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Contract Report

**Initial Investigation into
Development of
Accelerated Pavement
Evaluation (APE) Vehicle.**

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| <p>Abstract: CSIR Transportek has for many years been at the forefront of Accelerating Pavement Testing (APT) technology. The use of the HVS for research purpose has attracted much attention. One aspect of the HVS's capabilities has not been used that often. This is the option of using the HVS to <i>proof-test</i> a newly constructed or in-service pavement or even to only evaluate the pavement response qualitatively over a very short period. The problem addressed in this report is investigate the opportunity to develop a method by which a full pavement structure can be proof-tested in a very short time-span without the limitations that the current HVS-approach will provide. An amount of funding was obtained through the ADHI funding process to perform an initial feasibility study and preliminary market analysis on the development of a device to perform this evaluation role.</p> <p>Based on the information provided and the discussions in this STEP Report, the following conclusions are drawn:</p> <ul style="list-style-type: none"> • The technical need for the APE vehicle may exist with potential clients, although they may not be able to understand the possible usefulness of the device as yet; • More detailed data of typical applications and potential use will be required to enable potential clients to support the further development of the APE vehicle concept; • The development of a gravel road deterioration device may be a more urgent requirement in the light of the absence of such devices and the high number of these roads internationally. <p>Based on the information provided and the discussions in this Technical Report, the following recommendations are made:</p> <ul style="list-style-type: none"> • An investigation into the possible development of a gravel road evaluation device should be performed, and • An investigatory test should be done where an FWD is used to provide the load and these data then be used to market the concept to potential clients. | | | | |
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EXECUTIVE SUMMARY

CSIR Transportek has for many years been at the forefront of Accelerating Pavement Testing (APT) technology. The use of the HVS for research purpose has attracted much attention. One aspect of the HVS's capabilities has not been used that often. This is the option of using the HVS to *proof-test* a newly constructed or in-service pavement or even to only evaluate the pavement response qualitatively over a very short period. The problem addressed in this report is investigate the opportunity to develop a method by which a full pavement structure can be proof-tested in a very short time-span without the limitations that the current HVS-approach will provide.

An amount of funding was obtained through the ADHI funding process to perform an initial feasibility study and preliminary market analysis on the development of a device to perform this evaluation role.

Based on the information provided and the discussions in this STEP Report, the following conclusions are drawn:

- The technical need for the APE vehicle may exist with potential clients, although they may not be able to understand the possible usefulness of the device as yet;
- More detailed data of typical applications and potential use will be required to enable potential clients to support the further development of the APE vehicle concept;
- The development of a gravel road deterioration device may be a more urgent requirement in the light of the absence of such devices and the high number of these roads internationally.

Based on the information provided and the discussions in this Technical Report, the following recommendations are made:

- An investigation into the possible development of a gravel road evaluation device should be performed, and
- An investigatory test should be done where an FWD is used to provide the load and these data then be used to market the concept to potential clients.

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1. INTRODUCTION AND BACKGROUND

1.1. Background

CSIR Transportek has for many years been at the forefront of Accelerating Pavement Testing (APT) technology. The use of the HVS for research purpose (i.e. evaluating new designs, developing design transfer functions and related basic research) has attracted much attention and a lot of good work has been done. One aspect of the HVS's capabilities has not been used that often. This is the option of using the HVS to *proof-test* a newly constructed or in-service pavement or even to only evaluate the pavement response qualitatively over a very short period.

The cost of operating the HVS as well as its ancillary equipment and effort to move the HVS to a newly established site may have prevented this to be used on a wider basis. Further, although the HVS applies accelerated load (mostly using higher than standard tyre loads to accelerate the damaging effect of the loads) it still takes at least a week or two to realistically apply a life-cycle worth of traffic loads onto a pavement (40 kN – 24 000 repetitions per day – 41 days; 60 kN – 24 000 reps per day – 8 days). These time estimates excludes time required for doing essential measurements of pavement response (which can easily be up to 2 hours per set of measurements or a decrease of more than 2 000 repetitions per day). Measurements also need to be scheduled to only be performed during the day, which further hampers the progress with a test.

Although the HVS is thus a very useful tool, it has its limitations when applying it as a proof-testing device (which it has not necessarily been designed for).

The problem to be solved is thus to develop a method by which a full (conventionally constructed) pavement structure can be evaluated (i.e. proof-tested) in a very short time-span without the limitations that the current HVS-approach will provide (time-span, cost, need for a camp, stoppages for measurements etc).

An amount of funding was obtained through the ADHI funding process to perform an initial feasibility study and preliminary market analysis on the development of a device to perform this evaluation role.

1.2. Objectives

The objectives of this STEP Report are:

- To provide background information on the development requirements (needs evaluation) of the envisaged device;
- To indicate the anticipated needs for such a device;
- To define the probable market for the device, and
- To make recommendations for further developments.

For the purposes of this project the device is designated the Accelerated Pavement Evaluator vehicle (APE vehicle).

2. NEEDS EVALUATION

2.1. Introduction

In order to make plans around the development of the APE vehicle, it is important to define the specific needs that will drive the development of the device.

2.2. Reasons for development

The main need for the APE vehicle is based on the continued evaluation of the structural condition of existing paved roads. This is especially a requirement where these roads are part of a Public Private Partnership (PPP) and where the private partner needs to maintain the condition of the pavement for a set period.

For these circumstances there is a technical need to evaluate the pavement structure on a regular basis without disturbing the traffic or damaging the pavement. The evaluation should also provide a realistic estimate of the remaining structural life and current condition of the pavement structure in general engineering terms. Finally, the test to be conducted should be cost-effective to the client.

A further potential client is operators of Pavement Management Systems (PMS). A need exist to enter the structural condition of a pavement into these systems, and to develop deterioration models for specific types of pavements. Currently deterioration models for the pavement are either sourced from related pavement structures or from Accelerated Pavement Test results. These models either take many years to develop (actual pavement measurements) or are hampered by the limitations of APT models. Using the APE vehicle regular measurements can be made of pavement structures, developing life-to-failure curves (for parameters such as rutting and fatigue) that can be updated annually (this excludes road roughness measurements).

The envisaged main market for the device is thus perceived as toll road concessionaires and public road owners.

In Figure 1 the typical application of typical sample data from the APE vehicle is illustrated. Four tests have been performed at various intervals (number of load repetitions on the real road). Typically this will simulate tests performed after 1, 2, 3 and 4 years of opening the road to traffic. The data are then plotted for each of the tests starting at the load repetition interval at which the test was done. A final model of the expected

performance of the pavement can then be developed using the overlapping datasets. A prediction of final service life for the pavement can also be made with more accuracy than when only a few specific deflection or rutting parameters are measured annually. Although Figure 1 only shows data for the permanent deformation behaviour, the same type of graph can be developed for the elastic deflection of the pavement.

Use of this type of data can assist the owner of the road to dynamically plan the periods for different types of maintenance on the road, depending on factors such as changes in traffic patterns and material response.

Permanent deformation APE vehicle

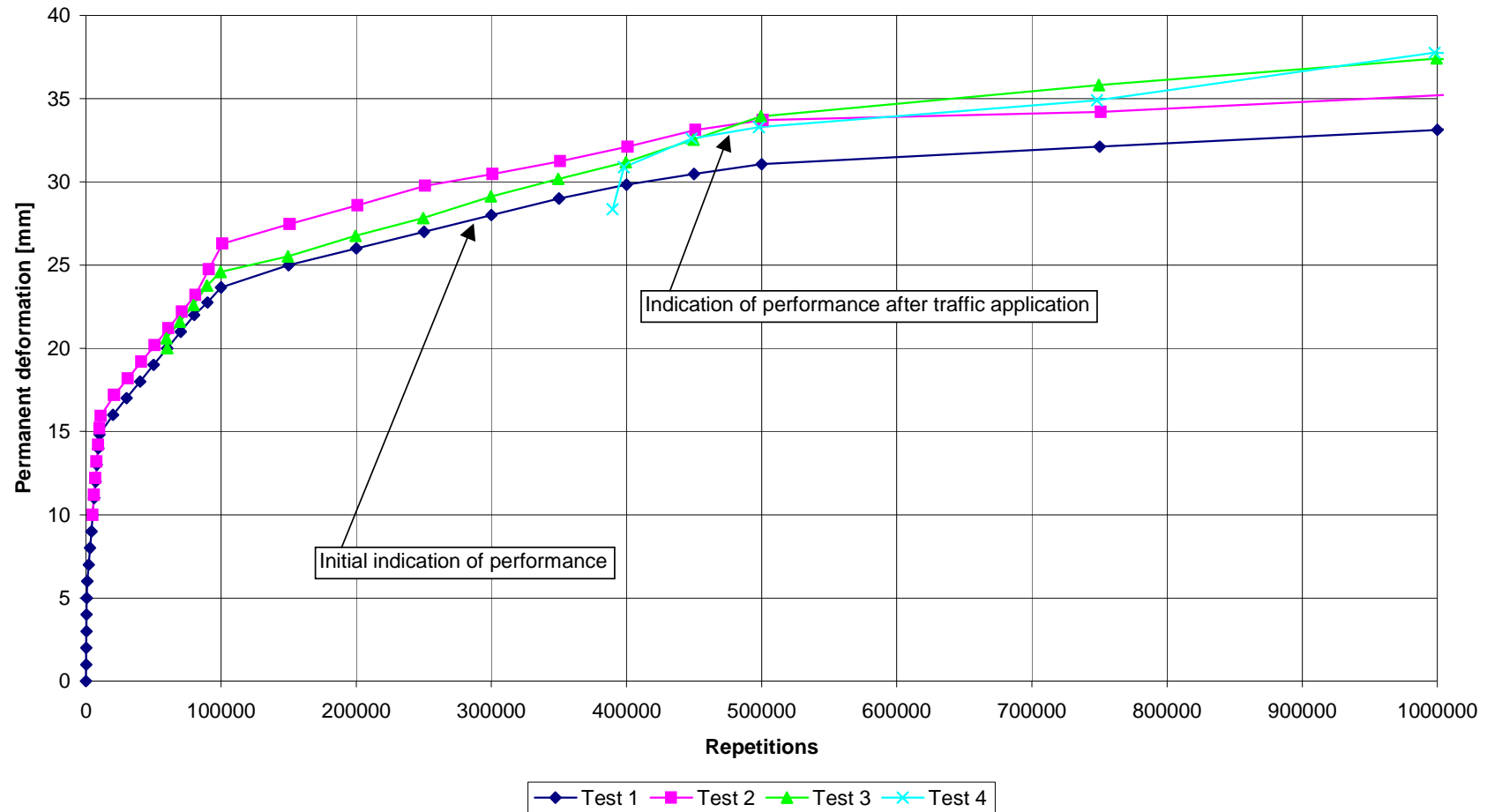


Figure 1: Typical data obtained from the APE vehicle.

2.3. Technical need

The main technical need can be defined as a device that can provide an estimate of structural pavement condition cost-effectively within a realistic time frame without undue disturbances to traffic.

The APE thus needs to test the pavement structure using typical load levels, and monitor the response of the road in terms of typical engineering parameters.

Further, a vehicle is needed that can operate on its own (i.e. a semi-trailer type of vehicle) where the basic frame can be used to attached a Load Application Device (LAD) and a Measurement Device (MD) to. This vehicle should have an office and power pack attached to it as a unit, and should be able to be moved to a new site only with the aid of a truck tractor. A typical schematic of the APE vehicle is shown in Figure 2.

The current method of applying accelerated loads via a rolling tyre is problematic if the rate of applying loads to the pavement needs to be increased significantly (currently running at 1 000 loads per hour (0,28 Hz) – required rate up to 10 Hz). It is proposed that instead of having a rolling tyre load application the load be delivered to the pavement through a dynamic loading cylinder – similar to a laboratory-type tri-axial load device or an FWD. The load cylinders will still be attached to a set of truck tyres, but they will only apply a Dynamic Load (DL) and not a Moving Dynamic Load (MDL) to the pavement. This is similar to the pavement being measured using an FWD, or a tri-axial sample in the laboratory being evaluated. However, the main difference lies in the fact that the complete pavement structure is evaluated (all layers together) and that it is done with real-life loads and tyres. (The limitation of variability in the pavement structure exists and will have to be addressed during further development). The position of the LAD on the frame should be moveable so that a number of positions on the pavement underneath the structure can be evaluated without the need for moving the vehicle.

The loads applied to the pavement are defined as Dynamic Loads (DL) - this means that the load magnitude changes with time but not the position of the load. To ensure more realistic loads on the pavement the actual Vehicle-Pavement Interaction (V-PI) load signal for a pavement with a specific profile can be developed using existing software and this 'real-life' load programmed into the LAD to ensure not only a constantly changing DL. Either single or dual tyre configurations can be used with the LAD.

The main Measurement Device (MD) will be designed similar to the High-Speed Profilometer (HSP) type laser measurement system and will function on a continuous basis thereby providing elastic surface deflection and permanent surface deformation

data on a continuous basis as the pavement is being loaded and unloaded. This circumvents the need for stoppages in the loading cycle to perform measurements. The MD will be attached to the bottom of the loading frame. The effect of localised application of the load may cause the measured data to differ from that normally encountered with rolling wheels.

Further to the elastic and permanent deflection measurements a Ground Penetrating Radar (GPR) device is proposed to evaluate the in-depth changes in the pavement structure. This may be difficult to achieve with current GPR technology, and further developments may be required in this area.

As most of the failures currently observed on roads are related to the upper layers in the pavement it may also be practical to device a scaleable / lighter version of the APE vehicle which cannot apply the full standard loads, but that apply smaller loads through smaller tyres and that is more mobile than the full version.

The potential benefit of having the proposed device is that a market segment that up to now has proved not be covered adequately (due to time and cost limitations) with the current APT technology can be addressed. The potential exists that a pavement can be evaluated at a rate of 800 000 loads per 24 hour cycle using a standard 40 kN load. When increased load levels are used up to 4 000 000 E80s (60 kN, n=4) can potentially be applied (and measurements taken) in a 24 hour period. This makes the potential of evaluating / proof testing both new and in-service (to be rehabilitated) pavements a reality. The possible effects of the environment (temperature and moisture) will have to be addressed together with a more detailed feasibility study.

2.4. Comparison with other devices

The question may well be posed as to the real need for the APE vehicle when devices such as the Heavy Vehicle Simulator (HVS) and Falling Weight Deflectometer (FWD) are already available. In some sense the APE vehicle performs the same role than the HVS (accelerated evaluation of a pavement's structural condition) and the FWD (structural evaluation of a pavement at a specific stage of its life).

However, the APE vehicle provides a combination of these two features in such a way that a set of deterioration curves can be developed at a regular interval that can be compiled to develop a master curve for a specific pavement structure over the years. The APE vehicle also potentially performs at a much higher production rate than the HVS (up to 4 million load repetitions over 24 hours as opposed to 25 000 load repetitions over 24 hours). A much more detailed data sample is collected than using the FWD

(permanent deformation and elastic deflection at selected intervals). However, the shape of the deflection basin may become incorrect at higher number of load application, due to possible localised failures.

Based on an initial search for similar devices internationally no such devices could be located.

2.5. Market need

The South African National Roads Agency (SANRAL) has been contacted for comments on the proposed generic idea of the APE vehicle. In discussions with Mr Louw Kannemeyer (August 2002) it was indicated that a technical need for the type of testing vehicle does exist. However, the cost-effectiveness of the test and willingness of the clients to use the test remains a question. Private clients will only use the test if it is forced upon them through a contract (as is the case with road roughness measurements presently) and it shows to provide them with data that are essential for their increase of profitability of their typical toll-road projects.

Mr Kannemeyer also indicated that the current needs of SANRAL (and especially its PMS section) focuses on evaluating the type of information they do collect using existing devices (both functional and structural measurements). It does not appear as if the use of a device such as the APE vehicle is currently high on the priority of SANRAL. However, if the cost-effectiveness and technical impact of such a device can be proven, it is also not necessarily outside their scope.

It may thus be more important at this stage to develop the technical scope of the potential use of the APE vehicle to such a level (without developing the vehicles itself) that it can be used to sell the concept to potential users. A plan for this approach is provided in the next section.

During the preparation of this report it became apparent that, although there are some devices that can evaluate the deterioration of paved roads, no such a device appear to exist for the evaluation of deterioration in gravel roads. In South Africa, gravel roads make up approximately 80 per cent of the road network and the evaluation of their typical deterioration curves (focussing on issues such as gravel loss) may be a more urgent need. There may also be a wider international market for such a device.

Accelerated Pavement Evaluator (APE) Truck

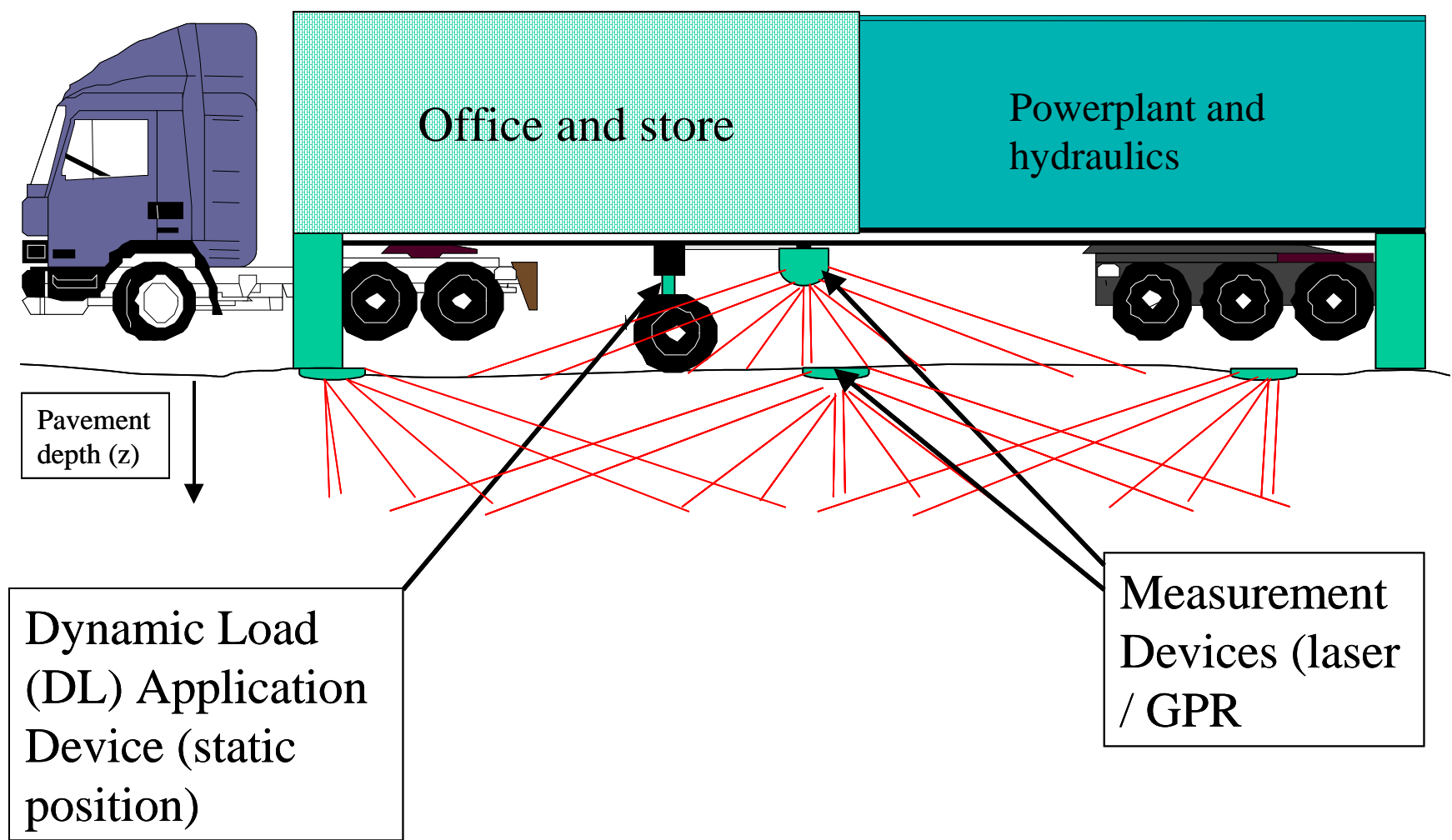


Figure 2: Schematic indication of the Accelerated Pavement Evaluator (APE) Truck.

3. DEVELOPMENT NEEDS AND PLAN

3.1. Introduction

In this section the further development needs for the APE vehicle are highlighted to indicate the road forward.

Based on the information provided in the previous sections, especially on market needs and expectations, it is proposed that any near-future focus should be on proving the concept that the APE vehicle is based on. Such an exercise will entail proving that the application of Dynamic Loads to a portion of pavement, with the monitoring of elastic deflection and permanent deformation at the same stage, can provide information that are currently not available and of benefit to the client.

A second part of the proposed evaluation plan will entail the feasibility study for a gravel road deterioration device.

3.2. Plan

Either the HVS Mark IV+ or the FWD can be used to provide the type of Dynamic Load to a pavement. As the HVS may be too expensive and large for an investigatory study such as is anticipated in this project, it is proposed that the FWD be used for the study.

A relatively weak pavement will be identified to ensure that the effect of the FWD on the pavement would be visible in a short period. The FWD would be applied to a selected location on the pavement for a set number of applications (drops). The elastic surface deflection bowl will be measured after each drop. The collected deflection bowls will be analysed and compared to the typical deterioration curve for the pavement. The objective is to evaluate whether the FWD curve of deflection deterioration are comparable to the expected behaviour of the pavement. The shape of the deflection bowl will also be compared to that of typical deflection bowls on normal roads, to evaluate the expected localised failure effect.

In the same process the permanent deformation below the FWD loading plate will be measured. The permanent deformation caused during this process will also be evaluated, and a similar comparison with expected behaviour made.

The results of this investigatory test should enable a more informed decision to be taken on the possible usefulness of the APE vehicle concept. These data can also be used in proving to potential clients the possible benefit of the concept, if further development is sought.

For the second part of the detailed feasibility study, it is proposed that the options of developing a deterioration measurement device for gravel roads specifically be investigated. This study should focus on issues such as the main parameters to be monitored (such as gravel loss) and ways to enable this type of deterioration on a typical test section.

3.3. Funding and costs

It is proposed that the investigatory testing be funded through the ADHI funding stream. Negotiations need to be entered into with FWD service providers to obtain a beneficial cost for the relatively large number of drops that are planned.

4. CONCLUSIONS AND RECOMMENDATIONS

Based on the information provided and the discussions in this STEP Report, the following conclusions are drawn:

- The technical need for the APE vehicle may exist with potential clients, although they may not be able to understand the possible usefulness of the device as yet;
- More detailed data of typical applications and potential use will be required to enable potential clients to support the further development of the APE vehicle concept;
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