A NEW ERA OF OVERLOADING CONTROL IN SOUTH AFRICA

Pages 34 to 50

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ABSTRACT

This paper describes recent developments in South Africa both in terms of increased axle load limits and policies by the national and provincial road authorities to try and control heavy vehicle overloading and thereby protect an aging road network which is experiencing an accelerated rate of deterioration. As a result of a minimum level of enforcement in many areas, low levels of fines, limited success with prosecution in the courts and varying levels of corruption at weighbridges from country to country, many transport operators seem to have adopted a policy of deliberate overloading, some of which regularly overload their 22 metre combination vehicles by more than 40 tons. The low and/or diminishing level of funds available for road maintenance in most southern African countries has resulted in an alarming rate of deterioration of the road network as a whole. The concept and implementation of a new class of weighbridge or Traffic Control Centre, the first of which was constructed on National Highway 1 (N1) at Mantsole, 130 km north of Johannesburg, is described. Associated problems including alternative routes and methods of vehicle screening are also addressed.

A Stress-In-Motion (SIM) system, which has been developed in South Africa over the past five years, has also been installed as an experimental demonstration project at the Mantsole Traffic Control Centre on the N1. This system has been developed to measure three dimensional tyre/pavement contact stresses under moving tyre loads. Initial results show a significant difference between tyre inflation pressures and maximum and average vertical contact stresses for many tyre types under various loading conditions of heavy vehicles. It is anticipated that the contact stress information obtained from this SIM system will have a significant impact on future pavement design and traffic operations in South Africa.

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INTRODUCTION

Roads are the most important transport communication medium in a country and are used by almost everyone on a daily basis. Besides the fact that roads are provided for the benefit of the road user, they also play a significant role in promoting economic growth and the living standards of the population. In the words of the motto of the South African Road Federation, “Good roads lead to prosperity”. The more than half a million kilometres of roads in South Africa have a current replacement value in excess of US$ 35 billion. About US$ 460 million per annum is spent on road construction and maintenance in order to safeguard this national asset. In 1985, 35 percent of the national road network was classified as being in a good condition, based on the Visual Condition Index. This figure fell to 25 percent in 1991 and even further to 9 percent in 1995. South Africa’s road network is steadily deteriorating in the face of severe funding constraints and this is further aggravated by the simultaneous deregulation of the transport industry, resulting in a shift of freight transport from rail to road as well as an unacceptably high level of overloading in most parts of the country. As a result of a minimum level of enforcement in many areas, low levels of fines, limited success with prosecution in the courts and varying levels of corruption at weighbridges, many transport operators appear to have adopted a policy of deliberate overloading, some of which regularly overload their 22 metre combination vehicles by more than 40 tons. During 1996, of the 58 900 heavy vehicles weighed in South Africa, 19 300 or 33 per cent were overloaded [1]. The number of vehicles weighed in each of the nine provinces varied dramatically from 51 000 in the province of KwaZulu-Natal to 260 in the Northern Cape. The low level of overloading enforcement in certain provinces is largely due to a lack of manpower and weighing facilities and to some extent due to the perception that heavy vehicle overloading is not a serious traffic offence.

The seriousness of heavy vehicle overloading in terms of hampering economic development in southern Africa has been widely recognised. According to a report on vehicle overloading in southern Africa by the SATCC Five Country Working Group on overload control, "The onerous and costly impact of vehicle overloading in the SADC region has been a negative feature of the transport industry for the past few decades. Precious infrastructure, worth millions of dollars, has been lost through accelerated deterioration of roads and indifferent attention to maintenance. Unless urgent steps are taken to halt this unacceptable situation of overloading, the poor condition of roads will provide a formidable barrier to further economic development in the SADC region." [2]

DEVELOPMENTS IN OVERLOADING POLICY

South African axle load study

During 1991 an extensive study [3] funded by the South African Department of Transport (DoT), was carried out with the aim of determining an optimum axle load limit for heavy vehicles in South Africa. The study was initiated mainly as a result of strong pressure on the government from the road transport sector to increase the maximum permissible axle load limits. Various teams of consultants and representatives of the DoT addressed various aspects of the study including the effect on pavement deterioration, bridges, the trucking industry as well as the potential impact on modal split between road, rail and coastal shipping. The results of the study showed that, from an infrastructure and road transport perspective, the optimum 4-wheel single axle load was 9,4 tons. The recommendation of the pavement and bridge study was to increase the existing maximum loads of 8,2 16,4 and 21 tons to 9 18 and 24 tons for single axles with dual tyres, tandem axle units and tridem axle units respectively, on condition that a substantial portion of the benefit accrued by the road transport industry be channelled into a dedicated road fund specifically for road and bridge maintenance and construction. This condition would ensure the preservation of the existing road network under the increased axle loads. However, the economic study recommended that, due to a negative impact on the diminishing tonnage of freight transported by rail and coastal shipping, the maximum permissible axle loads remain unchanged. The road transport industry were obviously not satisfied with this outcome and continued to pressurise the government to increase the permissible axle loads, claiming that the state-owned railways were being unfairly protected.

As a result of this continued pressure, in July 1992, Regulation 365A of the Road Traffic Act of 1989, also known as the 'bridge formula', which limits the concentration of load on a vehicle or group of axles, was relaxed from a permissible mass of 1,8 L + 16 tons to 2,1 L + 15 tons, where L is the distance in metres between the centres of the extreme axles of any group of axles. This change, together with a simultaneous increase in the maximum permissible vehicle length from 20 to 22 metres, resulted in an increase in the permissible gross combination mass of 18 percent for the long combination-type vehicles (from approximately 50 tons to 59 tons).

SATCC axle load study

The recommendations of a study [4] conducted on behalf of the Southern Africa Transport and Communications Commission (SATCC) which forms part of the Southern African Development Community (SADC) found that the optimum maximum permissible axle load was significantly more than the maximum axle loads in all the southern African countries. The SATCC study proposed an optimum 4-wheel single axle load of 13 tons (60 percent more than the corresponding permissible load in the majority of the Member States). After some interaction and discussion within the region, an interim legal axle load of 10 tons was recommended as a goal for achieving uniformity in the SADC region.

The results of this study led to further pressure on the South African government from the road transport industry to increase the legal axle load limits. The S.A. road authorities, however, were not prepared to bow to the pressure completely, but on 1 March 1994, did allow a relaxation of the allowable tolerance on non-steering single axles and axle units from 5 to 15 percent on the grounds that a greater degree of flexibility should be allowed in terms of load distribution. The tolerance on steering axles, gross vehicle and combination masses and the bridge formula remained at 5 percent. The net result, however, was an increase in the average overloads on single axles and axle units measured at static weighbridges by 19 percent, from 1 378 kg in 1993 to 1 644 kg in 1994 [5].

Revised South African axle load limitations

Once South Africa became a member of the SADC community in 1994, increased pressure was placed upon the government to increase the axle load limits and fall in line with the recommended SATCC maximum axle loads in an attempt to achieve harmonisation in the SADC region. Thus in December 1995, at a meeting of the Ministers of Transport of each of the newly-formed nine Provinces and the national Department of Transport, a decision was taken to increase the permissible axle loads in South Africa with effect from 1 March 1996, as indicated in Table 1.

Table 1: Increases in maximum permissible loads of common axle and axle unit configurations

Axle/axle unit description	Maximum permissible mass before 1 March 1996 (kg)	Maximum permissible mass after 1 March 1996 (kg)
Single axle with four wheels	8 200	9 000
Tandem axle unit (four wheels per axle)	16 400	18 000
Tridem axle unit (two or four wheels per axle)	21 000	24 000
Any group of axles (Bridge formula)	2 100 L + 1 500 *	2 100 L + 1 800 *
Gross combination mass	none	56 000

* L is the distance in metres between the centres of the extreme axles of any group of axles

As can be seen from Table 1, Regulation 365A, the bridge formula, was relaxed for the second time in two years from 2,1 L + 15 to 2,1 L + 18 tons. However, the significance of this relaxation was nullified for long combination vehicles by the introduction of a new regulation (362D), which limits the gross combination mass of any vehicle or combination of vehicles to 56 tons. In the case of most long (22 m) vehicle combinations, this new regulation resulted in a net *decrease* in GCM from approximately 59 tons to 56 tons with an equal decrease in payload. The major benefit was experienced by the six axle vehicles (tridem semi-trailer) in the form of an increase in payload of approximately 3 tons.

Policy on weighbridge infrastructure

At the same time as the decision to increase the axle load limits, another significant decision was made by the committee of Transport Ministers which has had a major impact on the provision of facilities for overloading control and general public awareness of the seriousness of heavy vehicle overloading on the required annual funds for road maintenance and rehabilitation. In order to try and curb the increase in the practice of overloading, a decision was taken to allocate 1,3 percent of the national and provincial annual roads budgets, for a period of five years, to a dedicated central fund to be used for upgrading existing and providing new weighing facilities throughout the country. The provincial road authorities had a total of 55 operational weighbridges during 1996 [1], and the long term aim of the dedicated fund is to increase the number of weighing facilities to approximately 100.

The allocation of 1,3 percent of the national and provincial roads budgets amounts to some US$ 9 million per annum for a period of five years, i.e. a total of some US$45 million. During the past 18 months a total of 14 weighbridges have either been upgraded or newly constructed. A further 15 weighbridge sites are in the planning stage or are currently under construction. The newly upgraded weighbridge at Greytown in the province of KwaZulu-Natal is shown in **Figure 1** on the day of the official opening.

Three grades of weighbridges or Traffic Control Centres have been defined as follows:

Grade A: A facility which normally operates 24 hours per day on strategic national and provincial routes which carry high volumes (>2 000/day) of heavy vehicles.

Grade B: A facility which normally operates from 8 to 24 hours per day on routes which carry medium volumes (500 to 2 000/day) of heavy vehicles.

Grade C: A facility which normally operates less than 8 hours per day on routes carrying relatively low volumes of heavy vehicles.

The facilities provided at each Traffic Control Centre, such as size of parking-off area, number of weighbridge decks, extent of computer facilities, etc. vary considerably even within the same grade, depending on the traffic volumes, available manpower, etc.

Although Grade B and Grade C type facilities are common in South Africa, the Grade A facility is a completely new concept and is based on the types of weighbridge sites commonly found on Interstate highways in the United States.

MANTSOLE TRAFFIC CONTROL CENTRE

The first Grade A Traffic Control Centre was constructed at Mantsole, 130 km north of Johannesburg on the N1 national route (**see Figure 2**). This is the primary road forming part of the major regional corridor between South Africa (Johannesburg and the ports of Durban, Richards Bay and Cape Town) and countries to the north including Zimbabwe, Zambia and Malawi. Since the acceptance of South Africa into the SADC community in 1994, there has been a significant increase in regional trade, resulting in increases in both road and rail freight transport.

The new weighing facility was officially opened by the Minister of Transport on 27 May 1997 and has subsequently more or less operated on a 24 hour basis. The main centre is situated on the west side of the national road (controlling northbound traffic) and an almost identical centre is situated directly opposite to control southbound traffic. Road signs up to two kilometres on either side of the centre instruct vehicles not to overtake and to decelerate to 80 km/h. Heavy vehicles (more than 5 tons gross mass) must proceed on the left hand, slow lane from which they are channelled into a dedicated screening lane where a high speed weigh-in-motion (WIM) sensor is used to determine whether the vehicle is overloaded. Although South Africa has a number of locally developed high speed WIM sensors, the Department of Transport opted for the German PAT system for the first Grade A Traffic Control Centre. Overhead variable message signs are used to redirect legally loaded vehicles back onto the highway while vehicles suspected of being overloaded are directed to an adjacent lane for accurate weighing on a static scale.

The weighbridge consists of four independent decks on which approximately 95 percent of vehicle combinations can be weighed in a single operation (about 3 percent of vehicles weighed have 5 axle groups and about another 2 percent have uncommon axle/axle group spacings). If the vehicle is found to be legal or within the 5 percent tolerance limit, the driver is allowed to proceed back onto the highway. If the vehicle or one or more of the axles/axle units is more than 5 percent overloaded, it is directed by means of traffic signals to the holding area where prosecution is instituted.

Once the driver has been charged, he is only allowed to proceed once the vehicle has been made legal, either by redistribution of the load on the vehicle, or by transferring part of the load onto another vehicle. Storage of payload on the ground is not permitted.

The Traffic Control Centre has a computer system which monitors the weighing/prosecution process from when the vehicle is intercepted until it leaves the centre. The system also includes a process for the issuing of prosecution notices, which apart from speeding up the issuing of these documents, ensures uniformity and minimises transcription errors.

Alternative routes

An obvious alternative route, in order to bypass the weighing facility, is the old main road (R101) which runs parallel to the N1, and at the site of Mantsole is a mere 700 metres to the west. WIM sensors have been installed on this route covering both directions, and vehicles suspected of being overloaded are directed by the officer on duty on the alternative route (where there is a small building) to the main centre for static weighing and prosecution if overloaded.

On another, slightly longer alternative route, a Grade C weighbridge has recently been completed in order to discourage operators from opting for this route.

Despite the monitoring of these alternative routes, many truck drivers (obviously the serious overloaders) have found other alternative routes, most of which include sections of gravel roads in order to bypass the weighbridge. In fact, local farmers have submitted complaints to the road authorities to the effect that heavily loaded vehicles are using previously quiet local gravel roads and causing inconveniences including excessive noise and dust.

Prior to the opening of Mantsole, statistics from two WIM sensors on the N1, one 70 km to the south of Mantsole and the other 35 km to the north, showed that 30 percent of heavy vehicles travelling on this section of highway were overloaded. Shortly after the opening of the Traffic Control Centre, this percentage dropped to approximately five percent. The figure has subsequently increased to between 20 and 30 percent at the two WIM sensors, but the extent of overloading recorded at Mantsole remains at about the five percent level, indicating that many overloaded vehicles are using alternative routes to bypass the weighbridge.

In order to overcome this problem, it is essential that the Road Traffic Inspectorate make use of mobile weighing teams to monitor alternative routes on a random basis. Although mobile static scales are currently not used for prosecution in South Africa, a number of road authorities are making use of a locally developed Vehicle Load Monitor (VLM) to screen vehicles on alternative routes and then escorting them to the weighbridge for static weighing and prosecution. The VLM is a portable (25 kg) weighing pad over which the vehicle drives at a walking pace (5 km/hr). The hand held unit gives individual axle loads and the gross mass with a 90 to 95 percent accuracy.

Road signs

Adequate information, warning and regulatory signs have been provided on the N1 freeway as well as on the R101 alternative route. Drivers failing to obey the regulatory messages displayed on the road signs e.g. avoiding the screening lanes, will be liable for prosecution. One of the problems experienced at Mantsole has been the fact that many drivers of heavy vehicles simply ignore the screening lane and continue past the weighbridge. In many cases, because of a shortage of staff at the Traffic Control Centre, these vehicles are not stopped and escorted back to the weighbridge for weighing. A lack of driver discipline is a major problem faced by traffic authorities in South Africa, and one which needs to be addressed in the long term through driver education programmes and increased traffic police visibility on the roads.

Weighing statistics at Mantsole

Since the opening of the Traffic Control Centre at Mantsole, vehicle weighing has not been optimal, partly because of some initial technical problems at the scale adjacent to the southbound lanes and also due to human resource constraints. During most months at least one side of the Centre has been operational 24 hours per day. The vehicle weighing statistics are shown in Table 2. The ‘Vehicles overloaded’ column includes vehicles which were less than five percent overloaded, i.e. they fell within the tolerance limit and were not charged.

Table 2: Vehicle weighing statistics at Mantsole Traffic Control Centre May to August 1997

Month	Vehicle weighed (after screening)	Vehicles overloaded	Vehicles charged	Fines imposed (US$)
May	3 014	794	490	28 400
June	4 525	1 270	651	46 500
July	6 748	2 067	979	64 900
Aug	5 105	1 537	719	50 400
Total	19 713	5 668	2 839	190 200

Alternative screening methods

In order to address the problem of lack of driver discipline, a different approach to vehicle screening has been adopted at a number of weighbridges in the province of KwaZulu-Natal, which are currently being upgraded to Grade A standard. The WIM sensors are located on the highway in the left-hand (slow) lane rather than in a dedicated screening lane. These permanent sensors have a dual purpose of both screening heavy vehicles which are overloaded and capturing traffic information (including vehicle speed and length, axle loads and spacing) of all vehicles on a 24 hour basis.

During periods when the weighbridge is operational, a traffic officer is stationed in a vehicle at the off ramp which leads to the weighbridge. The WIM sensor is upstream of the off ramp and has a radio link to a receiver in the officer's vehicle, which triggers a warning buzzer and flashing light when a vehicle is detected as being overloaded. The officer will then direct the vehicle to the weighbridge for static weighing. At this stage, the WIM sensors have only been installed in the slow lanes. Heavy vehicles avoiding the sensor by travelling in the fast lane(s), will automatically be directed to the weighbridge unless obviously under-loaded. This system has proved to be very effective, particularly at night, when the traditional method of visual screening is difficult. It also significantly reduces the cost of the weighing facility as neither screening lanes nor variable message signs are required.

Other functions of Traffic Control Centres

The Traffic Control Centres such as at Mantsole are intended to fulfil a multiplicity of functions relating to all Road Traffic Quality System (RTQS) transgressions with regard to driver and vehicle fitness and stolen vehicles. These will include aspects related to driver's licence, alcohol and drug abuse and seat belts. Vehicle fitness aspects to be inspected include vehicle registration and licencing, number plates, special and temporary permits (e.g. abnormal load vehicles), roadworthiness (e.g. brakes, tyres, lights, oil leaks, noise, smoke emission, etc.), plating, operator vehicle registration and transportation documents such as cross-border permits. Vehicles transporting dangerous goods will also be checked for documentation, safety and security.

The RTQS has as its underlying principle the establishment of national standardised safety requirements in respect of all goods and passenger vehicles with a gross vehicle mass exceeding 3 500 kg. This includes all breakdown vehicles, convertor dollies and mobile cranes. Vehicles designed or adapted for the conveyance of 12 or more persons, irrespective of their mass are also classified as RTQS vehicles.

STRESS-IN-MOTION LOAD CELL AT MANTSOLE

Background

Part of the project at Mantsole is the installation of a three dimensional, stress-in-motion (SIM) load cell which has been developed at the Division of Roads and Transport Technology, CSIR, during the past five years. This section of the paper basically describes the development, characteristics and typical outputs of the 3-D load cell. A paper by de Beer et al [6] presented at the 8th International Conference on Asphalt Pavements (ICAP) in July 1997 in Seattle, Washington, describes the load cell and related research in significantly more detail.

The development of this rather unique WIM sensor arose out of the need to focus research activity on the actual contact stress acting at the tyre/pavement interface. For a number of years in South Africa, large scale use has been made of relatively thin (<50 mm) asphaltic concrete surfacing layers on flexible pavements, supported by high quality crushed or natural gravel bases. Extensive use has also been made of cementitious materials as part of the main structural (base and subbase) layers. This resulted in so called "inverted" pavement structures which have performed extremely well over the last two decades, although many of these pavements are now reaching the end of their design life. However, the major problems observed on most of the national and provincial paved roads are not related to bearing capacity but rather to problems such as surface cracking, potholes, surface crushing failures, pavement deformation within the asphaltic concrete surfacing layers, ravelling and bleeding. More than ten years of experience on test sites on actual roads has demonstrated that most of the traffic associated failures in South Africa result from the top down and most from a lack of subgrade support. This led to the conclusion that the road damage or wear is not only caused by loading of heavy vehicles but also by the load intensity (i.e. effective contact stress) acting at the tyre/pavement interface. To study these contact stresses a three dimensional load cell or Vehicle-Road Surface Pressure Transducer Array (VRSPTA) was developed to measure contact stresses under moving pneumatic wheel loads.

System development

The first prototype system of the 3-D stress-in-motion load cell, the SIM MK I was developed during 1992/93 in order to prove the concept of measuring the three stress components at the tyre/pavement interface. However, the SIM MK I gave certain inconsistencies of up to 25 percent of the total load measured after integration of the vertical stress volume. These problems were addressed and further improvements led to the development of the SIM MK II system which is currently being used in the research programme.

The VRSPTA system consists primarily of an array of triaxial strain gauged steel pins fixed to a steel base plate together with additional non-instrumented supporting pins, fixed flush with the road surface. Each of the instrumented pins (sensors) is independently calibrated using a high precision miniature load cell. A separate calibration frame is installed on top of the VRSPTA system and calibration for each of the three directions of each instrumented pin is done from zero load to a safe maximum recommended load of approximately 500 Newton.

The data acquisition system allows for the simultaneous recording of 63 channels (strain gauges) up to a reading rate of 12 kHz per channel. The system is automatically triggered by a moving wheel and is designed to measure at wheel speeds from 1 to 25 km/hr (0,3 to 7 m/s) and vertical and horizontal loads up to 200 kN and 20 kN respectively. A schematic layout and photos of the VRSPTA system are shown in **Figures 3** and **4**. Vertical, transverse and longitudinal stresses are measured while the wheel moves across the load cell.

The VRSPTA is installed flush with the surface of the pavement to within a few millimetres in order to minimise the dynamic effects of wheels moving at relatively high speeds. With field testing done to date, it was found that the random error of the VRSPTA system relating to the measurement of total load as well as maximum contact stresses is generally less than 10 percent. At the site at Mantsole, the system has been installed approximately 20 metres from the static scale adjacent to the northbound lanes, where heavy vehicles travel across the VRSPTA at speeds from 5 to 10 km/hr as they approach the static scale.

Typical outputs from the VRSPTA system

Figures 5 to 8 show results of tests with a smooth tyre at various wheel loads and inflation pressures. Figures 5 and 6 show the maximum vertical contact stresses at two load levels (18 kN and 48 kN) with the inflation pressure varying from 420 kPa to 720 kPa. Both figures show that the greatest influence on the development of contact stress is towards the tyre centre and is primarily controlled by the tyre inflation pressure. Furthermore it can be seen that the average stress over the tyre centre is higher than the associated inflation pressure.

Figures 7 and 8 represent the case where the inflation pressure was kept constant and the wheel load varied from 20 kN to 50kN. In this instance it is clear that the varying wheel load had little influence on the vertical contact stresses towards the centre of the tyre, but had a strong influence on the development of vertical stresses at both the tyre edges. This relative overloading and under inflation will cause relatively high tyre edge contact stresses, exceeding the inflation pressure by a factor of two or three.

Graphic illustrations of typical tyre contact stress distributions (vertical, transverse and longitudinal) are given in **Figures 9 and 10**.

CONCLUSIONS

Extensive overloading as a result of transport deregulation, a highly competitive market, a lack of enforcement in many areas and insufficient funds for road maintenance have resulted in a marked deterioration in the condition of the South African road network during the past ten years. Recent policy developments both in South Africa and the SADC region as a whole have resulted in an increase in the permissible axle loads of heavy vehicles operating in the region.

A new generation of weighbridge facility has been implemented in South Africa for the control of overloading on strategic national routes on a 24 hour basis. The first of these so-called Traffic Control Centres has been constructed at Mantsole, 130 km north of Johannesburg. Despite careful planning in terms of monitoring escape routes, many overloaded vehicles are still managing to bypass the weighbridge. Other measures such as mobile screening teams will have to be utilised in order to cover all possible alternative routes, including sections of unpaved roads.

A Stress-in-Motion system has been developed in South Africa during the past five years, and has been installed as an experimental demonstration project adjacent to the static weighbridge at Mantsole. The load cell can measure contact stresses in three directions and will provide a valuable source of information for the design of pavements, particularly those with thin (<50 mm) asphalt layers, which are more sensitive to tyre/pavement contact stresses than pavements with thick asphalt layers. Results from the VRSPTA system show that in certain cases, the vertical tyre contact stresses exceed the inflation pressure by a factor of two or three.

Introduction

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Introduction Content

AUTHOR BIOGRAPHY

Paul Nordengen was born in South Africa and grew up in the coastal port of Durban, where he completed his schooling. He completed his Bachelor's degree in civil engineering at the University of Natal, Durban in 1981. He then joined the South African Railways and worked in the bridge design office and on a construction site as a resident engineer. He joined the Division of Roads and Transport Technology, CSIR in 1986 where he worked as a researcher in the Bridges section and subsequently in the Maintenance and Infrastructure Management Systems section. In 1988 he completed a master's degree in structural engineering at the University of the Witwatersrand, Johannesburg. Since he started at the CSIR his main areas of research have been bridges, vehicle overloading, abnormal load vehicles and heavy vehicle cross-border freight. He was the project leader of a two year project for the Ministry of Works in Malawi which included an evaluation of the effect of increasing the permissible axle loads on road deterioration and maintenance and the implementation of a vehicle overloading management system. He has been involved in the development of management systems for vehicle overloading, abnormal loads, bridges and cross-border freight movements for various road and railway authorities in South Africa, Malawi, Botswana and Taiwan.

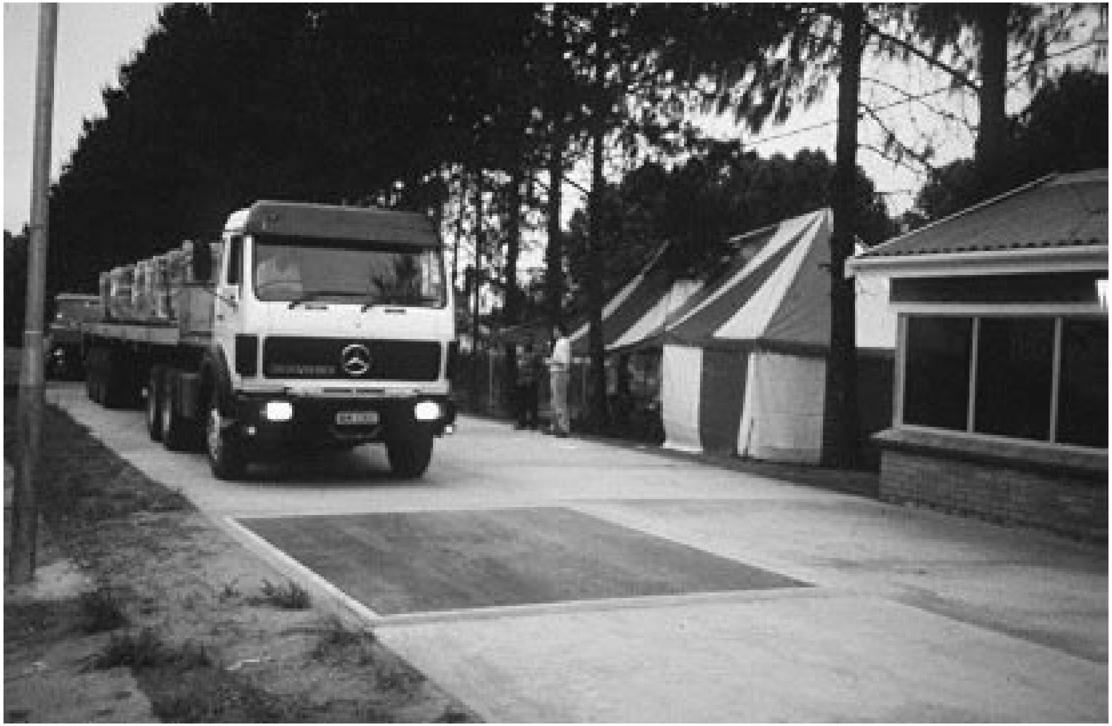

Figure 1: The newly upgraded weighbridge at Greytown on the day of the official opening

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Figure 2: Aerial view of the Grade A Traffic Control Centre at Mantsole

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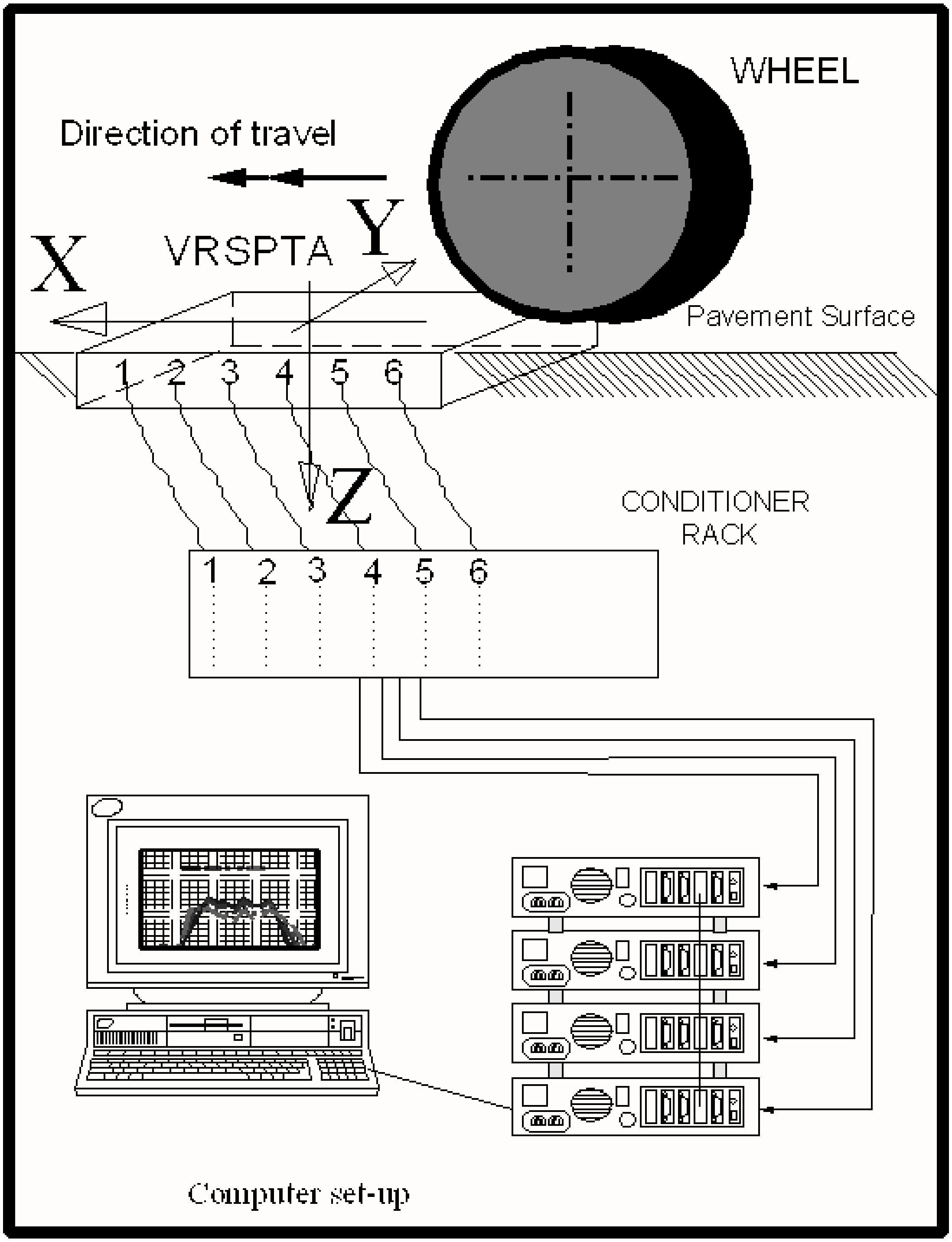

Figure 3: Layout of the Vehicle-Road Surface Pressure Transducer Array (VRSPTA) system

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View figure 4

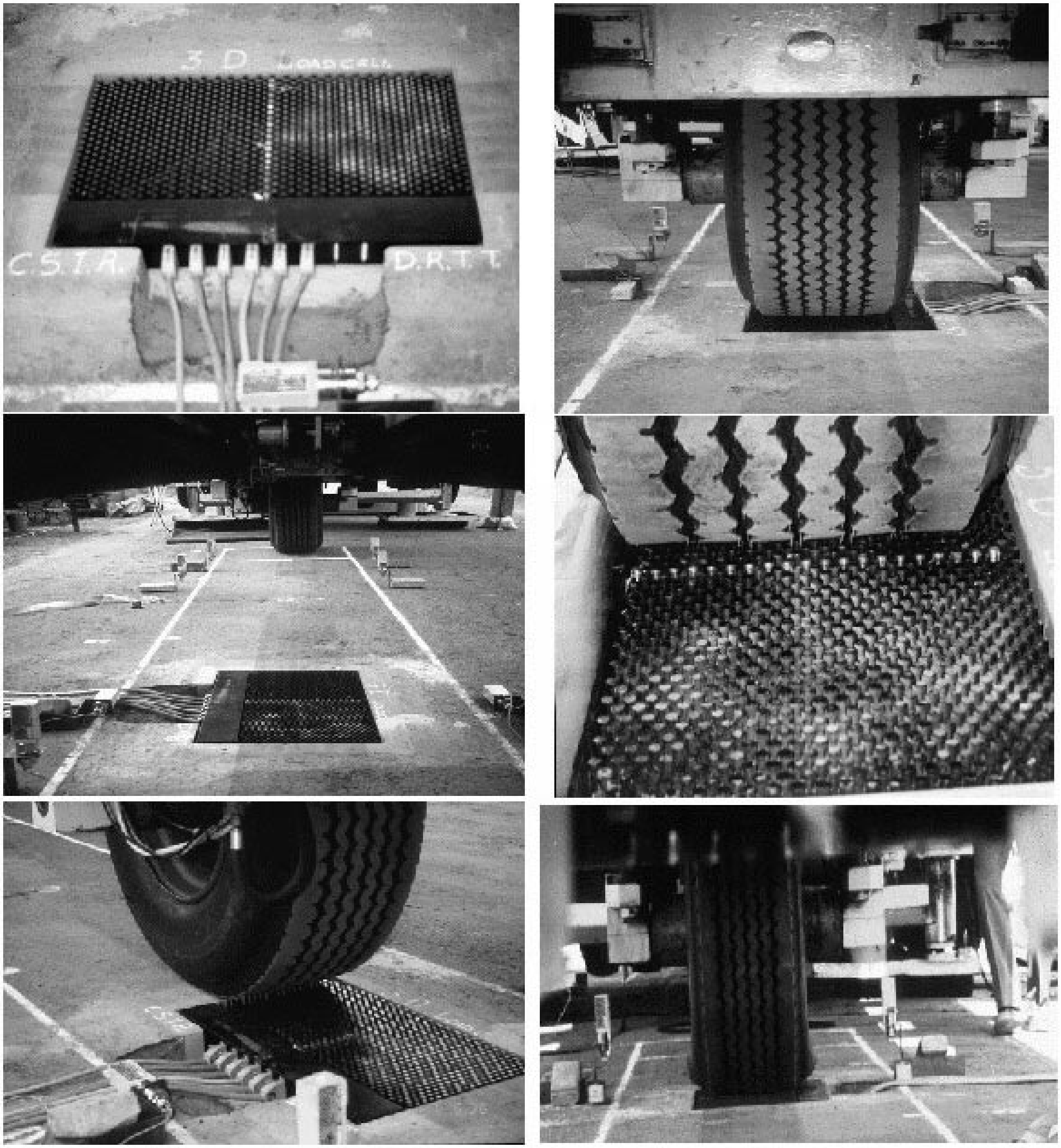

Figure 4: *Images of the VRSPTA as used under the Heavy Vehicle Simulator (HVS)*

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View figure 3

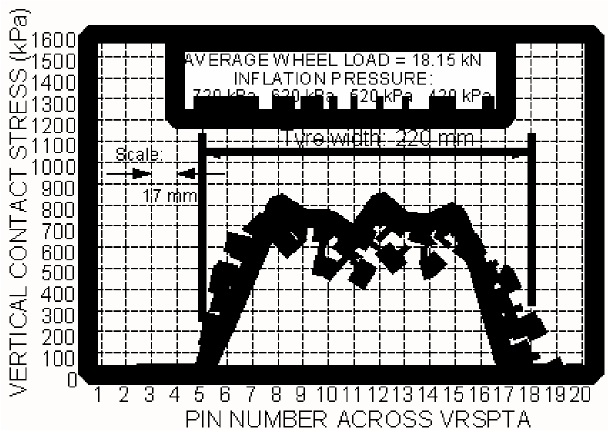

Figure 5

Maximum vertical contact stress across the smooth tyre at various inflation pressures at a constant load (18 kN)

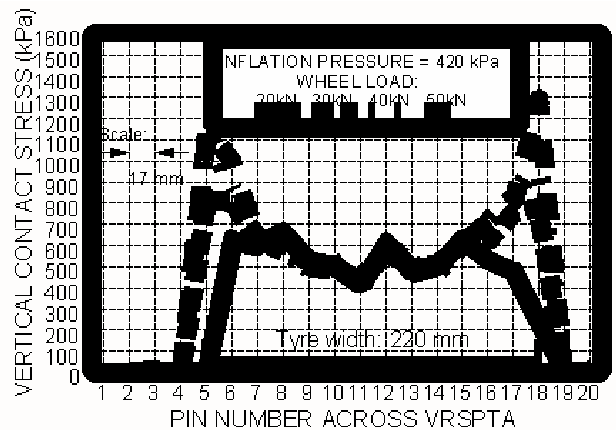

Figure 7

Maximum vertical contact stress across the smooth tyre at various loads at a constant inflation pressure (420 kPa)

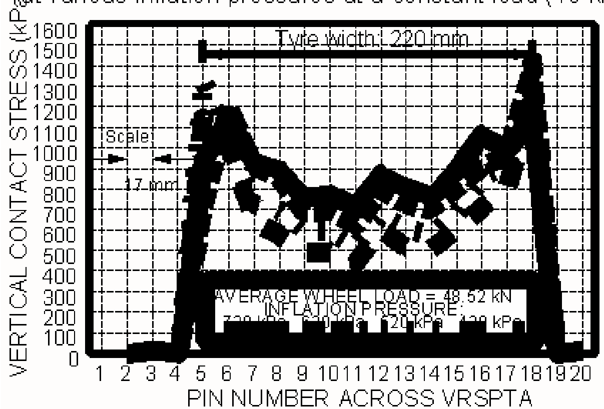

Figure 6

Maximum vertical contact stress across the smooth tyre at various inflation pressures at a constant load (48 kN)

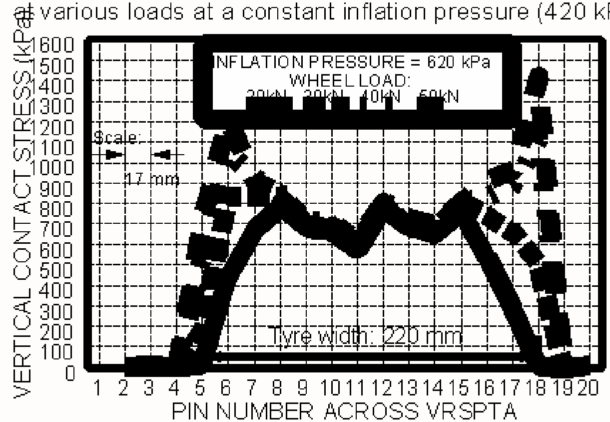

Figure 8

Maximum vertical contact stress across the smooth tyre at various loads at a constant inflation pressure (620 kPa)

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315/80 R22.5: TREADED TYRE
Inflation Pressure = 800 kPa ; Load = 40 kN

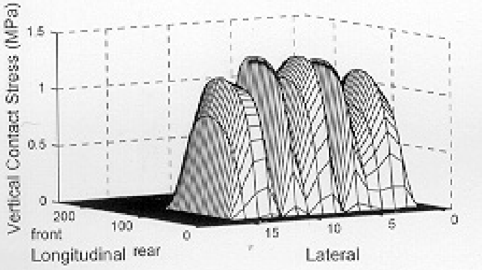

Figure 9a: Vertical Contact Stress

425/65 R22.5: "SMOOTH" TYRE
Inflation Pressure = 500 kPa ; Load = 75 kN

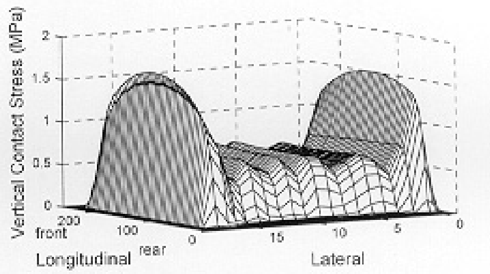

Figure 10a: Vertical Contact Stress

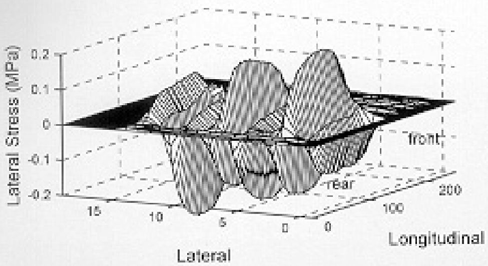

Figure 9b: Lateral Contact Stress

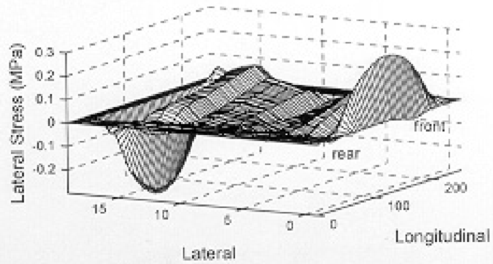

Figure 10b: Lateral Contact Stress

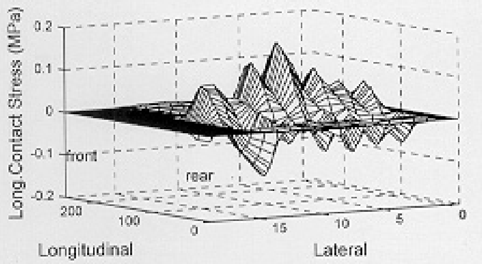

Figure 9c: Longitudinal Contact Stress

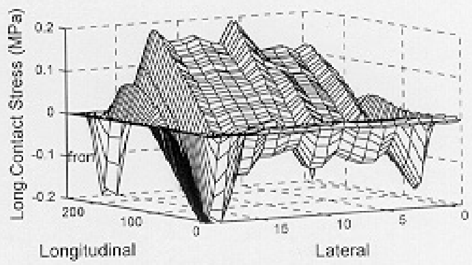

Figure 10c: Longitudinal Contact Stress

Figure 9a,b and c: 3-D Contact stresses of a 315/80 R22.5 tyre at rated load

Figure 10a,b and c: 3-D Contact stresses of an overloaded wide base tyre

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