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TESTING OF NEXT GENERATION WIDE BASE TYRES – PAVEMENT IMPACTS

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Abstract

This paper records the conduct and major findings of a research project conducted by the Australian Road Research Board (ARRB) for the Truck Industry Council (TIC) with the support of the National Heavy Vehicle Regulator (NHVR), Michelin and Goodyear.

The aim of this project was to conduct a relative comparison of the performance of trial pavements trafficked by wide single tyres and dual tyres under accelerated loading and at a range of tyre pressures. The motivation for this work was to gain a better understanding of the impacts of ultra-wide base tyres relative to dual tyres so that the benefits offered by these next generation tyres can be realised by the heavy vehicle industry and road managers in Australia.

The test program included the measurement of contact area and pressure distribution. Pavement wear was mainly quantified by measuring the pavement deformation rates.

This paper documents the work conducted as part of this project, including the design and construction of the test pavement, the test program and the analysis of the results.

Keywords: Pavement wear, wide single tyres, heavy vehicles, accelerated trafficking, inflation pressures, contact area, pressure distribution.

1. Introduction

This paper presents details of the research conducted by the Australian Road Research Board (ARRB) aimed at quantifying the pavement impacts associated with next generation wide load base tyres. The research was conducted as part of a Heavy Vehicle Safety Initiative (HVSI) project focused on enabling on-road safety for heavy vehicles by exploring the potential benefits offered by wide load base tyres. The research was carried out by ARRB with the support of the Truck Industry Council (TIC) and representations from the Australian tyre industry: Michelin and Goodyear Dunlop. This paper provides an overview of the test pavement design and construction, the test using ARRB's Accelerated Loading Facility (ALF), the analysis of the data, and the findings.

2. Background

Efficient and safe transportation of freight using heavy vehicles remains a priority for the road freight industry. As a means of improving heavy vehicle productivity and safety, there is a growing interest in exploring the potential advantages of the next generation wide load base tyres, particularly within Australia's Performance Based Standards (PBS) vehicle fleet.

Wide single and ultra-wide single tyres have been available for decades internationally, based on the results of many studies including the COST 334 project that investigated and quantified the relative pavement wear of ultra-wide single tyres compared to dual tyres for heavy duty asphalt and concrete pavements. Consequently, widespread adoption of ultra-wide single tyres has occurred in place of dual tyre configurations in Europe and the USA. However, there have not been any significant studies of the relative performance of granular pavements with a thin bituminous surfacing (sprayed seal) – which makes up about 90% of sealed pavements in Australasia – subject to ultra-wide single and dual tyre loading. This is a barrier to the adoption of ultra-wide single tyres in Australia.

The TIC promotes the community benefits offered by adopting modern truck technologies, that result in a greener, safer and more productive heavy vehicle fleet. It is common to associate modern truck technologies with electronic devices such as advanced driver assist systems. However, advancements in heavy vehicle components extend beyond devices to individual components, which include the tyre. The tyre is the point at which the vehicle contacts the road and it is critical to overall safety, efficiency and pavement wear. As tyre technology evolves, heavy vehicle regulations that determine safe axle group limits must be aligned to facilitate and manage the next generation of wide base tyres.

The main tyre assemblies used on road-going heavy vehicles are:

- single tyre
- dual tyre
- wide base single tyre
- next generation ultra-wide-base tyre.

Within these four tyre types there are a range of sizes available. The most common single tyres are the 295/80R22.5, which are almost exclusively fitted to the steer axle. This study focused on the other three types – dual tyres, wide base single tyres, and ultra-wide-base tyres – which are fitted predominantly to drive axles and trailer axles.

Consultation with the Australian tyre industry indicated that the most common tyre assembly is the dual 11R22.5, which makes up over 50% of total tyre sales of the entire heavy vehicle market. It is also one of the oldest tyre designs available on the Australian market. Dual tyre assemblies also use other tyre sizes, including narrow section widths such as the 255/70R22.5.

3. Motivation and Benefits

The tyres most commonly used on Australian heavy vehicles are one of the oldest design of tyres available on the Australian market. The range of tyres available is changing, with improvements seeing the development of wide single tyres. Australian regulation has not evolved along with the developments in tyre technology, such as the addition of ultra-wide base tyres. This paper describes the conduct and results of an industry-initiated research project which aimed to benchmark the impact of wide base tyres compared with the tyres most commonly adopted by heavy vehicle operators. This work was supported by the heavy vehicle industry, including transport operators, truck original equipment manufacturers, trailer manufacturers, and tyre suppliers.

There is a wide range of truck tyres available in the Australian market that fulfil a range of applications, from trailer axles, driving axles through to steering axles. Heavy vehicle transport operators select a tyre type based on the vehicle, the freight task, the operating environment, functions that must be carried out, and, importantly, the axle loads at which the vehicle will be operating.

The decision to use ultra-wide base tyre instead of dual tyres would usually involve consideration of the advantages offered by ultra-wide base tyres in the areas of vehicle design and maintenance, safety and sustainability. These include:

- increased track width – for improved vehicle stability
- potential to lower the centre of gravity (CoG) of the load – for improved vehicle stability
- reduced tare weight, and the potential to increase payload
- easier tyre pressure checks
- easier inspection of brake components
- exposure of more of the braking system for increased air flow
- single tyre inflation point per wheel
- reduced rolling resistance
- reduced raw materials and end-of-life recycling opportunities.

4. Project Scope

The aim of this project was to quantify the relative pavement wear of wide single and ultra-wide base tyres compared with common dual tyres. The following tyres were tested:

- a representative ultra-wide base single tyre with a section width of 445 mm
- a representative wide single tyre with a section width of 385 mm
- a reference 11R22.5 dual tyre set
- a reference 255/70R22.5 dual tyre set.

5. Method

5.1. Experimental Design

The experiment design involved the selection of appropriate tyres for the study and the development of a comprehensive test program. Consideration was given to previous research conducted in Australia and overseas, including project Austroads (2008a) which had a similar aim of comparing the pavement wear of tyres with different section widths.
Quantifying and comparing the performance of the next generation wide load base tyres required the selection of representative sizes and models of these tyres, as well as typical dual tyres as a reference. The tyres which were selected for testing are shown in Figure 1.

Michelin
445/50R22.5
Section width
445 mm

Michelin
385/55R22.5
Section width
385 mm

Goodyear
11R22.5
Section width
280 mm

Dunlop
255/70R22.5
Section width
255 mm

Figure 1– Tyre selected for testing

In order to gain an understanding of the effect of tyre size, as well as the different tyre pressures, the test program was constructed as per Table 1.

Table 1 Test program

Test no.	Load (kN)	Section	Tyre size	Tyre config.	Inflation	Inner pressure/ Outer pressure
1	40	4006	255/70R22.5	Dual	Recommended	675 kPa (98 psi) 675 kPa (98 psi)
2	40	4007	11R22.5	Dual	Recommended	525 kPa (76 psi) 525 kPa (76 psi)
3	40	4008	11R22.5	Dual	Mismatch	525 kPa (76 psi) 682.5 kPa (99 psi)
4	40	4005	11R22.5	Dual	Over inflated	682.5 kPa (99 psi) 682.5 kPa (99 psi)
5	40	4004	445/50R22.5	Single	Recommended	700 kPa (102 psi)

6	40	4003	445/50R22.5	Single	Under inflated	560 kPa (81 psi)
7	40	4000	445/50R22.5	Single	Over inflated	840 kPa (122 psi)
8	40	4001	385/55R22.5	Single	Over inflated	900 kPa (131 psi)
9	40	4002	385/55R22.5	Single	Recommended	790 kPa (115 psi)
10	40	4012	445/50R22.5	Single	Recommended	700 kPa (102 psi)

Note: Test 10 was a repeat of Test 5, conducted on Section 4012 which was located between the lanes.

When comparing the results with Austroads (2008a) it should be noted that the tyres used to represent tyres with 445 mm section were different in design and construction from the 445/50R22.5 tyres tested as part of this project. The tyres used in the Austroads study were 445/65R22.5, which had an aspect ratio of 65 as opposed to the aspect ratio of 50 adopted in the current study. This impacted the footprint of the tyres and how the load was transferred to the pavement. The 445/65R22.5 tyre was not selected for this test as it is not commonly used in normal highway applications.

6. Pavement Design and Construction

To ensure that the pavement design was representative of the road environment nationally, it was designed in consultation with the Austroads Pavement Task Force, which is comprised of pavement engineers from each of the Australian road authorities. The test pavements were constructed within the indoor site at ARRB's Accelerated Loading Facility (ALF) (Figure 2) to provide three test lanes.

Figure 2 ARRB's indoor ALF site

6.1. Pavement Layout & Pavement Composition

The aim was to conduct testing on identical test pavements (each 12.0 m in length) subjected to loading under different tyre configurations. To accommodate the number of intended loading configurations, the three main test lanes at the site were designed to be 40 m long and 3.5 m wide, each divided into three test pavements, or experiment sections. Provision was made for four extra test sites between the main three lanes, for additional testing.

To ensure that useable results were obtained, the cross-section of the test pavement was designed to be:

- representative of the network on which these tyres would typically travel
- likely to experience measurable deformation within the timeframe of the project

6.2. Pavement Layout & Pavement Composition

An overview of the selected pavement layer materials is given in Table 2.

Table 2: Overview of pavement layer materials

Layer	Thickness (mm)	Description
Sprayed seal	~10	10/5 Double/double (high binder content emulsion (HBCE))
Granular base	200	20 mm Class 3 crushed rock (Hornfels – Lysterfield)
Imported subgrade	400	Sandy silty clay (Californian Bearing Ratio (CBR) 6)
Pre-existing stabilised clay subgrade and drainage layer	~350 mm	(Remaining material from previous project, Austroads 2017)
Subgrade	-	Natural subgrade

6.3. Pavement Construction

Pavement construction, including site preparation, commenced in February 2021 and was completed mid-September 2021.

The existing pavement tested in a previous project was excavated to a depth of approximately 600 mm from the surface level to ensure the removal of any moisture contamination.

This material removal left an approximately 350 mm thick layer of cement-stabilised clay subgrade material, over which the new pavement was constructed. Once exposed, the stabilised subgrade was then levelled in preparation for subbase construction.

The subgrade was assessed using FWD surveys to confirm uniformity. The results of this survey showed that the maximum deflections and curvature values of the subgrade were consistent and uniform along, and between, each of the offset lengths.

The three lanes to be constructed spanned to the edge of the test facility. Surrounding concrete walls and required drainage provisions were constructed to ensure the tests were not affected by outside moisture entering the test areas. The prepared subgrade and walls of the concrete tank are show in Figure 3.

Figure 3 The test pavement subgrade and surrounding concrete walls

6.3.1 Imported Subgrade Construction

Following subgrade preparation, the local sandy silty-clay material for the imported subgrade was placed to a depth of 300 mm which was subsequently increased by an extra 100 mm thick layer of subgrade material to reach the level – 200 mm below the pavement surface. Once placed, this subgrade material was compacted and trimmed to ensure the target level was met. The uniformity in layer moisture content and density was also assessed and confirmed to be sufficiently uniform before construction proceeded further.

6.3.2 Basecourse Construction

The basecourse material for the test pavements was placed to a depth of 200 mm (i.e. meeting the pavement surface level) and was laid in two lifts, each 100 mm thick. The basecourse was then compacted and levelled. Quality testing of the moisture content, layer density, and strength of the basecourse was undertaken, and the dry-back of the material was monitored before construction proceeded further. The basecourse material was a standard quarry crushed rock homogeneous material of higher quality than initially planned, due to lower-quality material not being available locally., thus more representative of good practice for road construction.

6.3.3 Surface Priming and Spray Sealing

Once sufficient dry-back of the basecourse had occurred (i.e. a target moisture ratio of ~80% overall moisture content) the surfacing was applied. A primer trial was first conducted by applying patches of primer in a trial area of the pavement to ensure a suitable application rate could be selected. This trial determined an application rate of 1.0 L/m2 was most appropriate. Following the primer trial, the emulsion primer was applied to the test pavement surface and then the double coat sprayed seal was applied. After the completion of the pavement surfacing, the pavement was evaluated to determine its quality.

Figure 4 The test pavement after the spray seal was applied

7. Monitoring of Pavement Response and Performance

The pavement condition was monitored before the testing commenced, at regular intervals during the trafficking of the pavement and after the tests were completed.
The experiment monitoring methods included:

- Falling Weight Deflectometer (FWD) to measure pavement deflection.
- Transverse profilometer to measure surface profile and pavement surface deformation.
- Sand Patch Texture: volumetric method to measure texture depth.
- British pendulum testing to measure skid resistance.
- Moisture content testing was undertaken using the Nuclear Density Gauge.

7.1. Deflection

FWD measurements were taken to assess pavement response and evaluate the pavement uniformity after the priming and sealing of the surface. Testing was conducted in both the trafficked sections (wheel paths) of each lane, as shown Figure 5. The pavement surface vertical deflection was recorded at offsets of 0, 200, 300, 450, 600, 900, 1200, 1500 and 1800 mm from the centre of the loading plate and at every half-metre chainage along each of the test pavements. Deflections were all normalised to a 40 kN load.

Figure 5 Deflection testing at ALF site using the FWD

FWD measurements were taken to assess pavement response and evaluate the pavement uniformity after the priming and sealing of the surface. The average deflections from three sets of measurement were used to identify sections of the pavement which had a similar response (mean pavement deflection).

The measured deflection values are summarised in Table 3. The Standard Deviation of the mean maximum deflection (d0) was considered to ensure that the test sites had similar deflections to ensure uniformity of the pavement.

Table 3: Maximum deflection measured during testing

Section	**Date**	**Maximum deflection d0 (µm)**			
		Mean	Std Dev.	Min	Max
4000	01/10/2021	653	7.5	643	661
	08/10/2021	652	6.8	644	660
	12/10/2021	647	9.8	636	666
4001	01/10/2021	655	6.0	649	666
	08/10/2021	653	6.0	645	659
	12/10/2021	657	12.4	643	676
4002	01/10/2021	659	7.7	644	667
	08/10/2021	654	5.6	647	662
	12/10/2021	653	8.9	642	667
4003	01/10/2021	653	8.2	640	664
	08/10/2021	652	7.4	641	659
	12/10/2021	652	8.7	643	668
4004	01/10/2021	658	6.4	647	666
	08/10/2021	650	5.8	644	656
	12/10/2021	658	15.8	645	688
4005	01/10/2021	657	6.1	649	666

	08/10/2021	648	9.0	638	659
	12/10/2021	651	3.4	647	656
4006	01/10/2021	657	6.5	647	667
	08/10/2021	648	5.2	640	654
	12/10/2021	655	3.6	650	659
4007	01/10/2021	655	7.2	643	661
	08/10/2021	652	7.6	642	661
	12/10/2021	655	10.3	641	670
4008*	01/10/2021	661	2.6	658	664
	08/10/2021	659	6.3	653	670
	12/10/2021	657	5.7	647	662

*Measurements for test section 4012 were not included as part of these lane measurements, however as this test section was located between lanes it can be assumed that these measurements apply to the additional test section.

The measured mean maximum deflections are shown in Figure 6. The orange points show the maximum deflections based on the three tests, while the blue points show the mean maximum deflection. The orange line identifies the overall mean, with the dashed orange lines showing approximately ±0.5% deviation of the mean. This shows that the maximum deflections in most of the experiments were within 0.5% of the mean.

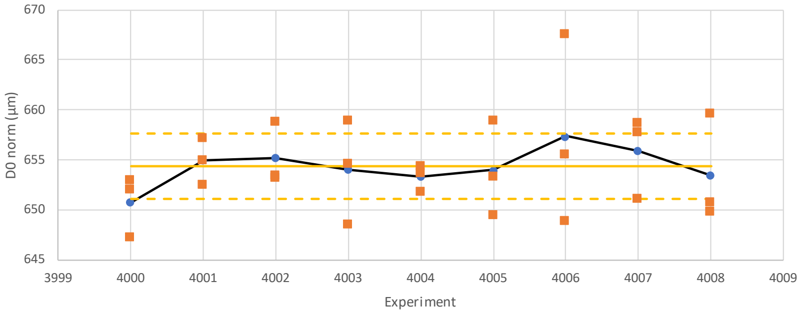


Figure 6 Mean maximum deflection

7.2. Transverse Profile

The transverse profile of the trafficked area of each test lane was monitored using an automated transverse profilometer (TP), at every half-metre along each test pavement.

At each chainage, the data was measured across the width of the test lanes. Due to the higher rate of increase in the pavement surface deformation at the start of the experiment, the transverse profile was measured at shorter time intervals for the first 15 000 cycles for each lane (i.e. after 0, 300, 1,000, 9,000, 10,000, 15,000, 22,500, 30,000, 37,500, 45,000 and 52,500 cycles). Subsequently the measurements were conducted after approximately every 7,500 cycles of loading until the trafficking was completed.

7.3. Surface Texture

Testing was undertaken using the Sand Patch method before and after the pavement was trafficked to identify the changes caused by the trafficking. Testing is undertaken by spreading a known volume of fine-grained sand on the pavement into a circle and measuring the average diameter of the sand over a number of readings. The texture depth is then calculated by dividing the volume of the sand by the area of the patch (i.e. texture depth = volume of sand/area of patch). The test method utilised for the sand patch method was AGPT-T250-08 (Austroads 2008b).

7.4. Skid Resistance

British Pendulum Testing was undertaken both before and after the pavement was trafficked to measure the skid resistance value of the pavement at different locations on the test bed. The test method used for the testing of the freshly constructed pavement was *AS 4586-2013: slip resistance classification of new pedestrian surface materials* and once the pavement was trafficked, test method *AS 4663-2013*.

7.5. Tyre Contact Pressure Distribution

The contact pressure distribution of each tyre was measured with the assistance of Goodyear Dunlop Australia and O'Brien Traffic using ARRB's pavement surface wear measurement trailer and an electronic pressure sensor pad (X-Sensor) provided by Goodyear (Figure 6). Footprint data was collected at:

- varying loads and inflation pressures
- the load and inflation pressures used for ALF trafficking.

Figure 6 Recording tyre contact pressure distribution

The pressure distribution data for the tyres is summarised in Table 4,

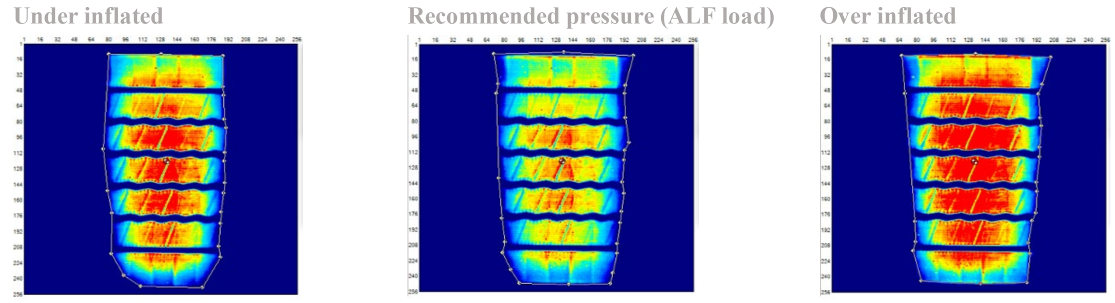
Table 4: Summary of pressure and area of tyres

Test	Tyre Size	Tyre inflation pressure	Area (cm^2)	Pressure (kPa)	Vertical force (kg)
1	255/70R22.5	689 kPa (100 psi)*	400.40	800.27	3267.5
2	11R22.5	524 kPa (76 psi)*	502.50	617.49	3164.0
3	11R22.5	–	–	–	–

4	11R22.5	689 kPa (100 psi)*	447.82	679.61	3103.3
5	445/50R22.5	689 kPa (100 psi)	606.14	709.33	4384.4
6	445/50R22.5	558 kPa (81 psi)	665.55	599.36	4067.5
7	445/50R22.5	841 kPa (122 psi)	675.73	826.54	5695.4
8	385/55R22.5	903 kPa (131 psi)	599.06	912.25	5572.5
9	385/55R22.5	792 kPa (115 psi)	511.30	822.89	4290.3

* Testing is for single tyre configuration.

The pressure heat maps for 445 mm tyres are shown in Figure 7. Areas of red are the highest pressures recorded. Other colours across the spectrum (from red to blue) represent lower pressures, with blue being the lowest pressure. The concentrated red section – usually in the centre of a contact patch – is referred to as a ‘hot spot’. This term does not imply a higher temperature, but a higher pressure.


Under inflated

Recommended pressure (ALF load)

Over inflated

* Testing is for single tyre configuration.

Figure 7 445/50R22.5 Tyre pressure heat map

Nine specific tyre configurations were subjected to controlled temperature and climatic testing conditions, with a minimum of 50,000 load cycles applied for each tyre type. The reference dual tyres fitted to the ALF during trafficking are shown in Figure 8.

Figure 8 Trafficking of the test pavement

8. Results and Analysis

8.1. Deformation Rate

The measured deformation rate was calculated from the slope of the deformation curve between 9,000 and 52,500 cycles, assuming a linear rate using the measurements at 0.5 m intervals. Due to the high moisture content of the pavement, the deformation rate for test 6 was excluded from further analysis. Outliers were identified and removed if outside the range of ±1.5 times the inter quartile range (IQR) from the mean (i.e. chainages where the deformation rate deviates from the average over the entire test section).

The measured deformation rates were adjusted based on the calculated adjusted structural number (SNP), using the method outlined in following the section.

8.1.1. Adjusted Structural Number (SNP)

The adjusted structural number was determined by summing the pavement structural number (SN) and the subgrade structural contribution (SN_{sg}), using the following equation:

$$SNP = SN + SN_{sg} \tag{1}$$

The method used to estimate the structural number was developed by Roberts (1995) based on FWD deflection data collected in Australia and the Philippines:

$$SN = 12.992 - 4.167 \times log_{10}(D_0) + 0.936 \times log_{10}(D_{900}) \tag{2}$$

The structural contribution of the subgrade (equation 3) was calculated using an estimation of the CBR of the subgrade developed by Jameson (1993) (equation 4).

$$SN_{sg} = 3.51 \times log_{10}(CBR) - 0.85 \times \left(log_{10}(CBR)\right)^2 - 1.43 \tag{3}$$

$$\text{CBR} = 10^{3.264 - 1.018 \times log_{10}(D_{900})} \tag{4}$$

The deflection values used in the calculation, D_0 and D_{900}, were normalised to a surface stress of 700 kPa, using the deflection measured after the bedding-in of the pavement after 9000 cycles.

8.1.2. Average Adjusted Structural Number (SNP)

The relationship used to correct the measured deformation rate for variability in the test pavement was developed for a similar high-quality 20 mm base material (20 mm Montrose crushed rock) and reported in Austroads (2006), with an approximate value of SNP_0 = 4.7 (i.e. average SNP across all test sections) and a = –3.5 (representative of good quality crushed rock). Using the pavement deformation model shown in equation 5, the relationship between the rutting and SNP is shown in equation 6.

$$Rut = SNP^a \times Cycles^b \times f(load, Tyre, Pressure) \tag{5}$$

$$\frac{\Delta Rut(SNP_i)}{\Delta Rut(SNP_0)} = \left(\frac{SNP_i}{SNP_o}\right)^a \tag{6}$$

To adjust the deformation rate for the same pavement response the following equation is used:

$$\Delta Rut(SNP_0) = \left(\frac{SNP_0}{SNP_i}\right)^a \times \Delta Rut(SNP_i) \tag{7}$$

After adjusting the deformation rate using the adjusted structural number, they were considered more comparable as they were adjusted to an average pavement condition for all tyres configurations.

The average deformation rate and adjusted deformation rates are shown in Table 5.

Table 5: Adjusted deformation rate

Test	Section	Tyre Size	Tyre pressure	Deformation rate (mm/cycle)	Adjusted deformation rate (mm/cycle)
1	4006	255/70R22.5	675 kPa (98 psi) for both tyres	1.91×10^{-5}	1.83×10^{-5}
2	4007	11R22.5	525 kPa (76 psi) for both tyres	1.17×10^{-5}	0.99×10^{-5}
3	4008	11R22.5	525 kPa (76 psi) inner 682.5 kPa (99 psi) outer	1.42×10^{-5}	1.07×10^{-5}
4	4005	11R22.5	682.5 kPa (99 psi) for both tyres	1.60×10^{-5}	1.28×10^{-5}
5	4004	445/50R22.5	700 kPa (102 psi)	1.70×10^{-5}	1.79×10^{-5}
6(1)	4003	445/50R22.5	560 kPa (81 psi)	2.17×10^{-5}	3.22×10^{-5}
7	4000	445/50R22.5	840 kPa (122 psi)	1.24×10^{-5}	1.75×10^{-5}
8	4001	385/55R22.5	900 kPa (131 psi)	1.12×10^{-5}	1.28×10^{-5}
9	4002	385/55R22.5	790 kPa (115 psi)	1.44×10^{-5}	1.40×10^{-5}
10	4012	445/50R22.5	700 kPa (102 psi)	1.80×10^{-5}	1.27×10^{-5}

Note: (1) High moisture content was identified at the location of Test 6.

Figure 9 shows the measured deformation rate, with one standard deviation above and below the mean shown in grey and one standard deviation above and below the mean shown in red.

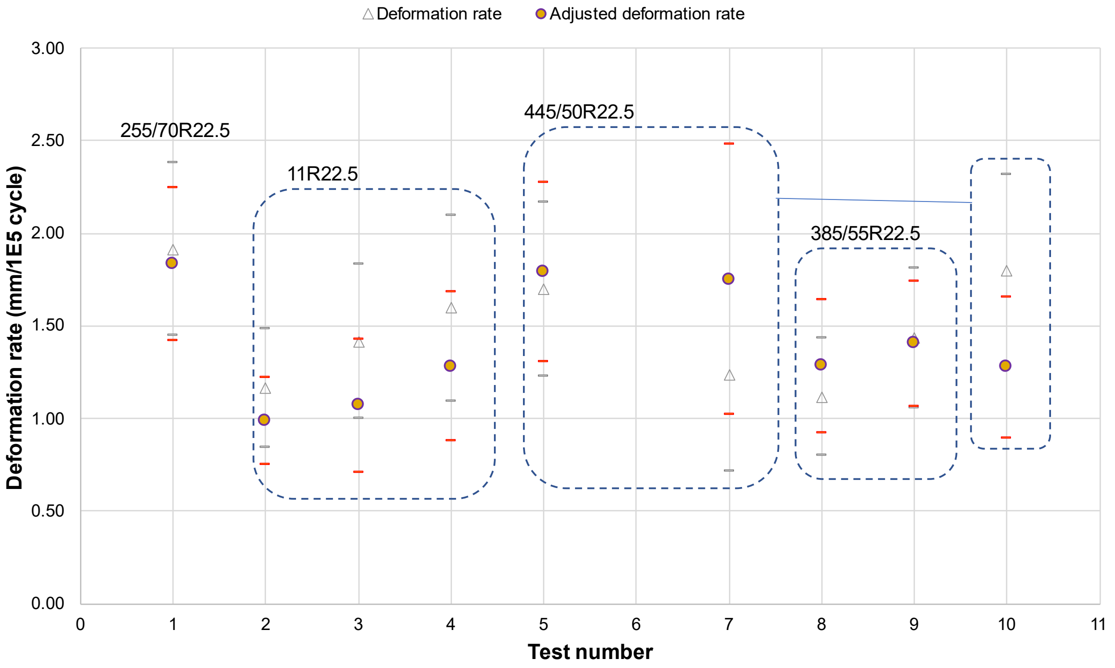


Figure 9 Deformation rate against adjusted deformation rate

8.1.3. Effects of inflation pressure

The results show that inflation pressure had a significant effect on the performance of the sites trafficked with the dual 11R22.5 tyres, with the deformation rate increasing as pressure increased. However, there was no statistically significant result for the wide single tyres. The most damaging option for the 11R22.5 tyres was when they were over-inflated (100 psi (689 kPa)). A review of data collected from roadside inspections, made available by the NHVR, found that is common for 11R22.5 dual tyres to be inflated to 100 psi (689 kPa); hence this test scenario was included to represent what is currently occurring in practice.

The differences in the results for the 11R22.5 dual tyres at 99 psi (683 kPa); with the 445/50R22.5 tyres at 102 psi (703 kPa) and the 385/55R22.5 tyres at 115 psi (793 kPa) were marginal, with deformation rates of 0.0000128 mm/cycle, 0.0000127 mm/cycle (Test 10) and 0.0000179 (Test 5) and 0.000014 respectively.

In summary, the tests designed to quantify the effects of tyre inflation pressure showed that over-inflated 11R22.5 dual tyres had increased pavement wear, However, the wide single tyres produced some counter-intuitive results that were not statistically significant, and could not be attributed to the characteristics of the tyre. This implies that wide single tyres can operate at a wider range of inflation pressures, with no discernible difference in pavement wear. This finding was consistent with the pressure distribution tests which showed less variation in contact patch area and peak pressure than dual tyres.

Figure 10 shows the ratio difference of the deformation rate and adjusted deformation rate for the wide single tyres compared to the 11R22.5 tyres with recommended pressure. This chart highlights the difference between the inflation pressures and also shows the difference between the ultra-wide tyres and the wide single tyres relative to the 11R22.5 dual tyres at their recommended pressure.

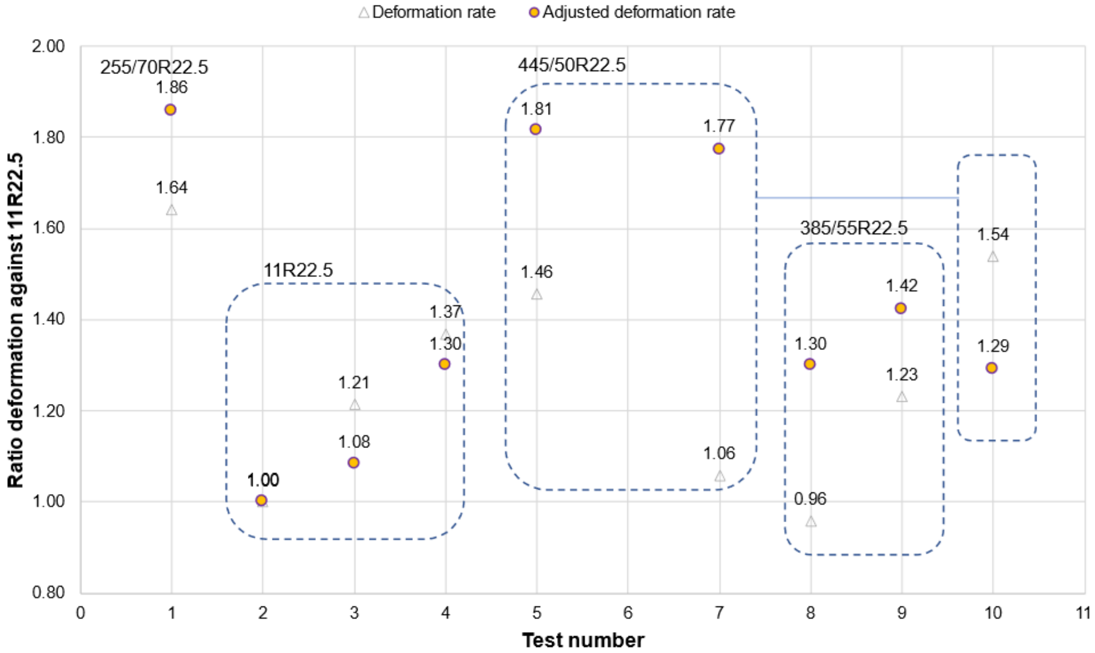


Figure 10 Ratio deformation rate of wide single tyres compared with 11R22.5 tyres

8.2. Transverse Deformation Profile

This section discusses the relationship between the deformation for each tyre and the transverse profile. A comparison of the transverse profiles was made by calculating the average deformation for all chainages, area of deformation, and applied pressure. The measured average deformation in Figure 11 is shown in light blue, whereas the dark blue line shows the theoretical cumulative pressure (number of cycles x measured contact pressure applied to the pavement. The cumulative pressure was calculated based on the contact pressure and the number of cycles, and altering the transverse distribution of the loading during trafficking.

It is evident when comparing the average deformation profile for each of the different tyres that the depth and width of the deformation relative to the tyre pavement contact stress. Generally, the dual tyres caused transverse deformation spread over a wider area than the single wide tyres. The 445/50R22.5 tyre had a smaller area of deformation than the 11R22.5 tyre. It is noted that, while the 445/50R22.5 tyre caused a smaller area of deformation, the maximum deformation was larger and occurred over a narrower width than the profile of the 11R22.5 tyre.

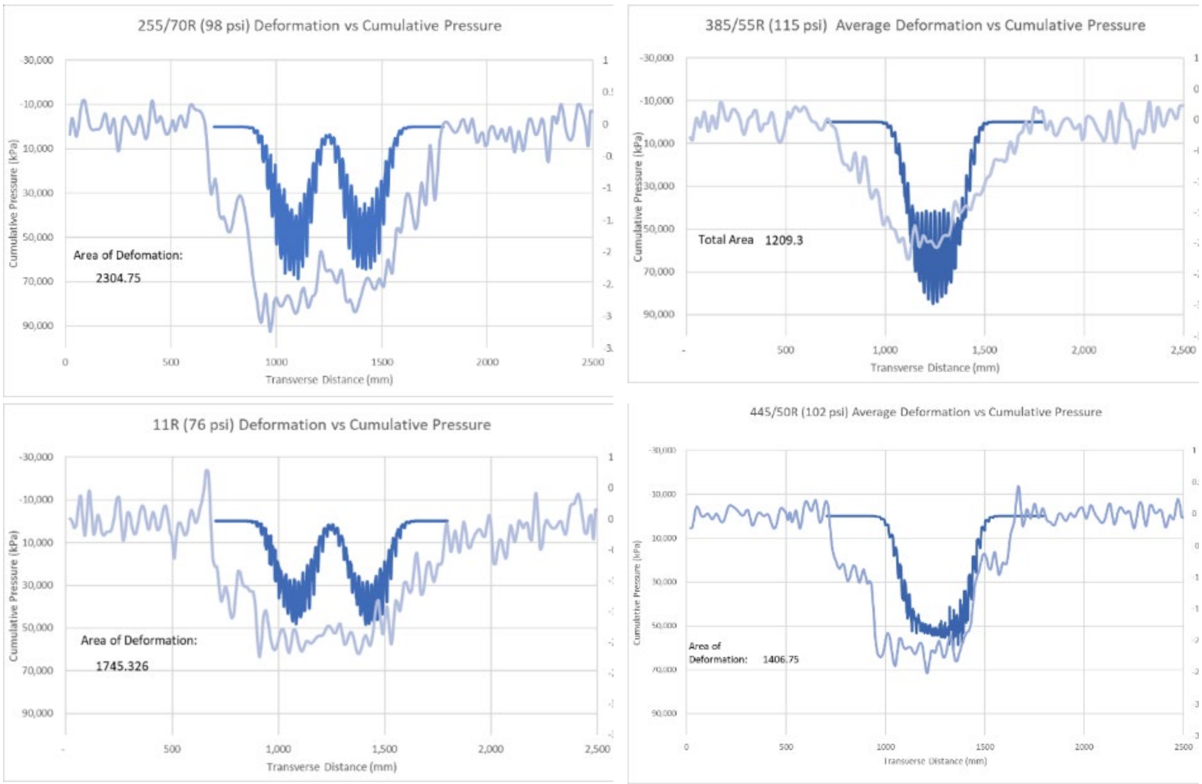


Figure 11 Deformation profiles at 52,500 cycles

It can been seen in Figure 11 that the area of deformation varied along the length of the test pavement. The effect of the wide tyres remained relatively consistent, while the effect of the dual tyres was more variable. In general, the dual tyres caused a larger area of deformation than the wide single tyres.

In summary, the wide single tyres generate a narrower and slightly shallower rut than the dual 11R22.5 tyres. There was, however, very little difference in rut depth between all tyre sizes.

9. Conclusions

This paper has described the results of accelerated pavement testing of an unbound granular pavement with nine tyre configurations in order that the pavement wear effects of wide single tyres and dual tyre sets carrying the same loads could be compared.

Wide single and ultra-wide single tyres have been available for decades internationally, based on the results of many studies including the COST 334 project that investigated and quantified the relative pavement wear of ultra-wide single tyres compared to dual tyres for heavy duty asphalt and concrete pavements. Consequently, widespread adoption of ultrawide single tyres has occurred in place of dual tyre configurations in Europe and the USA. However, there have not been substantial studies of the relative performance of sprayed seal unbound granular pavements subject to loading by ultra-wide single tyres and dual tyres.

The results showed similar pavement wear from all of the tyre configurations tested. However, there were some differences as follows:

9.1 Deformation Rate

The deformation rate was selected as the definitive metric to compare the pavement wear caused by the tested tyres. The deformation rates for all tyres, both the dual and single tyres, were all within a similar range (within the variability of the experiment) with the 255/70R22.5 dual tyres having the highest deformation.

The data showed that when inflated to their recommended inflation pressures, the differences in deformation rates were small (but statically significant). The order of deformation rate from highest to lowest was 255/70R22.5, 445/50R22.5, 385/55R22.5 and 11R22.5.

Based on these results, tyre size (section width) alone does not correlate with deformation rate; other contributing factors include contact patch area, shape and pressure distribution.

9.2 Pavement Rutting Profile

The peak value of the rut profile (over 3 mm) caused by the 255/70R22.5 tyres was higher than the peak values for the 445/50R22.5, 385/55R22.5 and 11R22.5 tyres, which were between 2 to 2.5 mm.

When comparing the profile of the ruts, the dual 255/70R22.5 and 11R2.55 tyre sets produced a rutting wider and deeper than the rut produced by wide single tyres. However, the difference in rutting between the 11R22.5 and the wide single tyres was small enough that it may be insignificant. Further work is required to determine whether this difference in rut depth has any effect on road pavement longevity.

Comparisons of the profile shape for each tyre were made, including consideration of the gradients and total area; however, no conclusions could be drawn from this analysis. Further work is required to understand the effect the shape of the rutting profile has on pavement wear.

A clear conclusion that can be drawn from the comparison of the rutting profiles is that the dual tyres and single tyres wear different areas of the pavement: the dual tyres wear a wider path, whereas the wide single tyres wear a narrower path in the centre of the trafficking lane, an area which is less trafficked by dual tyres. It is expected that, when trafficked over the same pavement section, dual tyres and wide single tyres would have a more evenly dispersed lateral wear pattern.

It should also be noted that the traverse distribution of the ALF loading (which can be varied) was narrower than what would be expected in practice. This traverse profile was selected so that the loading could be concentrated, resulting in an increase in the amount of deformation.

9.3 Inflation Pressure

Based on deformation rates, inflation pressure was found to have a significant effect for dual 11R22.5 tyres, but not for wide single tyres. The most damaging option for the 11R22.5 was when the tyre was over-inflated (100 psi), which has been found to be a common occurrence in practice.

When comparing the results representative of common practice for the 11R22.5 dual tyres at 100 psi with the 445/50R22.5 at 102 psi and the 385/55R22.5 at 115 psi the differences were marginal, with deformation rates of 0.0000128 mm/cycle, 0.0000179 (Test 5) and 0.0000127 mm/cycle (Test 10) and 0.000014 respectively.

The tests designed to quantify the effects of tyre inflation pressure for wide single tyres produced some counter-intuitive results. The results were not statistically significant and could not be attributed to the characteristics of the tyre. This implies that wide single tyres can operate at a wider range of inflation pressures with no discernible difference in pavement wear. This finding is consistent with the pressure distribution tests which showed less variation in contact patch area (maintained a regular rectangular contact area) and less high-pressure locations (hot spots) compared with dual tyres.

9.4 Effect on pavement wear

A hypothesis to explain the small difference in wear observed between all tyres, and the low absolute values of deformation, is that the variations due to environmental factors, pavement construction and measurement tolerance had a greater impact on pavement wear (approximately 0.000012 mm/cycle) than the differences associated with variation in tyre configuration.

Significant effort was put into the design and construction of a uniform sprayed seal-surfaced unbound granular test pavement, such that the pavement would be representative of common (good) construction practice and aligned with previous pavement design for testing by Austroads (2008a). Despite this, the total deformation after 50,000 cycles of the ALF 40 kN load was only 3-4 mm for the dual tyres and 2-3 mm for the single tyres.

The test conditions were well controlled, with the test pavements protected from the elements and located in a concrete isolation tank. Despite this, the variations in the test environment were a significant factor, and required adjustments to be made as part of the analysis. The adjustments in deformation rate, due to environmental factors, were of a similar magnitude to the differences between the tyres tested. In practice, the environmental factors would be greater.

These results suggest that the wider adoption of wide single tyres with a section width between 385 and 445 mm – at the same loads as currently allowed on dual 11R22.5 tyre sets – would not necessarily cause a discernible increase in road pavement wear. However, this would be clarified by determining the load equivalency for each tyre. Further testing – perhaps involving a wider range of axle loads and more loading cycles – is required to confirm these findings.

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