

IMPROVING THE ROAD WEAR PERFORMANCE OF HEAVY VEHICLES IN SOUTH AFRICA USING A PERFORMANCE-BASED STANDARDS APPROACH

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As a result of successful initiatives in Australia, New Zealand and Canada, the introduction of a performance-based standards (PBS) approach in the heavy vehicle sector in South Africa was identified by the CSIR as a research area warranting funding because of the potential benefits in terms of transport efficiency, road/vehicle safety and the protection of road infrastructure. Whereas most countries throughout the world regulate heavy vehicle use predominantly by prescriptive regulations, some countries have implemented a PBS approach, which involves setting standards to specify the performance required from the operation of a vehicle on a network rather than prescribing how the specified level of performance is to be achieved. This approach allows more flexibility for vehicle designers to utilise innovative solutions and the latest available technology to meet the required performance standards with improved safety outcomes and more effective use of the road infrastructure.

As part of the PBS research programme, a need was identified to design, manufacture and operate a number of PBS demonstration projects in South Africa in order to gain practical experience in the PBS approach and to quantify and evaluate the potential infrastructure preservation, safety and productivity benefits for road freight transport. To this end, two PBS demonstration projects were implemented in the forestry industry, which were designed and manufactured to comply with Level 2 safety standards of the Australian PBS system. These include high and low speed directional and non-directional manoeuvres such as gradeability, slow speed swept path, static rollover threshold, rearward amplification and high speed transient off-tracking.

In order to evaluate the impact of the PBS vehicles on road pavements, a comparison between three baseline vehicles and the PBS vehicles was carried out using the South African Mechanistic-Empirical Design Method. Eight typical SA pavement designs were used both in the wet and dry conditions. Both PBS vehicles were found to be more road-friendly than the baseline vehicles by between 2 and 23 percent. Further potential improvements were identified such as reducing the load on the steering axle and increasing the transverse wheel spacing of the dual tyres on the trailer. The positive performance of the demonstration project has resulted in the approval of 30 additional permits for PBS demonstration vehicles in the forestry industry, some of which will incorporate additional modifications in order to further optimise productivity in terms of road wear.

1 INTRODUCTION

In most countries throughout the world, heavy vehicle use on the road network is controlled predominantly by prescriptive regulations. These regulations, in many cases, differ significantly from one country to another. Efforts in various parts of the world to achieve regional harmonisation and effective road use have had limited success. Another approach is to consider performance-based standards (PBS); in this case standards specify the performance required from the operation of a vehicle on a network rather than prescribing how the specified level of performance is to be achieved. This approach allows more flexibility for vehicle designers to utilise innovative solutions and the latest available technology to meet the required performance standards with improved safety outcomes and more effective use of the road infrastructure. The PBS approach also allows a more optimum “match” between the PBS vehicle and the road infrastructure (roads and bridges) which it uses. Heavy vehicles operated under a PBS framework are typically limited to travel on a subset of the network to ensure protection of the road infrastructure and acceptable safety levels. As a result of initiatives in Australia, New Zealand and Canada, the application of performance-based standards in the heavy vehicle sector in South Africa was identified by the CSIR as a research area warranting funding because of the potential benefits in terms of transport efficiency, road/vehicle safety and the protection of road infrastructure.

2 PBS DEMONSTRATION VEHICLES

As part of the PBS research programme, a need was identified to design, manufacture and operate a number of PBS demonstration projects in South Africa in order to gain practical experience in the performance-based standards approach for heavy vehicles and to quantify and evaluate the potential safety and productivity benefits of this approach for road freight transport. To this end, two PBS demonstration projects, commissioned by Mondi and Sappi, have been implemented in the forestry industry. Operators of these vehicles are required to be accredited through the Road Transport Management System (RTMS) self-regulation accreditation scheme (1). The two PBS vehicles were designed and manufactured to comply with Level 2 of the Australian PBS system (2, 3). Further research work is planned to develop an appropriate PBS framework for South Africa.

The vehicle performance standards that have been used to design the two PBS demonstration vehicles cover high and low speed directional and non-directional manoeuvres such as startability, gradeability, acceleration capability, frontal swing, tail swing, slow speed swept path, tracking ability on a straight path, static rollover threshold, rearward amplification, yaw damping and high speed transient off-tracking.

The Sappi PBS vehicle has an overall length of 27.0 m and a maximum combination mass of 67 500 kg. The Mondi PBS vehicle has an overall length of 24.0 m and a maximum combination mass of 64 100 kg. These PBS vehicles compare with the baseline (legal) vehicle of similar configuration, which has a maximum overall length of 22.0 m and maximum combination mass of 56 000 kg. All the axle and axle unit loads of the PBS vehicles comply with the requirements of the South African National Road Traffic Act. The layout of the baseline and the two PBS vehicles are shown in Figure 1 and the PBS vehicles are illustrated in Figures 2 and 3.

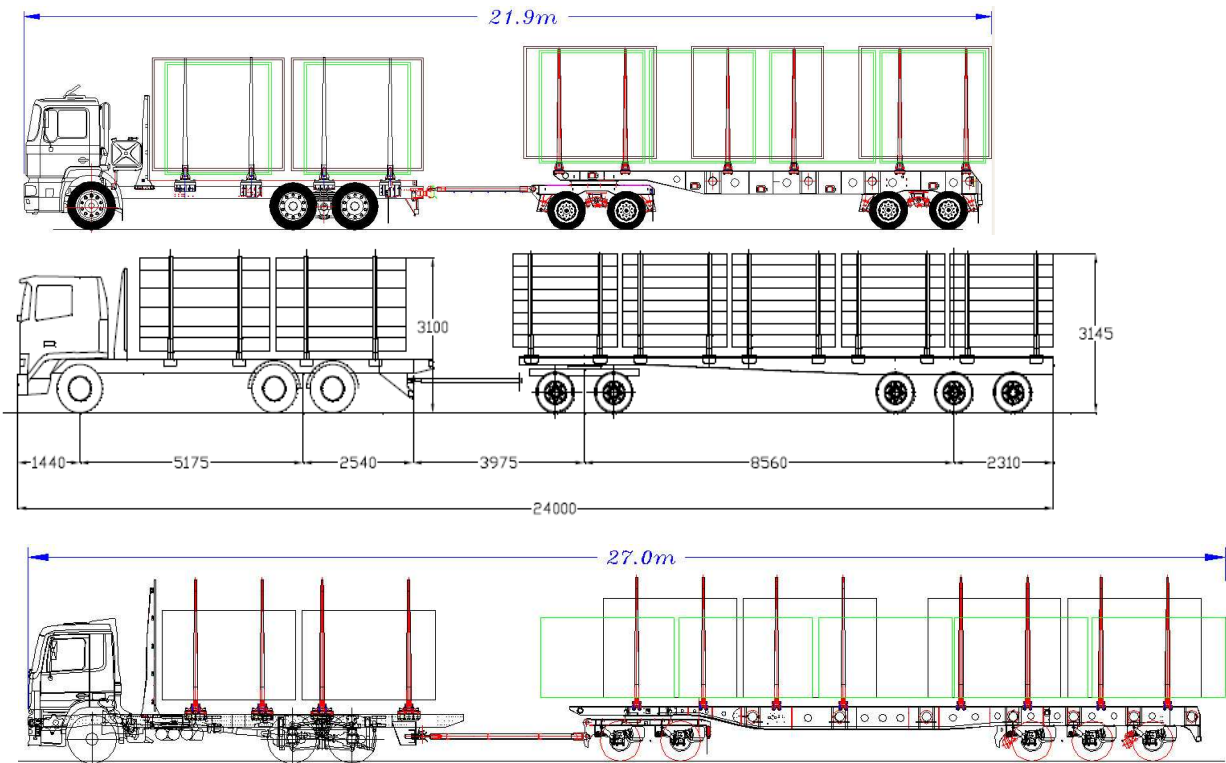


Figure 1: Layout of the 22 m baseline (legal), Mondi (24 m) and Sappi (27 m) PBS demonstration vehicles



Figure 2: Mondi PBS demonstration vehicle



Figure 3: Sappi PBS demonstration vehicle

3 MONITORING OF PBS DEMONSTRATION VEHICLES

Monitoring of the PBS demonstration vehicles commenced once the vehicles had been commissioned. Data including payload per trip, average trip speeds, kms travelled per month, average monthly fuel consumption, maintenance costs and records of incidents and accidents are collected on a monthly basis. Initial results show improved productivity, including fuel consumption, improved safety performance and a reduction in CO₂ emissions (5).

4 ASSESSMENT OF ROAD WEAR EFFECTS

In order to assess the relative road wear between the PBS and baseline vehicles, the CSIR Pavement Design Software MePads (6) was used. MePads is the electronic version of the current South African Mechanistic-Empirical Design and Analysis Methodology (SAMDM) (7). It is anticipated that a methodology will be developed using this approach, which could become part of the PBS assessment process in South Africa. The software combines a stress-strain computational engine with pavement material models developed at CSIR. The Windows Graphical User Interface enables any pavement system and vehicle load configuration to be defined and analysed for bearing capacity and design reliability. The design outputs include pavement layer's life and contour plots of stresses and strains. Pavement layer life is expressed in terms of the number of repetitions of an axle load until failure. Layer life is based on the typical linear-log damage functions (or "transfer functions") obtained (and calibrated) from experience and also on the results of Heavy Vehicle Simulator (HVS) testing on the various pavement types carried out in South Africa since 1975.

The SAMDM approach is used to estimate the Load Equivalency Factors (LEFs) of each vehicle under static loading based on the critical pavement layer life approach. The philosophy of "Equivalent Pavement Response - Equivalent Pavement Damage" (EPR-EPD) is used rather than reducing a vehicle to a single Equivalent Standard Wheel Mass (ESWM), or to an equivalent Standard Axle Load (ESAL). With the EPR-EPD approach, no "fixed equivalencies" are used per se, and each vehicle is considered with its full axle/tyre configuration (i.e. tyre/axle loading and its associated tyre inflation pressure) as input into the SAMDM and the road wear caused by the freight vehicle is directly estimated for the pavement type under consideration. With the EPR-EPD approach the stresses and strains (i.e. mechanistic pavement response parameters) are directly related through the associated transfer functions for pavement damage to layer life and hence "pavement life". With this approach, the pavement life is considered as being equal to the "critical layer life", i.e. the life of the structural layer with the shortest life in the pavement structure.

The pavement life or bearing capacity of the pavement under consideration is also determined under a Standard 80 kN axle with four tyres (two dual sets) at a tyre inflation pressure of 520 kPa. The Load Equivalency Factor of the vehicle (LEF_v) is calculated as the sum of the ratios (for all axles of a particular vehicle) between the critical layer life of the pavement determined from the Standard 80 kN axle with four tyres (two dual sets) at an inflation pressure of 520 kPa (i.e. the bearing capacity of the pavement), divided by the critical layer life under each individual axle load and its associated tyre pressures.

This was done for each vehicle in question for eight typical South Africa pavement design types, two of which are shown in Figure 4. For example, Pavement type A is a typical granular base with 50 mm asphalt surfacing supported by two cementitious subbase layers (a

relatively strong pavement). All eight pavements were analysed in both a wet and dry condition. Road wear costs for a wet pavement are typically 50 to 100 percent more than the same pavement in a dry condition, depending on the pavement type.

For the purposes of this comparison, and to simplify the presentation of results, an average wear cost was calculated for the 16 cases (8 pavement types, wet and dry conditions) for each of the baseline and PBS vehicles. In addition, the effect of increasing the wheel spacing of the dual tyres on the drawbar trailer was also investigated. The standard wheel spacing for a dual tyre is 350 mm. Road wear costs for the Sappi PBS vehicle with wheel spacings of 400 mm and 450 mm on the trailer tandem and tridem axle units were also calculated.

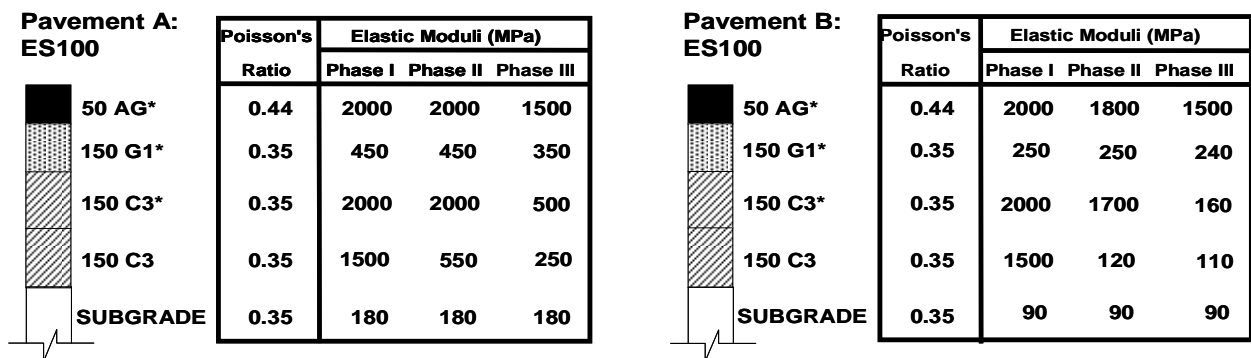


Figure 4: Examples of the eight road pavement structures and their material properties used for the mechanistic analysis for the PBS road wear comparative analysis (* classification according to TRH14, CSRA, 1985)

The average road wear costs (in South African cents) for each vehicle type are given in Table 1. Taking into account the different permissible maximum payloads on each vehicle, a road wear cost per km per ton of payload transported (c/ton km) was also calculated for each vehicle. These are also shown in Table 1 and in Figure 5.

Table 1: Road wear costs (in SA cents) for three baseline and the two PBS vehicles

Vehicle Description	Combination mass (kg)	Payload (kg)	Average Road Wear Cost (c/km)	Average Road Wear Cost (c/ton km)
Baseline: 5-axle articulated	43200	28150	296	10.6
Baseline: 6-axle articulated	49200	31900	299	9.4
Baseline: 7-axle rigid-drawbar	56000	38400	324	8.4
PBS 1 (Sappi)	65400	46200	375	8.1
PBS 1a (400mm wheel spacing)	65400	46200	337	7.3
PBS 1b (450mm wheel spacing)	65400	46200	324	7.0
PBS 2 (Mondi)	64250	45200	375	8.3
PBS 2a (Steer axle – 7 200 kg)	64250	45200	363	8.0

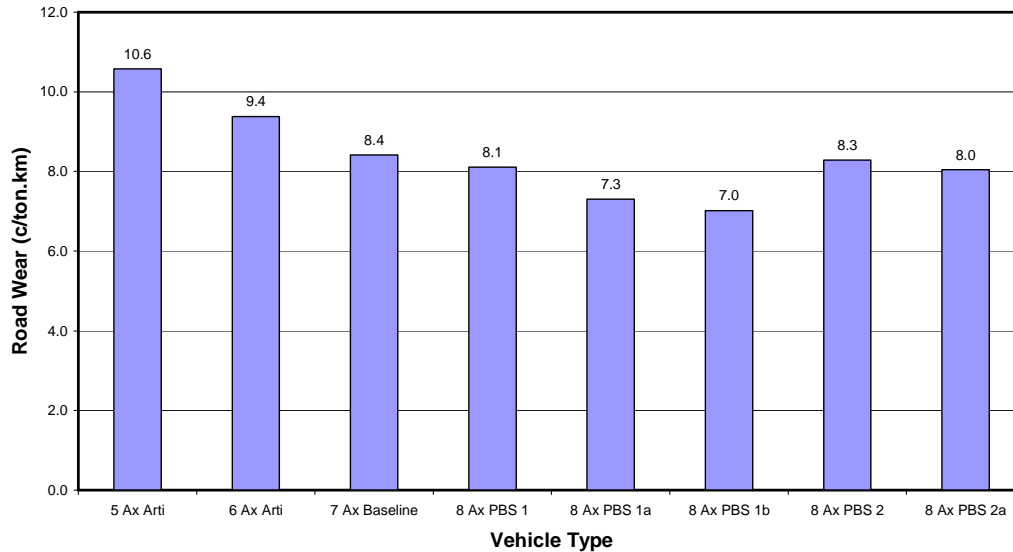


Figure 5: Average road wear costs *in cents per km per ton of payload* for the three baseline and two PBS vehicles calculated from MePads.

Figure 5 shows a comparison of the baseline and PBS vehicles in terms of road wear in cents per km per ton of payload. These results show that the 5- and 6-axle baseline vehicles are the least efficient in terms of road wear (10.6 and 9.4 cents/ton.km). Both the PBS vehicles (at 8.1 and 8.3 cents/ton.km) are significantly more efficient than these baseline vehicles (by 23 and 13 percent) and are slightly more efficient than the 7-axle baseline vehicle, despite the greater payload and combination mass of the PBS vehicles. A further reduction in road wear of the PBS 1 vehicle can be achieved by increasing the wheel spacing of the trailer dual wheels (to 400 and 450 mm). This modification improves the road wear efficiency of the PBS 1 vehicle by 9.9 and 13.6 per cent respectively. It should also be noted that the steering axle load (single tyres) has a relatively large influence on the road wear costs of a vehicle combination. The PBS 2 vehicle has an average steering axle load of 7 500 kg. By reducing the steering axle load to 7 200 kg (the same steering axle load as all the baseline vehicles and the PBS 1 vehicle) and maintaining the combination mass at 64 250 kg (i.e. a slight load redistribution), the road wear cost reduces by 3.6 per cent to 8.0 cents per ton km of payload.

5 CONCLUSIONS

As part of the Performance-Based Standards project in South Africa, a Mechanistic-Empirical pavement analysis methodology has been used to assess the road wear characteristics of two PBS demonstration vehicles. It has been shown that these PBS vehicles are more road-friendly than the typical baseline vehicles. Using this assessment methodology, other vehicle and tyre modifications can be implemented that result in more road-friendly vehicles without affecting the productivity of the vehicles.

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