History of the HVS programme and the HVSIA

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Why APT?

Accelerated Pavement Testing (APT) of roads provides the vital link between laboratory testing and Long-Term Pavement Performance (LTPP). Results from APT can be used to develop new or validate existing pavement design models and pavement performance prediction models. APT decreases the uncertainty and risk in these models.[1]

APT originated in the late 1950s with the execution of the AASHO road test in the USA. The 28 active APT programmes world-wide, reported in 1996, have, since then, played an important role in transforming road pavement design to a rational process.[2, 3] The approach in each of these programmes is different thus providing some uniqueness. The main attraction of APT is the time saving involved in achieving valuable results. In the case of the Heavy Vehicle Simulator (HVS), for example, 20 years of traffic can be simulated in as little as 3 to 6 months depending on the design class of the pavement and its sensitivity to overloading.

The instrumentation used with the HVS provides a wealth of data on the performance of the road pavement during the test. This includes surface rutting, surface deflection, in-depth deflection at layer interfaces and crack movement. This data is recorded at various stages during the test and indicates the deterioration of the pavement as well as the materials properties of the pavement layers. Such information is vital in modelling the performance of a road pavement under traffic.

Initiation of the HVS program in South Africa

South African government in the late 1960's recognised the need to develop road design models and methods that are applicable to the local environment to enhance the empirical design procedures based on the results of the AASHO road test. It was decided that APT had the capability to evaluate the performance of South African roads rapidly and to develop new or adjust the existing design models and processes of the South African Mechanistic Design method of the time.

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[1] L Du Plessis, NF Coetzee, TP Hoover, JT Harvey, CL Monismith. Three Decades of Development and Achievements: The Heavy Vehicle Simulator in Accelerated Pavement Testing. Pavement Mechanics and Performance, 2006.

[2] Metcalf, J.B, "Synthesis of Highway Practice 235: Application of Full-Scale Accelerated Pavement Testing". NCHRP Synthesis 235, Transportation Research Board, Washington DC, 1996

[3] Hugo, F., Epps, A, "NCHRP Synthesis 325: Significant Findings from Full-Scale Accelerated Pavement Testing". NCHRP Synthesis 325, Transportation Research Board, Washington DC, 2004

The South African APT programme had started by 1970 with the construction of full-scale test section loops at the Silverton test site of the CSIR. Initially, heavy vehicles were used as loading on the test sections, however, the low rate of load application was a challenge and provided the impetus for the design of an accelerated load testing facility.

The first HVS (known as Mk I) was designed to test airport runways and was manufactured from Bailey Bridge components. The facility produced useful results but was not mobile. In 1972 Van Vuuren[4] recommended that, a mobile loading facility should be developed that could test real, in-service pavements thus providing better data than that from specially constructed test sections.

The HVS Mk II was commissioned in 1970 and was fully mobile and self-powered. The Mk II could apply up to 800 repetitions per hour on a 6.2m test section. The initial maximum load capability was 35 kN (1/2 axle) and increase later to 75 kN (1 axle). This machine tested 10 sections in the first two years and by the end of 1975, 24 tests had been completed.

In 1972 failures occurred on a new road had been built to transport coal from Witbank to Johannesburg within the first year of operation. This resulted in 18 HVS tests on this road to investigate these problems.[5] The promising results lead to the manufacture of three more HVSs, the so-called Mk III machines, financed by the National Department of Transport and the Transvaal Department of Transport (now separated into three provinces). This was the birth of the South African HVS testing programme which is still continuing today. Although he Gauteng Province has since purchased a new HVS Mk V, one of the original Mk III machines is still in service in South Africa.

Initially the aims of the South African HVS programme were to:

- determine wheel load equivalencies;
- establish the effect of bi-directional trafficking;
- verify new designs proposed in the pavement design method;
- extend the data from above to four climatic regions in South Africa;
- verify the theoretical predictions of distress in cemented base pavements;
- evaluate the prediction of fatigue cracking in bituminous pavements, and
- evaluate stress-dependent response and deformation of existing pavement for overlay design purposes.

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[4] Van Vuuren, D.J. "The allowable wheel and axle loads of heavy vehicles". P.hD Thesis,University of Pretoria, 1972.

[5] Van Vuuren, D.J. "Pavement Performance in the S12 Road Experiment, an AASHO Satellite Test Road in South Africa". 3rd International Conference on Asphalt Pavements, London, UK, 1972

Although fundamentally similar to the Mk II, the Mk III machines had significant advances. The test wheel carriage was now designed to take normal dual truck wheels as well as aircraft wheels. Road transportation was changed to use a truck tractor for towing the HVS between remote locations at about 45 km/h while it was self-powered for on-site mobility. The design also allowed for both uni- and bi-directional trafficking on a test section of 6m long. Loads of up to 100 kN was possible with the dual truck wheel, and 200 kN if an aircraft wheel was used. The test wheel speed was about 8 km/h resulting in about 18000 bi-directional wheel load repetitions per day. The design allowed for simulation of up to 1 meter traffic wheel wander. Dimensions were 23m L x 3.7m W x 4.2 H. The Mk III weighed about 57 tonnes.

The three new production machines went into almost continuous use on roads throughout South Africa. The programme was funded from grants received from the NDoT and the Transvaal Provincial Administration (TPA) and were all operated and maintained by CSIR staff. This was done in close collaboration with the road authorities involved through representative advisory committees. This relationship has been a significant factor in the success of the programme, ensuring the earliest possible application of important findings.

From the late 1970s and throughout the 1980s, the expanded HVS programme was the source of most of the advances and developments in South African pavement engineering. While South Africa's political status at that time restricted direct exposure of the HVS' work there were, nevertheless, significant numbers of overseas visitors during this time, notably from the United States, United Kingdom and Australia.

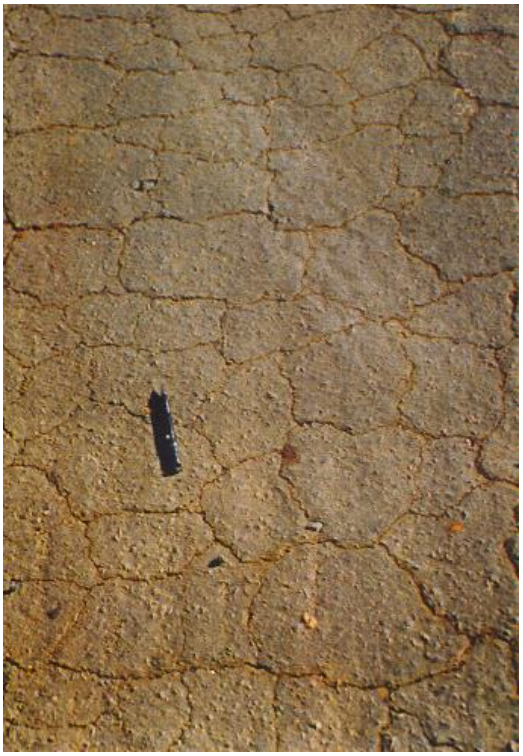
Currently South Africa still has an HVS Mk III and an HVS Mk V. The current programme is focussed on evaluation of alternative materials such as road bases and subbases stabilised with nano-silane modified emulsions.

The birth of the International HVS programme

The California Department of Transport (Caltrans) became interested in APT in the early 1990's. In 1993 Caltrans commissioned The University of California at Berkeley (UCB), Dynatest Consulting and the CSIR to conduct a pilot project in South Africa to evaluate the potential of the technology for use in California. The performance of a dense graded asphalt with a conventional binder was compared with that of a gap-graded asphalt-rubber hot mix – both in rutting and cold temperature cracking. In addition, the performance of the surfacings under channelized traffic compared with wandering traffic was compared. The tests were conducted on a cracked road near

Pretoria in South Africa. This road was tested with the HVS twenty years previously. It was enlightening to observe the surface cracking on the road at the time (see photograph below) with the result of the HVS test 20 years before. The two photographs are almost identical. The results of the pilot test were very positive and led to the signature of a collaborative agreement between UCB, Dynatest and the CSIR to conduct the California APT programme, funded by Caltrans.

Result of the HVS test on P6-1 in 1973



Surface distress on P6-1 after 20 years of traffic (1993)

Prof Carl Monismith, Hoffie Maree, Nick Coetzee and Chris Rust signing the UCB/ Dynatest/CSIR agreement

As part of the UCB APT programme, Caltrans purchased two refurbished Mk III HVS's from the CSIR. These were transported by sea to California, where they passed an acceptance test and were put to work immediately.

The first Caltrans/ UCB HVS being loaded for shipping

The success of the Caltrans APT programme led to enquiries from several other authorities and subsequently 18 new HVS's have been sold by Dynatest under license from the CSIR.

Further development of the HVS

The rising interest in APT internationally led to further development in HVS technology and a new generation of HVSs, the HVS Mk IV was developed by Dynatest Consulting under license from the CSIR. The HVS Mk IV remains closely aligned to its forerunners, but was modernised and re-designed from the ground up, resulting in an improved and more efficient machine. Fully computer controlled, many machine functions are monitored, and automatic shutdown occurs if these functions deviate beyond pre-set limits. Use of off-the-shelf running gear components and other improvements resulted in a weight reduction to approx. 46 tonnes. Height was reduced to 3.9m. Test wheel speed was increased to about 12 km/h allowing approx. 26000 bi-directional wheel loads per day. Other test specifications are similar to the Mk III. The first HVS Mk IV was purchased by the Cold Regions Research and Engineering Laboratory (CRREL) of the US Army Corps of Engineers, who took delivery in early 1997.

The HVS Mk IV airlifted to CRREL

A second HVS Mk IV, was sold jointly to the national Road Research Laboratories of Finland and Sweden (VTT and VTI respectively) and was delivered in June 1997.

In a parallel development, an HVS for the testing of airport pavements was designed for the Waterways Experiment Station (WES) of the US Army Corps of Engineers.

Apart from its physical size (36.3m x 4.23m x 4.99m , 102 tonnes), the fundamental difference between the new HVS–A (dubbed “Bigfoot”) and the HVS Mk IV lies in its loading capability - it can load the test wheel up to 440 kN over a 12m test section whereas the HVS Mk IV can only apply 200 kN over 6m. The HVS–A is also designed to utilise dual aircraft wheels. This machine was delivered to WES in 1998.

An improved version of the Mk IV, the HVS Mk IV+ was also designed for CSIR and was delivered in March 1999. The HVS Mk IV+ is based on the HVS Mk IV, but the frame and loading beam have been strengthened in order to allow the simulation of full dynamic loading. The hydraulic systems of the HVS Mk IV+ and the strengthened frame will allow for a future hydraulic and systems upgrade to simulate dynamic loading at a frequency of 10 Hz.

“Bigfoot” – The Waterways Experimental Station double sized HVS

In March 1999, an enhanced version of the Mk IV, the HVS Mk IV+ was designed and delivered to the CSIR in South Africa.[6] Although the HVS Mk IV+ is based on the HVS Mk IV, it has a strengthened frame and loading beam to withstand the impact of full dynamic loading. The hydraulic systems of the HVS Mk IV+ and the strengthened frame allows for a future hydraulic and systems upgrade to simulate dynamic loading at a frequency of 10 Hz. Three Mk IV+ were delivered: to the Florida Department of Transportation in June 2000; to the CSIR in South Africa and to Central Road Research Institute (CRRI) in India in June, 2010.

[6] L. du Plessis, A. Ulloa-Calderon, J.T. Harvey and N.F Coetzee. Accelerated pavement testing efforts using the Heavy Vehicle Simulator. International Journal of Pavement Research and Technology. 2017.

The CRRI HVS Mk V+ in India

In 2006 Dynatest was awarded a contract to provide a new HVS, the Mk VI, to Chang'An University in Xian, PRC. The Mk VI's main functional changes involved the ability to use a beam extension to allow an increased test section length of 12m from the previous 6m, or to apply higher wheel speeds (up to 20 kph) on the 6m test section. The design also included changes that allow easier transportation of the HVS over the road network, or in containers for shipping. All HVS units delivered since Chang'An University have been Mk VI and include KCIT, Korea (Nov. 2014); IRE, Indonesia (Nov. 2014); Lanname, Costa Rica (Oct. /2012); IMT, Mexico (Oct, 2015); MOT, Saudi Arabia (May, 2015), VDOT, Virginia (Nov. 2015) and the DNV in Argentina (2019). The US Federal Aviation Administration (USFAA) purchased an airfield version of the Mk VI, which allows the use of aircraft wheel loads, and was delivered in November 2013.

To date 20 HVS units (Mk III to Mk VI) have been deployed worldwide.

The HVS Mk VI

The HVSIA

The impetus for establishing an HVS user's group came from experience with the TRB APT efforts. Joe Mahoney, as chair of the Pavement Management section at TRB in the early 90's, had realized that the APT facet of pavement research was not well represented at TRB. He press-ganged Nick Coetzee into organizing a workshop on APT at the 1994 TRB Annual Meeting. Attendance at the workshop was such that it was clear that APT needed to be included in TRB activities to increase its impact on the pavement community. Nick was asked to convene and chair Task Force A2B52 on Full Scale/Accelerated Pavement testing, which went on to become the current AFD40 committee on APT. There were many discussions between Joe, Nick, Chris Rust and others, typically over a libation or two, about the function and objectives of this APT effort, and two ideas consistently cropped up. Firstly, APT was expensive and would therefore be well served by collaboration between APT programs, since that could prevent, or at least reduce, duplication of research efforts – in other words, collaboration may reduce incidences of 're-inventing the wheel' in APT efforts. Secondly, and this would enhance the ability to collaborate, a database of APT results should be established and populated with all APT data that was available. In retrospect, these ideas were somewhat naïve. Reality began to intrude in the late 90's when information about the SHRP LTPP database, a much less ambitious effort than an 'all of the existing' APT database, started becoming available. This information seemed to suggest that development and management of such databases were more labour intensive and cumbersome than the Joe *et al* discussions had envisaged, so that idea needed modification. Also, Nick's chairmanship of the TRB APT Task Force, which included members from many APT programs worldwide, made it clear that, although lip service was paid to collaboration, there was not much in the way of true collaboration taking place—most programs were largely working in their own fox holes. Indeed, most collaboration offers that Nick witnessed with his involvement at the then Cal/APT program, which was relatively well funded, were of the 'We'd like to collaborate by helping you spend your money' type. More discussion ensued and Joe suggested that the collaboration idea scope should be reduced to a smaller group that would have a very apparent common interest – the APT programs that were using the HVS, which had become the most widely used full-scale APT device in the world, and demand seemed to be continuing for the machine. Chris Rust at CSIR in South Africa was approached and the first HVS workshop was convened in Pretoria in October 2002 under his direction. It was attended by representatives of HVS programs at WES, CRREL and Cal/APT (USA), VTI (Sweden), Gautrans and CSIR (South Africa), Federal Highways, a contractor and a consultant from Brazil as well as members of the South African HVS steering committee. At the final workshop Joe proposed that a formal organization, tentatively dubbed the HVS international Consortium, be established. Assent was unanimous, and the rest is history. The organization was formally

established as the HVA International Alliance (HVSIA) and a constitution and organizational structure was adopted at the subsequent meeting held in 2003. It was also at the 2003 meeting that Joe suggested the use of an activity matrix summarizing past, present and proposed HVS research topics in an easily accessible and simple system for quick reference to members' research activities. In summary, annual meetings of the HVSIA were held at various locations as shown elsewhere on the website, with links to information about each meeting.