depth re-evaluation of the strategic objectives of and the detail activities of the programme.

The possibility of co-operation with other agencies and organisations, such as the National DoT and Sabita should be investigated in order to enhance the benefits obtained from the programme.

3 BRIEF REVIEW OF THE FIVE YEAR STRATEGY FOR THE GAUTRANS HVS PROGRAMME

The five year strategy for the Gautrans HVS programme[1] indicated the following vision and mission statements as well as strategic objectives :

Vision

The Gautrans HVS programme will enhance the provision of an economically viable and environment- and user- friendly road network through accelerating the delivery of technological solutions of high quality.

Mission Statement

The Gautrans HVS programme enhances the provision of and evaluation of technologies and solutions which will address the cost-effective provision of new roads as well as the upgrading of existing roads in order to improve the accessibility, mobility and safety of road transport users in accordance with the aims of the development of the new South Africa.

In particular, the Gautrans HVS programme will :

- enhance understanding of pavement and materials design, performance principles and deterioration models through the investigation of the behaviour of various pavement compositions including labour-intensively constructed layers and new materials and technologies;

- endeavour to deliver practical solutions to problems experienced in road design, construction, maintenance and management, and

- evaluate and demonstrate the application of new technologies through practical verification of research results.

Strategic Objectives

The Gautrans HVS programme will aim to develop, improve understanding of, verify or evaluate :

- the design and performance of pavement structures suitable for basic access roads and collectors and rural road networks;
- Labour-Intensive Construction (LIC) friendly pavement compositions;
- techniques for upgrading and maintenance of existing gravel (and other) low volume pavement structures;
- the use of innovative, cost-effective materials and methods , optimising the use of in-situ materials (including waste materials);
- technologies for the preservation of the existing road network in order to extend its service life;
- technologies for optimisation of the use of scarce road building materials (eg gravel roads), and
- calibration of pavement deterioration models suitable for use in Pavement Management Systems.

4 STRATEGIC OBJECTIVES FOR THE PERIOD APRIL 1997 TO MARCH 1999

The objectives stated in the Gautrans HVS five year strategy were :

Objective 1 (completed) :

To complete the HVS testing on a relatively strong in-situ gravel pavement which had been upgraded by application of a gravel bonding agent (road S702) with the purpose of evaluating the ability of inexpensive upgrading measures to provide an all-weather riding surface for moderate to low traffic.

Objective 2 :

To evaluate the performance of very light gravel pavements (G4 to G10 base material) upgraded by application of a gravel bonding agent with the purpose of evaluating the ability of inexpensive upgrading methodologies to provide roads suitable for basic access. ***This objective now has a lower priority than that of Objective 3.***

Objective 3 :

To investigate the performance of various upgrading options constructed with LIC methods on existing gravel roads with the purpose of evaluating their suitability for providing basic access roads, collectors and rural, lightly trafficked roads. ***The work towards this objective is currently being conducted on road 2388 near Cullinan.***

Objective 4 :

To maximise the use of the historic HVS data base as well as future HVS testing results to calibrate and validate pavement deterioration models suitable for Pavement Management Systems. ***This is an ongoing objective.***

5 DETAILED PLANNING FOR HVS TESTING AT ROAD 2388

5.1 Detailed objectives for Road 2388

The detailed planning for the HVS testing on Road 2388 has been reported by Steyn.[4] In order to address Objective 3 above, a detailed experiment was planned on Road 2388 near Cullinan. This work is focussed on the evaluation of ten labour-intensively constructed bases using a number of different materials. As mentioned before the project includes, in addition to the usual HVS testing, the evaluation of construction issues, determination of the relative engineering properties of the materials used through laboratory testing, the mechanistic analysis of all pavement structures and of the relative structural behaviour of the various pavement sections under HVS trafficking (in relation to a conventionally-constructed G2 base) as well as the monitoring of the long term performance of the trial sections under normal traffic.

The objectives of the experiment are to :

- evaluate construction issues related to the materials and techniques used, with

particular emphasis on the advantages and disadvantages of labour-intensive construction;
- evaluate the cost differences in conventional and labour-intensive construction;
- determine the engineering properties of the materials used both in the laboratory and in the field;
- develop appropriate test methods for the materials used;
- conduct mechanistic analyses of the pavement structures;
- determine the relative structural behaviour of the various pavement sections under HVS trafficking and in relation to a conventionally-constructed G2 base;
- monitor the long term performance of the trial sections under normal traffic and to compare this with the HVS test results;
- to develop guidelines on the design and construction of LIC bases for the upgrading of roads, and
- to provide some inputs into the development of transfer functions for the design of these bases.

5.2 Sections constructed

The following trial sections were constructed :

- two conventional Emulsion-Treated Bases (ETB) with a natural gravel parent material - 100 mm and 150 mm thick (this is the structure used for the remainder of the road on which the HVS test sections are constructed);
- two waterbound Macadam bases (WM) - 100 mm and 150 mm thick;
- two composite Macadam bases (CM) - 75 mm and 125 mm thick;
- two coarse SASOL clinker ash bases - 100 mm and 150 mm thick;
- a coarse SASOL clinker ash ETB - 100 mm thick, and
- a conventionally constructed G2 base as control.

These bases were constructed on the same subbase conditions, at the indicated layer thicknesses and using different construction techniques. The trial sections are located approximately 12 km north-east of Cullinan, on road 2388, between km 2.400 and 3.134. The location is indicated on the map in Figure 2.

A comprehensive report on the construction of the above sections, including a discussion of construction issues and basic materials properties, is currently being compiled.

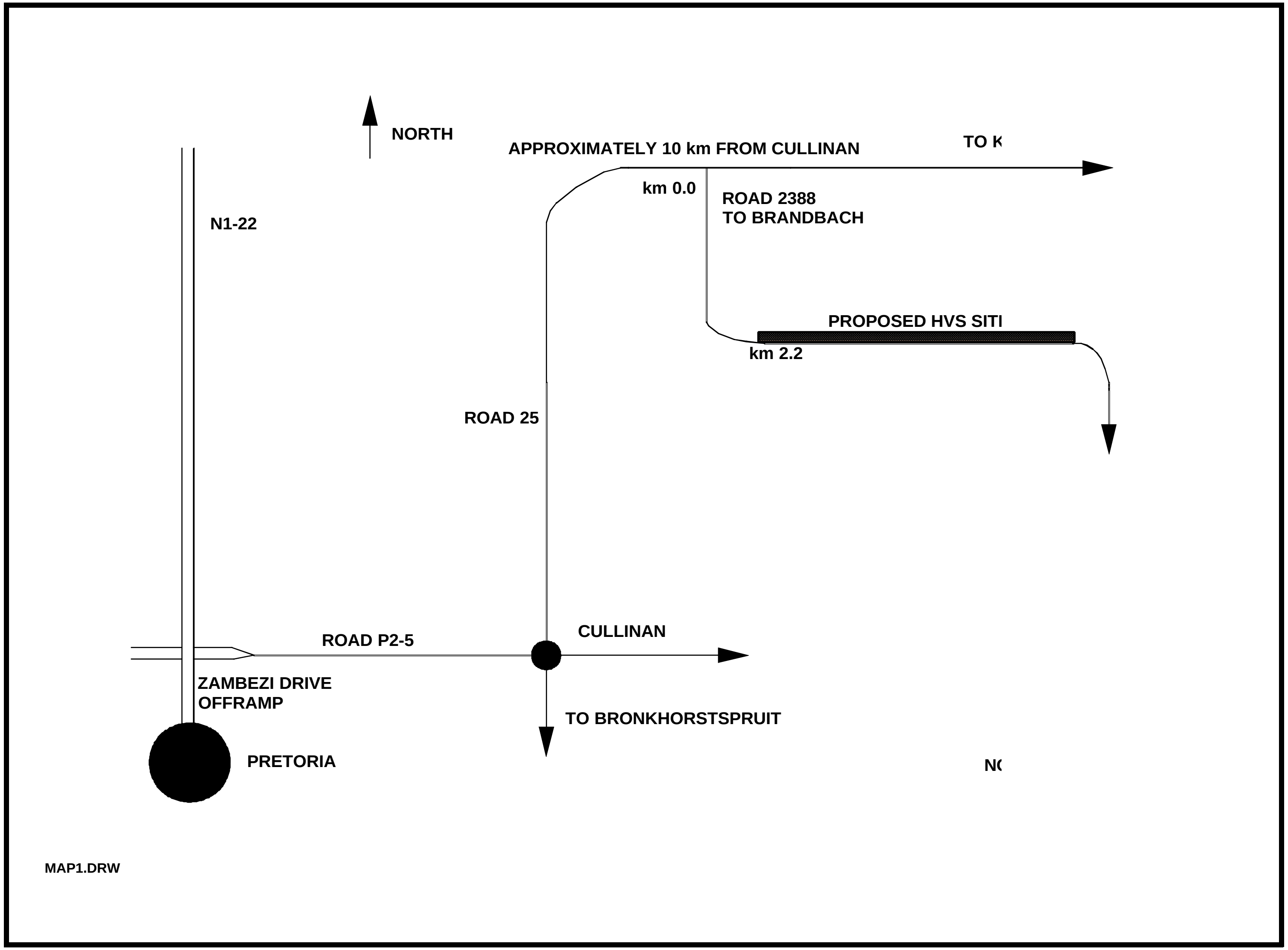

Figure 2 : Location of the HVS test site on Road 2388 near Cullinan

5.3 Laboratory testing

Tables 1 and 2 give the laboratory tests conducted on the unbound and bound materials used in these trial sections respectively.

Table 1 : Number of laboratory tests per unbound material type

	Sandstone	**Ferricrete**	**Ash**	**Crushed stone**
Grading	4	1	4	1
Atterberg limits	4	1	2	1
MDD/OMC	4	1	2	1
CBR	4	1	2	1

Table 2 : Number of laboratory UCS tests conducted on the bound materials

	Subbase	**ETB Ash**	**Natural ETB**
UCS Tests	32	8	4

5.4 Field testing

Table 3 gives the field testing conducted during and after construction of the trial sections.

Table 3 : Number of field tests conducted on the selected, subbase and base layers constructed at the Cullinan trial sections.

	Selected	**Subbase**	**ETB base**	**ETB Ash base**	**Neat Ash base**	**Crushed Stone base**	**Mac-adam bases**
Nuclear density	8	70	90	21	21	9	27
DCP	91	79	43	21	22	9	-
RCCD	-	75	110	21	22	9	-
Clegg	-	-	18	19	14	-	27

5.5 HVS test programme

The stated objectives of the overall HVS testing programme enable the overall HVS programme to be divided into two phases :

- Phase 1 (quick relative rating phase)one HVS test at the same load/stress and nominal environmental conditions on each of the ten pavement types to determine their relative behaviour, and

- Phase 2 (enhancement phase) HVS testing of selected sections at two loading conditions (and preferably under both relatively dry and wet in situ moisture conditions) to determine the subsequent fundamental behaviour for development of interim design guidelines and transfer functions.

The number of HVS tests to be conducted in Phase 2 will be determined by the results of the testing conducted during Phase 1. All tests will be performed in the wandering mode, using standard dual truck tyres at the rated tyre inflation pressure for the specific load. In order to optimise the value obtained from the testing within the limited time available, the following test programme will be used for each of the sections during Phase 1 :

- up to 200 000 repetitions, wheel load of 40 kN in the dry state;
- 200 000 to 400 000 repetitions, wheel load of 70 kN in the dry state, and
- the introduction of in-depth water into the base followed by three days of testing at 40 kN and three days at 70 kN.

The usual HVS data acquisition measurements will be conducted. However, initially readings will be taken at 10, 1000, 5000 and 10 000 repetitions in order to characterise the early behaviour of these materials, which are relatively unknown. After the initial stage, measurements will be taken at appropriate intervals. The parameters to be monitored during the HVS tests will include the standard HVS test parameters, as well as some additional parameters. These will include (instruments to be used are enclosed in brackets) :

- Surface and in-depth permanent deformation and longitudinal roughness profiles (straight-edge; profilometer and MDD);
- Elastic surface and in-depth deflection (RSD, MDD and FWD);
- In situ moisture content and density (surface and strata gauge);
- Surface cracks and potholes (photographs);
- DCP behaviour, and
- Profiles and in depth layering (Test pits).

FWD tests will be conducted during HVS testing as and when the equipment becomes available. A separate project to develop an interim relationship between FWD and RSD/MDD measured elastic deflections on the types of pavement tested is proposed. This will enhance the results from the HVS tests in terms of their applicability to normal practice, where RSD and MDD measurements are normally not available. The parameters that may influence the data from the HVS tests, such as rainfall and temperature, will be measured and reported on the daily forms.

Mechanistic analyses will be conducted at two levels :

- before HVS testing, using only the available laboratory data as input in order to predict the behaviour of the sections under HVS trafficking, and
- after HVS testing in order to verify the accuracy of the predictions.

5.6 Long Term Pavement Performance Monitoring

The long term pavement performance (LTPP) of the sections will be monitored by Gautrans from time to time. Tests will be conducted on shoulder where the HVS tests were conducted as well as on the lanes under actual traffic. Tests will include deflection analyses, rut depth, riding quality and DCP analysis (where necessary) an will be conducted at a six monthly intervals.

5.7 Technology transfer

The technology and knowledge gained through the programme will be transferred to practice through the following :

- Reporting, including detailed and executive summary reports
- Committee presentations and mini-seminars
- Presentations to the Bituminous Materials Liaison Committee
- Technical papers and articles.

In the process of technology transfer, specific attention will be given to linkages with other projects and/or programmes, including the DoT research programme, the Sabita research programme, the development of the HVS data base, long term pavement performance studies and international projects such as Caltrans' Cal/APT project.

5.5 Expected deliverables

The following deliverables are expected from this work :

- construction report and recommendations;
- comparison of laboratory materials properties with the in-situ properties of the bases;
- the comparative behaviour of the bases under HVS trafficking;
- economic analyses of the different options;
- guidelines and recommendations on the design of these bases;
- initial transfer functions for the design of these bases, and
- the initiation of an LTPP programme.

6 CONCLUSION

This document briefly reviews the five year strategy for the Gautrans HVS testing programme. It furthermore provides a framework for the HVS testing of the trial sections constructed on Road 2388 near Cullinan and its link to the five year strategic plan. The objective of the planning process is to ensure the relevance of the work conducted within the ambit of the new South Africa and to maximise the benefit obtained from the programme through co-operation with other interested parties.

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