Heavy Vehicle Safety Initiative Final Report

TESTING OF NEXT GENERATION WIDE TYRES – PAVEMENT IMPACTS

PROJECT NUMBER HVSI 547 & HVSI 619

TRUCK INDUSTRY COUNCIL

Paul Caus - Technical Officer

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Acknowledgements

TIC would like to acknowledge the significant support from the National Transport and Research Organisation (formerly Australian Road Research Board) over and above the project scope. Significant in-kind support and expertise was provided by Thomas Ruessman – Customer Engineer, Goodyear and Mr Darren Wong - Senior Field Engineer, Michelin. Additionally, Mr Les Bruzsa - Chief Engineer, National Heavy Vehicle Regulator (NHVR), provided technical oversight and guidance. Finally, TIC would like to acknowledge the assistance of former TIC staff member and Technical Officer, Mr Chris Loose, who retired towards the end of the project, yet continued to be actively involved in the oversight of the project to ensure a successful seamless handover to new staff, thus avoiding additional delays for the project.

Executive Summary

The wider adoption of Next Generation Wide Tyres has stalled in Australia due to restrictive and inconsistent regulation. For example, under general mass limits a tandem axle with dual tyres has a maximum permitted mass of 16.5T but only 14T if the tandem axel is fitted with wide tyres. However, a tri axle can run up to 20T regardless if fitted with dual or wide single tyres.

The use of wide tyres brings a number of safety and operational benefits over dual tyres which are covered in further detail in Appendix 1 p9.

Current regulation around wide tyres is based on studies dating from 1976[1] and 1985[2], yet tyre construction has evolved significantly since that time. However, the regulations have not.

Road asset owners have cited lack of data around wear induced by wide base tyres on spray sealed pavements. It has been near impossible to collect such data in Australia given that wider tyres are a niche product, with only 3% of new tyre sales being wide tyres (of all sizes). Further, road asset owners have indicated that while data exists for many pavements types used overseas, very little data is available for spray sealed roads. Spray sealed roads account for around 80% of road pavement type in Australia.

To address this data shortfall and promote discussions with road asset owners, TIC submitted a proposal to conduct comparison wear testing between dual tyres and wide based tyres on a spray sealed pavement.

The purpose of this project was to use accelerated pavement testing to gauge the effects of heavy vehicle tyre size and configuration on pavement wear. Specifically, an unbound granular pavement with thin bituminous surfacing (sprayed seal). The project aimed to measure any difference between the wear generated by wide single tyres and dual tyres. The outputs of the work were intended to inform road managers and the NHVR in their consideration of load limits imposed on vehicles using wide single tyres in place of dual tyre sets.

The tyre sizes tested in this work were:

- 11R22.5 tyres in dual configuration, as commonly used on Australian heavy vehicles
- 255/70R22.5 tyres in dual configuration, the narrowest commonly used dual tyres
- 385/55R22.5 single tyres (known as 'super singles').
- 445/50R22.5 wide base single tyres (known as 'ultra-wide base single tyres').

Nine identical pavement test sections were constructed at the Accelerated Loading Facility (ALF) testing site in Dandenong South, and nine experiments were conducted using the ALF. Testing included the four tyre configurations listed above, with all configurations tested at two or more inflation pressures. Each single tyre or dual tyre set was loaded to 40 kN of half Standard Axle load and each test site was loaded with a minimum of 52,500 cycles. Pavement deformation, deflection, and surface texture and skid resistance were measured. These readings were taken at a number of points during each test and at the conclusion of testing.

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[1] National Association of Australian State Road Authorities 1976, *Economics of road vehicle limits: evaluation and conclusions*, report R-2, NAASRA, Sydney, NSW.

[2] *Review of Road Vehicle Limits (RoRVL)* for vehicles using Australian Roads (NAASRA 1985; Sharp, Sweatman and Potter 1986)

It was found that the level of pavement wear from all of the tyre configurations tested was similar, although there were some differences that merit attention:

- The rutting in the pavement tested by the dual 11R22.5 tyres was wider and deeper than the rut produced by wide single tyres. However, the difference was small and may be insignificant. Further testing would be required to determine whether this difference in rut depth had any effect on long-term pavement performance.
- The tyre inflation pressures had a significant effect on pavement wear for dual 11R22.5 tyres, but not for the wide single tyres.
- The magnitude of the rutting caused by the 445/50R22.5 tyres was larger than that caused by the 11R22.5 dual tyres and the 385/55R22.5 single tyres.
- The results showed 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.

Project Success

Effectiveness

It is important to note that this report was conducted to facilitate discussion with road asset owners. The study only looked at relative pavement wear between the different tyres and not any specific safety related item. However, as alluded to earlier, the lack of pavement wear data has been a significant impediment on progressing discussions with road asset owners, around relaxing axle mass limits when using wide single tyres.

Removal of this significant barrier to inform discussion has added legitimacy to the discussion between industry and road asset managers.

At this point it is important to recap the safety benefits that the wider adoption of wide tyres will bring, and why it has been important to overcome the above-mentioned reluctance of road asset manages to discuss the topic.

The key safety benefits of using wide single tyres versus dual tyres are:

- Reduced wheel end issues (namely fires).
- Cooler brakes – bringing better brake fade performance when descending steep inclines
- Easier inspection of brake components.
- Single tyre inflation point per wheel end, improving likelihood of operator maintaining correct pressures.
- Improved vehicle stability – wide tyres will allow chassis design options that will lead to the ability to lower the Centre of Gravity (CoG) of the payload, reducing likelihood of roll over.

Detailed explanation of the above safety benefits, with referenced research and data, may be found in Appendix 2, which was the original proposal document TIC submitted.

In the context of the study conducted on pavement wear there were some interesting results.

The worst performing of all tyre configuration is the 255/70R22 dual tyre which is not subject to any mass restrictions on any type of axle.

Testing intended to quantify effects of under or over inflation on wide tyres produced some counter intuitive results. The results were not statistically significant – that is, the differences in pavement wear due to the different pressures were not related. This was consistent with the tyre contact pressure patches, which showed less variation between wide tyres inflated at different pressures (that is maintained a consistent regular rectangular contact area at different pressures). This implies that wide tyres can operate at a wider range of inflation pressure and give very similar pavement wear.

The last finding is particularly interesting as it implies that two safety benefits can be obtained around inflation pressures.

1. Due to the reduction in the number of tyres that needs to be checked, the operator is more likely to maintain the correct tyre pressures.
2. As wide tyres appear to be more tolerant of pressure variations, a lapse in tyre pressure monitoring will be less critical.

Project Evaluation

The initial hypothesis that the project sought to answer was -

…… that pavement wear is no worse for Next Generation Wide Load Base Tyres (NG-WBT) than the industry standard dual 11R22.5 installations at the same loads

The study itself did not conclusively answer this hypothesis, from the results obtained from testing.

Appendix 1 outlines in detail the results and conclusions. However, in summary:

1. Dual tyres did not consistently show worse or better pavement performance compared to wide tyres.
2. The 255/70R22.5 dual tyre showed the worst pavement wear performance of all tyre types
3. The 11R22.5 dual tyres:
    a. Produced marginally less pavement wear than wide tyres when they were inflated at recommend pressure.
    b. that were over, under and unevenly inflated, showed virtually no difference in pavement wear compared to wide tyres.
4. Care had been taken in pavement design and construction to ensure controlled test conditions. This included protection from the elements (the testing was done inside a shed) and protection of substrate moisture ingress. Despite this, the unavoidable variations in test environment, such as the natural variation in the subgrade (that is, road base material) and its construction were a significant factor. This required adjustments to be made in the analysis to compensate for this. However, these adjustments were of a similar magnitude to the differences in tyre wear that were detected. In practice, therefore, environmental factors would have a greater influence on actual real world pavement wear.

Noting other factors from literature review and other findings.

- The NHVR's Operation "Explorer" enforcement activity, conducted in August 2019 undertook to assess inflation pressure in dual tyres axle positions. 456 tyres were tested. In summary the findings were –
    - Only 69% of all tyres could be tested
    - Of the 31% not tested - 97% were mounted on the inside
    - Difference in inflation pressures could only be calculated in 39% of the axle wheel ends
    - Of these, 27% had a difference in inflation pressure of more than 5%

  Consequently, based on these figures, potentially there could be up to 72% of tyres in a dual tyre set that have a miss match in their inflation pressures.

- Dual tyres and single tyres wear different areas of the pavement. Dual tyres traffic a wider transverse path, whilst the wide single tyres traffic a narrower path in the centre of the trafficking lane (an area less trafficked by dual tyres). It is expected that if trafficked over the same pavement section, both dual tyres and wide single tyres would result in a more evenly dispersed lateral wear pattern.

Taking into consideration in service tyre pressures as found by Operation "Explorer" and the effects of environmental factors on the pavement, it is clear that wide base tyres will not have a notable effect on pavement wear compared to dual tyres. Variations in environment, in service tyre condition and pressure will have greater effects than those noted in the report caused by different tyre widths.

Further, encouraging the adoption of super single tyres will likely lead to improved condition monitoring of tyres, as fewer tyres will need monitoring. This will lead to operators being more inclined to regularly check condition of tyres.

Project Management Evaluation

Overall

TIC assumed overall project management role, initially through its previous Technical Officer, Chris Loose and then, on his retirement, Paul Caus.

Anthony Germanchev coordinated the internal work program at NTRO to deliver the report, and authored a significant portion of the final report.

The outbreak of the COVID pandemic was a significant challenge to this project causing considerable delays due to lockdowns in Melbourne (March – May 2020 and July-October 2020) resulting in around 7 months idle time with no physical work possible.

Risk Management

The key risk that became evident during the project was the lack of depth (back up) of staff at NTRO at times. For example, a significant delay was incurred due to absence of one member of staff in early 2023. That staff was the key person in being able to manage and operate the ALF machine. However, at other times unforeseen challenges were dealt with quickly. For example, an accident incapacitated the graduate engineer who was tasked with analysing the raw data from the ALF unit. Another graduate engineer was placed on the task and only a minor delay was incurred.

They key learning here is to ensure a more thorough capability assement prior to project kick off.

Stakeholder Management

Meetings were held approximately every 2 weeks during the project, with additional ad hoc meetings as required. These in general were via web calls.

Testing and report preparation was carried out by the National Transport Research Organisation (NTRO) (formerly Australian Road Research Board). The project manager for NTRO was Anthony Germanchev.

Tyre manufactures Goodyear and Michelin provided significant in-kind support. Further, they actively participated in the regular project meeting providing regular technical support and data. Representative from these organisations were

Thomas Ruessman – Customer Engineer, Goodyear

Darren Wong - Senior Field Engineer, Michelin

NHVR's Chief Engineer, Mr Les Bruzsa, also contributed his technical expertise and was regularly involved in project meetings.

Project Communications

After project completion, a media release was distributed by both TIC and the NHVR receiving wide spared publication in various industry media outlets.

https://www.trucksales.com.au/editorial/details/wide-single-tyres-get-the-green-light-141979/

https://bigrigs.com.au/2023/08/10/research-highlights-benefit-of-super-single-tyres-on-trucks/

https://primemovermag.com.au/tic-calls-for-regulatory-changes-to-allow-super-single-tyres/

The AusRoads Pavement group was briefed on 19th October 2023 and the report distributed for consideration by the group.

A paper was presented at the 2023 Heavy Vehicle Transport Technology 17 (HVTT17) Conference in Brisbane 6—9th November 2023.

Issues

Delays in the project were attributed to the following:

- Immediately prior to the start of this project an Austroads project evaluating wide tyre had been in progress. Flaws in the methodology of that testing necessitated a retest and subsequently led to this HVSI project having a delayed start.
- COVID pandemic lockdowns in Melbourne making monitoring set up and monitoring of test an impossibility. (March – May and July-October 2020)
- Lack of depth in manpower at NTRO caused some delays in early 2023 due to hospitalisation of a key staff member.

Deliverables

A report was prepared by NTRO and is included as Appendix 1.

Project Transition and implementation

TIC will continue to advocate for regulatory reform to facilitate the wider adoption of wider tyres.

TIC will have numerous opportunities to show case the results of the study through our participation in various industry working groups and direct representation to regulators. Including

- Australian Trucking Association – ITC group
- Vehicle Standards Consultation Forum (DITRDCA)

Queensland Transport and Main Roads (QLD TMR) became particularly interested in our methodology and testing program. QLD TMR then subsequently initiated their own test program, however focusing on wide base tyres for steer axles. TIC and TMR signed a memorandum of understanding in December 2022 to share data.

Lessons Learned and Best Practices

Regular schedule web calls provided continuity in the management of the project and allowed the majority of issues to be addressed promptly.

There were a number of unforeseen and unavoidable delays, starting with the long delays in work due to enforced COVID pandemic shut downs. This spread the work over a significant period of time, encroaching on the project that could not be planned for, or were not considered risks under the initial project scope either because they were unforeseen (e.g. the COVID pandemic itself, long illness of key a NTRO staff member) or events that were expected to occur after project completion (e.g. retirement the TIC Technical Officer, Chirs Loose and replaced by the author of this closing report)

The key learning from this is that while a macro event like the COVID pandemic, or a natural disaster cannot be planned for (as likelihood is extremely low), staff issues need to be better managed (or rather, recognised beforehand that there were risks in having key staff members with no back up).

That shortfall was identified towards the end of the project by TIC, leading to an agreement between TIC and the previous TIC Technical Officer, Chris Loose to extend the handover phase to the author into Mr Loose's retirement until the testing phase was completed. This ensured continuity of the project at TIC to ensure that TIC was not the source of delays.

Post Project Recommendations

The final report mentions the following possible areas of further study

1. Test on weaker pavement to confirm results:
2. Counter intuitive result for the effects of inflation pressure wide single tyres requires further investigation as this result does not match other work in this area.
3. The project should be used as the foundation of further discussion with road asset manager, to promote the view that wider use of wide base tyres will not appreciably contribute to added pavement wear compared to dual tyred configurations.

Appendix 1: Final Report

Testing of Next Generation Wide Base Tyres - Pavement Impacts

NTRO Project No.: 016365

Author: Anthony Germanchev, Didier Bodin, Kenneth Lewis, Edward Warner, Danielle Garton

Prepared for: Truck Industry Council

4/09/2023

FINAL

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Version Control

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1	4/09/2023	Anthony Germanchev	Final report

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ARRB Group LTD trading as NTRO – NATIONAL TRANSPORT RESEARCH ORGANISATION

ABN 68 004 620 651

Summary

Wide single and ultrawide single tyres have been available for decades internationally, based on the results of many studies including the COST 334 study, 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 in place of dual tyre configurations has occurred in Europe and the USA. However, there have not been significant studies of the relative performance of sprayed seal unbound granular pavements subjected to ultrawide single tyre with dual tyre loading which is a barrier to the adoption of ultrawide single tyres here.

The purpose of this project was to use accelerated pavement testing to gauge the effects of heavy vehicle tyre size and configuration on pavement wear, specifically an unbound granular pavement with thin bituminous surfacing (sprayed seal), by far the most common sealed pavement type. Specifically, the project aimed to measure any difference between the wear generated by wide single tyres and dual tyres. The outputs of the work were intended to inform road managers and the National Heavy Vehicle Regulator in their consideration of load limits imposed on vehicles using wide single tyres in place of dual tyre sets.

The tyre sizes tested in this work were:

- 11R22.5 tyres in dual configuration, as commonly used on Australian heavy vehicles
- 255/70R22.5 tyres in dual configuration, the narrowest commonly used dual tyres
- 385/55R22.5 single tyres (known as ‘super singles’)
- 445/50R22.5 wide base single tyres (known as ‘ultra-wide base single tyres’).

Nine identical pavement test sections were constructed at the Accelerated Loading Facility (ALF) testing site in Dandenong South, and nine experiments were conducted using the ALF. Testing included the four tyre configurations listed above, with all configurations tested at two or more inflation pressures. Each single tyre or dual tyre set was loaded to 40 kN of half Standard Axle load and each test site was loaded with a minimum of 52,500 cycles. Pavement deformation, deflection, and surface texture and skid resistance were measured at a number of points during each test and at the conclusion of testing.

It was found that the level of pavement wear from all of the tyre configurations tested was similar, although there were some differences that merit attention:

- The rutting in the pavement tested by the dual 11R22.5 tyres was wider and deeper than the rut produced by wide single tyres. However, the difference was small and may be insignificant. Further experimental work would be required to determine whether this difference in rut depth had any effect on long-term pavement performance.
- The tyre inflation pressures had a significant effect on pavement wear for dual 11R22.5 tyres, but not for the wide single tyres.
- The magnitude of the rutting caused by the 445/50R22.5 tyres was larger than that caused by the 11R22.5 dual tyres and the 385/55R22.5 single tyres.
- The results showed 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.

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1. Introduction

The Truck Industry Council (TIC) commissioned the Australian Road Research Board (ARRB) to conduct a full-scale testing program to quantify the relative pavement impacts of next generation wide load base tyres.
The work undertaken by ARRB was part of the TIC-led Heavy Vehicle Safety Initiative (HVSI) project 557: Improving safety of on-road heavy vehicles by increasing axle loadings when fitted with next generation wide load base tyres.

This report documents the work conducted by ARRB, including the design and construction of the test pavement, the testing using ARRB's Accelerated Loading Facility (ALF) and the results and analysis of data collected during the test program.

The TIC promotes the community benefits offered by modern truck technologies, the result being 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 heavy vehicle contacts the road; it is critical to overall safety and pavement wear. As new tyre technology, models and sizes are released into the market, the 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 heavy vehicles travelling on roads are:

- single tyre
- dual tyre
- wide base single tyre
- next generation ultra-wide-base tyre (NG-WBT).

Within these four tyre types there are a range of sizes available. The most common single tyre is the 295/80R22.5, which is 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.

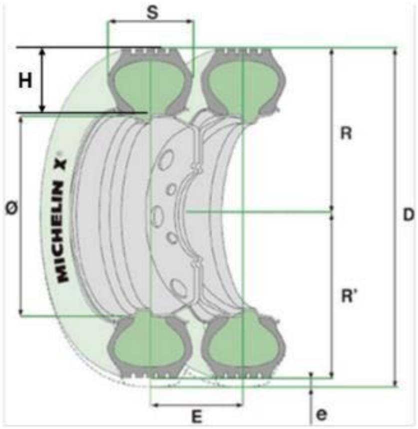
Consultation with the Australian tyre industry indicated that the most common tyre assembly is the dual 11R22.5, which makes up over 50% of total tyre sales. It is also one of the oldest tyre designs available in the Australian market. Dual tyre assemblies also include narrow section widths such as the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

1.1 Background

1.1.1 Tyre marking explained

Tyre markings and nomenclature are shown in Figure 1.1. The example shown is a Michelin tyre, but the nomenclature is consistent across all brands. The important dimension, and focus of this test program, was the nominal section width. The nominal section width, in millimetres, of a radial ply tyre is marked on the tyre, labelled S in Figure 1.1.

Figure 1.1 Tyre markings for a typical truck tyre

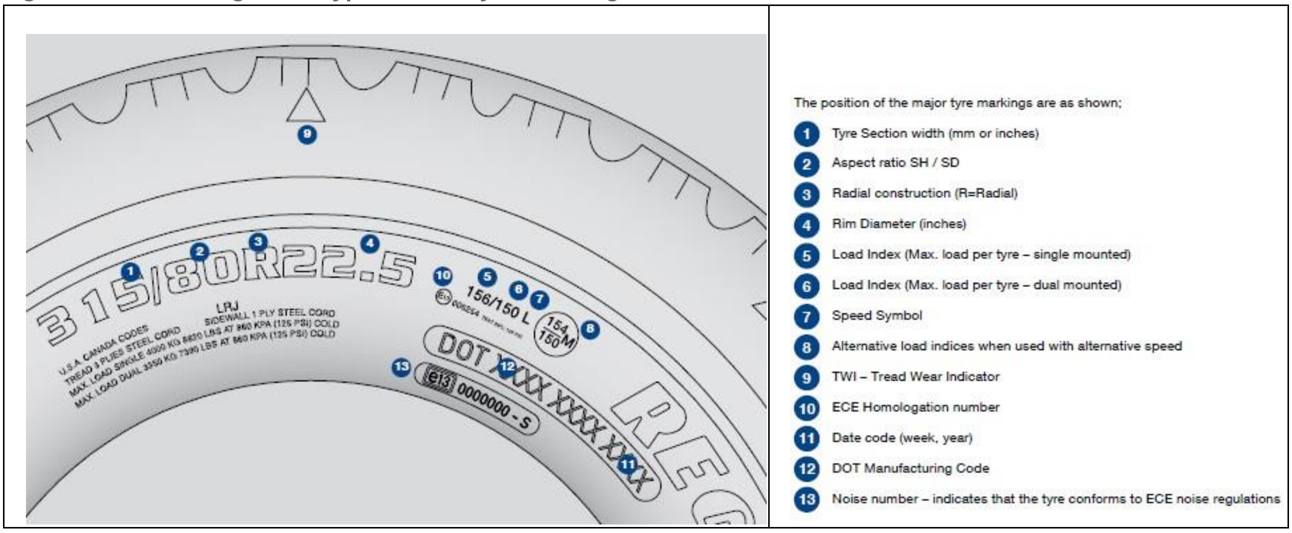


295	Nominal section width in mm (S = 295 mm)
80	Tyre aspect ratio (H/S = 0.80)
R	(Radial construction) Note: R and R' in the diagram do not refer to radial construction, but to nominal radius (R) and rolling radius (R')
22.5	Nominal diameter of the rim (22.5 inches)

Source: Michelin, through personal communication.

Figure 1.2 shows an example of tyre markings. The first number '315' is the nominal section width, in millimetres, of the tyre. It defines the distance between the inner and outer sidewall of the tyre. For example, 315 means that the tyre is nominally 315 mm wide (measurement 'S' in Figure 1.1). The second number (80) is the relationship between a tyre's sidewall height and the width. It is expressed as a percentage. For example, '80' indicates that the sidewall height, between the top of the tread and the rim, is 80% of the tyre width. The R refers to radial, which is how the tyre is constructed. Radial is the standard construction method for almost all on-road tyres: it refers to the geometric layout of the plies that make up the tyre carcass. The third number (22.5) is the wheel diameter in inches. In this example the tyre size indicates that the tyre is designed to be mounted on a 22.5-inch diameter wheel. This method of marking applies to the 445/50R22.5, 385/55R22.5, and 255/70R22.5 tyres.

Figure 1.2 Markings for a typical truck tyre showing sectional width



Source: Goodyear (2020).

As discussed in Section 1.1, the 11R22.5 is an older tyre size where the 11 indicates the section width in inches (or 279 mm). An image of an 11R22.5 tyre is shown in Figure 1.3. Despite being an older size, it remains one of Australia's most common tyre sizes on trailers and drive axles. The 11R22.5 tyre has a standard aspect ratio of 90% by default, which means that the tyre's sidewall width is 90% of the tread's width. If expressed in the newer nomenclature, an 11R22.5 tyre could be called a 280/90R22.5, with the 279 mm rounded up to the nearest 5 mm.

Figure 1.3 Tyre markings for an 11R22.5 truck tyre

Dual tyres are traditionally used on trailer axles and drive axles. The reason for this is historic; the bias-ply tyres used in the past – before the invention of radial-ply tyres – were not capable of carrying heavy loads when used as single tyres. Instead, they were fitted as dual-tyre assemblies to provide the necessary load carrying capacity. The wide base and next generation ultra-wide load base single tyres only require a single tyre to carry the same loads as a dual assembly. The improved design of next generation ultra-wide base tyres with section widths of 445 mm and 455 mm includes low section ratios to increase stiffness and provide a more uniform contact pressure distribution.

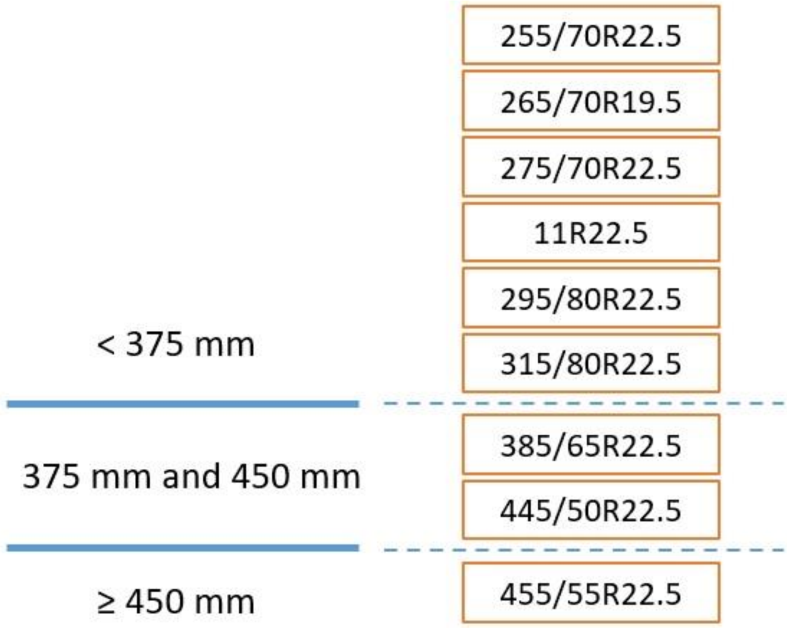
Current regulations for axle group limits are based on the section width of the tyre. The regulations are based on three intervals, which do not sufficiently categorise the range of sizes available within the market. The section width intervals are:

- less than 375 mm,
- between 375 mm and less and 450 mm

- greater than 450 mm.

Figure 1.4 shows these section width intervals alongside common tyre sizes available on the Australian market.

Figure 1.4 Axle (single) group regulations based on tyre section width compared with common tyre sizes

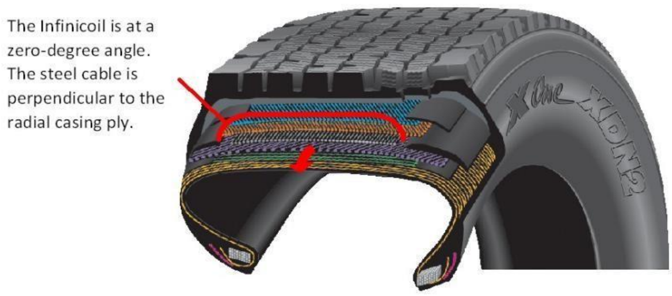


To ensure heavy vehicle regulations align with modern tyre technology, it is necessary to gain a better understanding of the contribution these modern tyres make to pavement wear. This is achieved by comparing the results of accelerated pavement testing of common dual tyre assemblies with those of wide and ultra-wide load base single tyres.

1.1.2 Ultra-wide tyre construction

Ultra-wide tyres require a unique construction to ensure they produce a uniform contact pressure on the pavement surface. This supports the centre of the tread to limit the vertical deflection of the tyre. The major tyre manufacturers employ different technologies to achieve this function. For example, Michelin utilise their patented Infinicoil technology, which is an additional steel belt that features a single steel cable wrapped around the circumference of the tyre in a zero-degree angle, as shown in Figure 1.5. The additional belt eliminates casing growth (deflection) and maintains a consistent tyre footprint. As the cable is wrapped around the circumference of the tyre and under tension, the tyre's tread area is constrained in the radial direction.

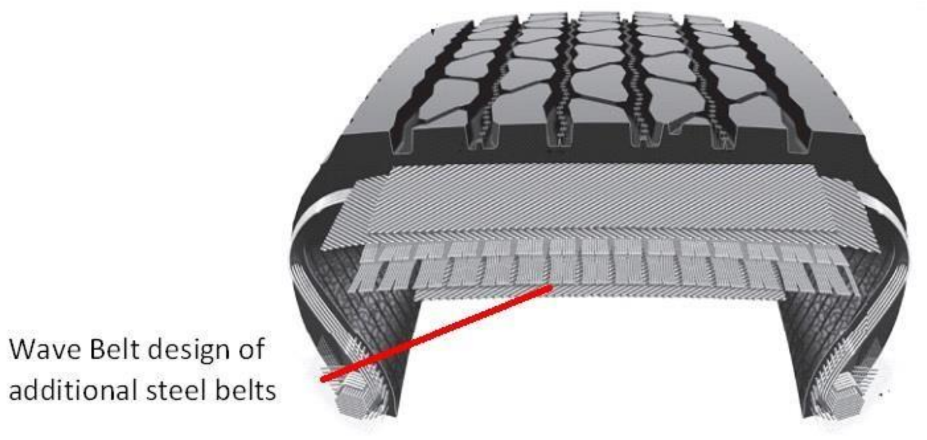
Figure 1.5 Tyre construction with Michelin Infinicoil



Source: Michelin, through personal communication.

An alternative method utilised to achieve the function of producing uniform contact area is provided in Figure 1.6.

Figure 1.6 Alternative ultra-wide constriction



Source: Adapted from Bridgestone (2020).

1.2 Scope

The aim of this project was to quantify the relative pavement wear of the following tyres:

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

A test program was prepared using the Accelerated Loading Facility (ALF), located in Dandenong in Melbourne. The ALF rolls a loaded vehicle wheel repeatedly over a section of specimen pavement, to enable measurement of the effects of repeated vertical loading on pavement response and performance. The test program included nine discrete experiments, each conducted on individual pavement sections. The test program was developed in consultation with the tyre industry, operators and the NHVR to ensure the appropriate vertical load and inflation pressure for each tyre, covering a range of likely on-road performance scenarios.

The project involved four stages:

Stage 1 – Planning and Review

During the first stage of the project the tyres were selected, and the test program was developed. This process considered previous research conducted in Australia (Austroads 2008) and overseas (European Commission Directorate General Transport 2001) and primarily focused on unbound granular pavement performance. The background and planning work completed during Stage 1 is described in Section 2.

Stage 2 – Pavement design and construction

Stage 2 involved the design of the pavement, in consultation with the Austroads Pavements Task Force. ARRB proposed an original pavement design, and this was revised after recommendations from the Task Force. During this stage, three lanes at the test facility were excavated back to the cement-treated base layer and sealed from moisture infiltration. The test pavements, consisting of a granular base and a sprayed seal surfacing, were then constructed. A full description of the work completed during Stage 2 is provided in Sections 3 and 4.

Stage 3 – Testing program: trafficking of the test pavement

The trafficking of the pavement test sections was completed during Stage 3 of the project. The tasks completed in Stage 3 included the following:

- Trafficking of the nine test sections for a minimum of 50,000 load cycles for each tyre type under in-doors testing condition to limit the impact of varying climatic conditions.
- Measurement of pavement profiles using the transverse profilometer at intervals of 0.5 metres along each test section before and after trafficking.
- Deflection testing using the Falling Weight Deflectometer (FWD) at various stages during trafficking.
- Friction testing with a British Portable Pendulum skid resistance tester at 1.0 metre intervals along each test section prior to and after trafficking.
- Texture measurements (sand patch method) at 1.0 metre intervals along each test section prior to and after trafficking.

Stage 4 – Data analysis and reporting

The final stage of the project was the analysis of data and the preparation of a report outlining the relative pavement wear using the following metrics:

- pavement deformation
- pavement strength (deflection)
- surface friction.

1.3 Format of Report

This report provides a summary of all work completed as part of this project. It comprises the following sections:

- Motivation and benefits (Section 2).
- Pavement design and construction (Sections 3 and 4).
- Experiment monitoring and measurements (Sections 5 and 6).
- Tyre contact pressures and test program (Sections 6.4 and 7).
- Results and analysis (Section 8).
- Discussion (Section 9).
- Conclusions (Section 10).

2. Motivation and benefits

The tyres most commonly utilised on Australian heavy vehicles are one of the oldest design of tyre available in the Australian market. The range of tyres available on the market is changing, with improvements seeing the development of wide single tyres. Regulation has not changed along with the developments in tyre technology, such as the addition of ultra-wide base tyres. This report describes research work that was an industry initiative, aiming to benchmark the impact of wide base tyres against the current industry standard tyres. This work is 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 host of different roles and positions from the trailer axles and driving axles to the steering axle. 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 tyres fitted onto heavy vehicles have different widths, inflation pressures and load-carrying characteristics. The main tyre types are:

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

The decision to use ultra-wide base tyres instead of dual tyres would usually involve consideration of a number of 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.

2.1 Current Legislation

The Heavy Vehicle National Law (HVNL) and regulations apply to all vehicles with a Gross Vehicle Mass (GVM) over 4.5 t, and define the axle group mass limits. The HVNL commenced in the Australian Capital Territory, New South Wales, Queensland, South Australia, Tasmania and Victoria on 10 February 2014. The Northern Territory and Western Australia apply their own heavy vehicle mass and dimension regulations, including exemption notices and permits.

2.1.1 Heavy Vehicle National Regulation

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The prescribed dimension requirements for heavy vehicles are set out under the Heavy Vehicle (Mass, Dimension and Loading) National Regulation 2013 (the Regulation) as outlined in Figure 2.1, Figure 2.2 and Figure 2.3.

Figure 2.1 Heavy vehicle national regulations, axle tables (single axles)

Description of single axle or axle group	Mass limit (t)
Single axles and single axle groups	
Steer axles on—	
(a) a complying bus that is not an eligible 2-axle bus or an eligible 3-axle bus	6.5
(aa) a complying steer axle vehicle	6.5
(b) a hauling unit or prime mover forming part of a road train fitted with tyres with section widths of—	
(i) at least 295mm	6.5
(ii) at least 375mm	7.1
(ba) an eligible 2-axle bus	7.0
(bb) an eligible 3-axle bus	6.5
(c) another motor vehicle	6.0
Single axle or single axle group fitted with single tyres with section widths of—	
(a) less than 375mm	6.0
(b) at least 375mm but less than 450mm	6.7
(c) at least 450mm	7.0
Single axle or single axle group fitted with dual tyres on—	
(a) a pig trailer	8.5

Figure 2.2 Heavy vehicle national regulations, axle tables (tandem axle group)

Description of single axle or axle group	Mass limit (t)
(b) a complying bus, or a bus authorised to carry standing passengers under an Australian road law, that is not an eligible 2-axle bus	10.0
(c) an ultra-low floor bus with no axle groups and only 2 single axles that is not an eligible 2-axle bus	11.0
(ca) an eligible 2-axle bus	12.0
(d) another vehicle	9.0
Tandem axle group	
Tandem axle group fitted with single tyres with section widths of—	
(a) less than 375mm	11.0
(b) at least 375mm but less than 450mm	13.3
(c) at least 450mm	14.0
Tandem axle group fitted with single tyres on 1 axle and dual tyres on the other axle on—	
(a) a complying bus that is not an eligible 3-axle bus	14.0
(ab) an eligible 3-axle bus with tyres on the axle fitted with single tyres that have a section width of at least 295mm	15.5
(b) another motor vehicle	13.0
Tandem axle group fitted with dual tyres on—	
(a) a pig trailer	15.0
(b) another vehicle	16.5
Twinsteer axle groups	
Twinsteer axle group without a load-sharing suspension system	10.0
Twinsteer axle group with a load-sharing suspension system	11.0

Figure 2.3 Heavy vehicle national regulations, axle tables (tri-axle and quad axle groups)

Description of single axle or axle group	Mass limit (t)
Tri-axle groups	
Tri-axle group on a vehicle fitted with— (a) single tyres with section widths of less than 375mm on all axles; or (b) single tyres with section widths of less than 375mm on some axles and dual tyres on the other axles	15.0
Tri-axle group on a pig trailer fitted with— (a) single tyres with section widths of at least 375mm on all axles; or (b) dual tyres on all axles; or (c) single tyres with section widths of at least 375mm on some axles and dual tyres on the other axles	18.0
Tri-axle group on a vehicle other than a pig trailer fitted with— (a) single tyres with section widths of at least 375mm on all axles; or (b) dual tyres on all axles; or (c) single tyres with section widths of at least 375mm on some axles and dual tyres on the other axles	20.0
Quad-axle groups	
Quad-axle group fitted with single tyres with section widths of less than 375mm	15.0
Quad-axle group fitted with single tyres with section widths of at least 375mm or dual tyres	20.0
Axle groups of 5 or more	
Rear group of 5 or more axles on a low loader fitted with single tyres with section widths of less than 375mm	15.0
Any other rear group of 5 or more axles on a low loader	20.0

As shown in Table 2.1, the regulation requires that, until there are three or more axles in a group, wide and ultra-wide single tyres cannot be loaded as heavily as dual tyre sets on tandem groups and are not eligible for higher mass limits (HML). In addition, Vehicle Standards Bulletin 11 (VSB11) states that a road-friendly suspension (RFS) must be fitted with dual tyres. This prevents axles with single tyres from being certified as RFS, and subsequently excludes an axle fitted with single tyres from operating at HML.

Table 2.1: Summary of general mass limits (GML) based on section width

Axle group	Single tyre (t)			Dual tyre (t)
	Width <375 mm	Width >375 mm & <450 mm	Width >450 mm	All widths
Single	6	6.7	7	9
Tandem	11	13.3	14	16.5
Tandem (HML)	11	13.3	14	17
Tri-axle	15	20	20	20
Tri-axle (HML)	15	20	20	22.5
Quad-axle[1]	15	20	20	20
Quad-axle (HML)[1]	15	20	20	27

Note: Pig trailers have a reduced allowable mass.

1. PBS vehicles only.

Source: Based on the Heavy Vehicle (Mass, Dimension and Loading) National Regulation 2013 (the Regulation).

A better understanding of the relationship between tyre section width and pavement wear will allow for an informed decision to be made regarding axle group limits. Appropriately set axle group limits will encourage the uptake of next generation tyres, resulting a shift towards tyres that are fit for purpose, and offer safety and economic benefits to the operators.

2.1.2 Impacts of dual tyres and wide-base tyres

This section outlines legislation relating to different tyre types, including the impact that tyre pressure has on the load imposed on the pavement, the stability of the heavy vehicle, induced pavement wear, and local and international uptake.

Tyre pressure management

The use of appropriately inflated tyres is critical for load-carrying capability. Tyres play a key role as part of a vehicle's suspension system, ensuring that: braking forces are transferred to the road, steering and handling systems can provide optimum control, and the vehicle's impact on the road infrastructure is moderated generally. Notwithstanding this, it is noted that the *National Heavy Vehicle Inspection Manual* (NHVR 2021) contains no direct reference to tyre pressure as a reason for a vehicle being considered as unroadworthy.

At present, the main area of concern with ultra-wide base tyres is their smaller footprint and narrower width compared to the current industry standard of dual 11R22.5 tyres. Figure 2.3 shows the difference in width compared to three other tyre configurations. The footprint area, rated load and rated pressure for the tyres under examination are provided in Table 2.2.

The smaller footprint of the ultra-wide tyres is likely to result in an increased vertical force being applied to the pavement, leading to increased pavement wear compared with the dual 11R22.5 tyres. Previous testing has assumed that all of the tyres on a dual-tyred axle are evenly inflated, but field experience has shown this not to be the case. Through personal communication with NHVR, it was identified that the NHVR found through its enforcement activity that only 69% of the inflation pressures of dual tyres was able to be measured. Of the remainder (i.e. those without measured pressures), the overwhelming majority were located on the inner wheel position. The difference in inflation pressures between the inner and outer tyres of the dual set differed by more than 5% in over a quarter of the tyres measured (27%). This imbalance of inflation pressures within a dual tyre set was not included in historical assessments of pavement wear and safety impacts. Having only a single inflation valve per axle-end, single tyres are not susceptible to this differential pressure issue. In addition to identifying the imbalance between inner and outer tyre inflation pressures, the enforcement activity also found that every tyre in an 11R22.5 dual set was over-inflated. The recommended inflation pressure for a tyre in an 11R22.5 dual set tri-axle group is 76 psi (524 kPa). However it was found that tyre pressures were often in excess 100 psi (689 kPa), with the lowest recorded pressure being 84 psi (579 kPa).

Figure 2.4 Illustrative comparison of shape and size of tyre footprints

Source: Michelin, through personal communication.

Table 2.2: Summary of tyre specification

Tyre sizes	Tyre model	Footprint area (mm²)	Relative difference (%)	Rated load – single (kg)	Rated load – dual (kg)	Rated Pressure (kPa)
11R22.5	SP160	183600		3150	2900	850
255/70R22.5	SP160	118400	–36%	2500	2300	800
445/50R22.5	X One Multi Energy T	121200	–34%	4625	–	825
385/55R22.5	X Line Energy F	116200	–37%	4500	–	900

Note: The footprint for 11R22.5 and 255/70R22.5 are provided as dual configuration.

Source: Based on consultation with tyre suppliers (Michelin and Goodyear Dunlop).

There is a need for updated research into the effects of tyre pressure, tyre size and configuration on pavement wear. The work compared the pavement wear for ultra-wide and dual tyre configuration, based on real-world inflation pressures, in order to obtain a better understanding of whether pavement wear is no worse, on average, than the current industry standard dual 11R22.5-wheel end set.

Vehicle Stability

The Australian Design Rules (ADRs) have implemented the requirement for vehicles built after 1 January 2022 to have stability control technology, as defined under ADR35/06. The ADR is not applied retrospectively, which typically means that the technology for stability control under the ADR is not able to be retrofitted to trucks. As such, it will take a number of years for the technology to fully saturate the market. Other means of improving vehicle stability – without the need to purchase a new truck fitted with stability control – will help to reduce the number of rollovers. One such measure would be the use of ultra-wide base tyres, which are able to provide an improvement in a vehicle stability.

Pavement Wear

The current legislation for tyre impact on pavement wear is founded on historical research, including:

- *Economics of Road Vehicle Limits (ERVL)* (NAASRA 1976)
- *Review of Road Vehicle Limits (RoRVL)* for vehicles using Australian Roads (NAASRA 1985; Sharp, Sweatman and Potter 1986)
- An investigation of axle load equivalencies and the relative damaging effect of wide single and dual tyres on granular pavements (Yeo & Sharp 2006)
- Axle load equivalencies and the effect of wide single and dual tyres on the performance of granular pavements (Yeo & Sharp 2007)
- *Relative pavement wear of an unbound granular pavement due to dual tyres and single tyres* (Austroads 2008)

There is a need to re-evaluate the effects of heavy vehicle wheel loads on pavement wear – in particular ultra-wide base tyres – in light of technological improvements to tyre construction since those studies were conducted.

Tyre Width

The axle load limits in Table 2.1 show that there is no minimum width required for tyres of single or dual configuration. This means that, while 11R22.5 is the industry standard, narrower tyres may be utilised and may generate larger pavement impacts, and thus should be considered in the Regulation. Similarly for the single tyres, for which there is no minimum width of tyre that may be utilised.

2.2 International Uptake

A review was conducted of the international uptake of wide and ultra-wide tyres, to estimate the potential popularity of such tyres when their use is not constrained by mass restrictions.

The main markets for ultra-wide base (445 mm wide and above) tyres are North America and Canada. Based on United States Tire Manufacturers Association (USTMA) and Tire and Rubber Association of Canada (TRAC) data, the ultra-wide base tyre has a consistent market share representing 1.4% of the total market. The size of the market in North America and Canada, based on the position of the tyre, is shown in Table 2.3.

Table 2.3: Market share for tyres in North America and Canada

Tyre position	2017	2018	2019	2020	2021
Steer	12,963,397	14,275,275	12,657,525	12,256,202	14,878,035
Drive	9,267,592	10,619,628	9,761,532	8,925,421	10,849,756
Trailer	4,984,372	5,487,247	5,009,745	4,481,287	5,313,727
Total mark size	**27,215,361**	**30,382,150**	**27,428,802**	**25,662,910**	**31,041,518**
Market size drive and trailer	**14,251,964**	**16,106,875**	**14,771,277**	**13,406,708**	**16,163,483**

Notes: The market share for drive and trailer is considered due to ultra-wide single tyres not being able to be fit in steer position. Source: Provided by tyre industry, adapted from USTMA and TRAC data.

The actual sales of the ultra-wide tyres in North America and Canada, along with the percentage of the relevant market share, are shown in Table 2.4. In terms of ultra-wide tyres applicable for drive and trailer positions, they represent 3% of new tyre sales. While ultra-wide tyres represent 3% of new tyre sales, it is noted that every ultra-wide tyre is the equivalent of two tyres required for dual configurations, so the effective share of the market is in the order of 6%.

Table 2.4: Ultra-wide market sales in North America and Canada

Tyre Size	2017	2018	2019	2020	2021
445/50R22.5	320,543 (2.2%)	346,643 (2.1%)	308,532 (2.1%)	296,865 (2.2%)	323,497 (2.0%)
445/55R22.5	56,157 (0.4%)	60,722 (0.4%)	54,555 (0.4%)	55,651 (0.4%)	53,177 (0.3%)
455/55R22.5	56,764 (0.4%)	62,887 (0.4%)	53,286 (0.3%)	51,709 (0.4%)	60,638 (0.4%)
Total market size (drive and trailer)	**14,251,964**	**16,106,875**	**14,771,277**	**13,406,708**	**16,163,483**

Source: Provided by tyre industry, adapted from USTMA and TRAC data.

The European market for wide base tyres is in the order of 32% of truck tyre sales in Europe as shown in Table 2.5. Of the wide tyres shown, both the 385/55R22.5 and 385/65R22.5 tyres sizes can be fitted to steer and trailer axles on vehicles, with the majority fitted on trailer axles.

Table 2.5: Wide market sales in Europe

Tyre Size	2015	2016	2017	2018	2019	2020	2021
385/55R22.5	480,555 (3.2%)	552,810 (3.4%)	587,770 (3.7%)	557,216 (3.5%)	689,048 (4.3%)	748,814 (4.8%)	909,453 (5.2%)
385/65R22.5	3,800,068 (25.1%)	4,080,569 (25.4%)	3,590,549 (22.4%)	3,129,949 (19.8%)	4,091,639 (25.8%)	4,167,434 (26.8)	4,712,051 (26.8%)
Total market size	**15,118,663**	**16,072,981**	**16,063,224**	**15,793,246**	**15,845,122**	**15,556,565**	**17,580,537**

Source: Provided by tyre industry, adapted from European Tyre & Rubber Manufacturers Association data.

3. Pavement Design

The project sought to understand the impact of wide base tyres on typical sprayed seal granular pavements. To assess this impact, pavement deformation was measured under accelerated loading for the range of test conditions considered. To ensure that the pavement design was representative of the road environment nationally, it was designed in consultation with the Austroads Pavement Task Force.

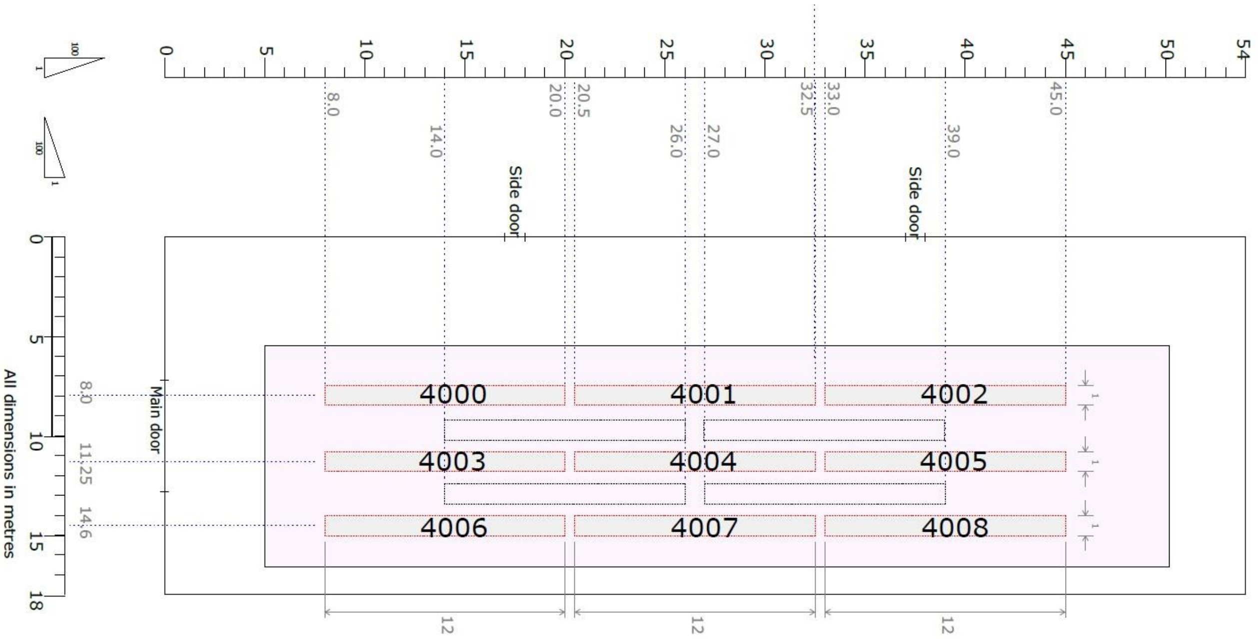
Three test pavements were constructed within the indoor site at ARRB's Accelerated Loading Facility (ALF) (Figure 3.1).

Figure 3.1 ARRB's indoor ALF site

3.1 Pavement Layout & Pavement Composition

The trial methodology used was based on the deformation of identical test pavements, in terms of materials and cross-section, 12.0 m in length and subjected to loading under different tyre configurations. To accommodate the number of intended loading configurations, the three main test lanes were designed to be 40 m long and 3.5 m wide, with each divided into three test pavements, or experiment sections (Figure 3.2). There was a provision made for four extra test sites between the main three lanes for additional testing.

Figure 3.2 Pavement layout (Experiments 4000 to 4008)

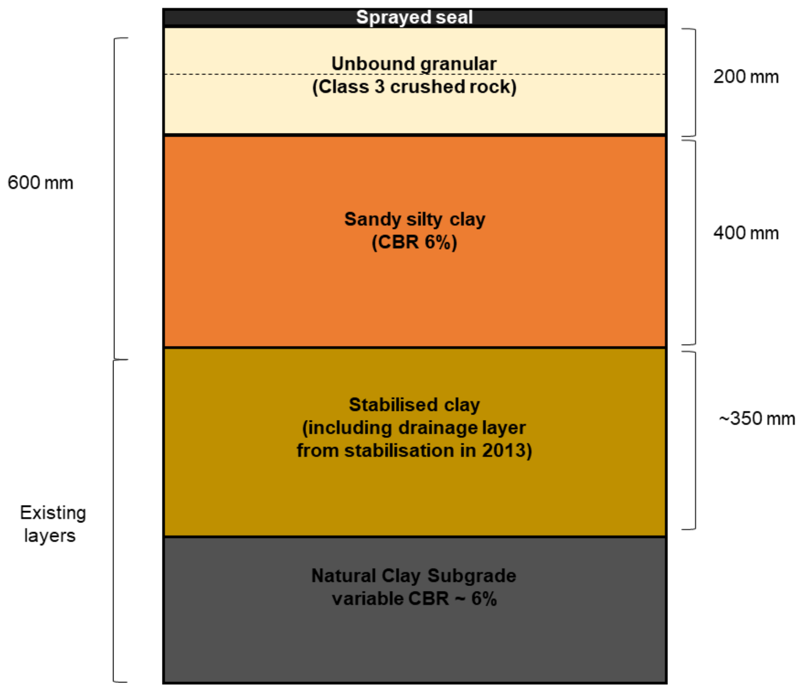


To ensure that useable results were obtained, the design of the test pavement was to be:

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

Accordingly, the test pavement selected was a granular pavement constructed on the pre-existing subgrade located within ALF's indoor test site. To minimise external influences (i.e. water ingress) on the test pavement, the pavement was also constructed within sub-surface concrete walls, designed to allow for drainage. The structural configuration of the test pavement is depicted in Figure 3.3, with the materials selected for the seal, basecourse, and subbase layers described in Section 3.2.

Figure 3.3 Cross-section of test pavement



Note: the existing "drainage layer from stabilisation in 2013" is a pre-existing material from a past ALF project – Austroads (2017b).

3.2 Materials Selection

Details of the selected pavement layer materials is given in Table 3.1. Detailed material descriptions are provided in the following subsections (Section 3.2.1 to Section 3.2.4).

Table 3.1: 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 2017a)
Subgrade	–	Natural subgrade

3.2.1 Pre-existing subgrade and stabilised clay

The natural subgrade and stabilised clay layer materials had been previously used at the site (Austroads 2014). Both were a typical Melbourne Silurian clay with a nominal dry CBR of 8-10% and a soaked CBR of approximately 3%. Whilst 350 mm of the clay had been cement stabilised, the material properties of the (unstablised) Silurian clay had previously been reported by Moffatt et al. (1997), and the results are presented in Table 3.2.

Table 3.2: Properties of Silurian clay

Property	Value
Plasticity Index	4-5%
Liquid Limit	16%
Linear Shrinkage	1-3%
Maximum Dry Density	2.08 t/m^3 (standard compaction)
Optimum Moisture Content	8.6% (standard compaction)
Unsoaked CBR	10%
Soaked CBR	3%

Source: Moffatt et al. (1997).

The bearing capacity of these lower layers was not re-measured for this project, with the natural subgrade assumed to have a CBR of approximately 6% (based on the historical information provided in Austroads 2014). The bearing capacity of the stabilised clay layer was not available, although historical information indicated it to be a very stiff layer (Austroads 2014).

3.2.2 Imported sandy silty clay subgrade

To help ensure that the test pavements would experience a meaningful level of deformation during the accelerated loading, it was necessary to source a subgrade that would be strong enough to avoid immediate pavement failure, but also soft enough to allow deformation to occur within the allotted number of loading cycles.

As such, and based on the similar trial conducted previously by Austroads (2006), a target CBR of approximately 10% was selected as a suitable strength level for this layer, with a layer thickness of 200 mm. However, due to difficulties in sourcing a material for the subgrade with a CBR similar to this target, it was agreed to utilise a locally sourced material with a lower CBR and adjust the granular base thickness to reinstate sufficient pavement strength, if required.

The locally-sourced subgrade material identified and selected for imported subgrade placement was classified as a sandy silty clay with an unsoaked CBR of 6% and a soaked CBR of 3-5%. With this lower CBR value, an increased target layer thickness of 300 mm was considered, but given the aims and timeframe of the project and after consulting with the Austroads Pavement Task Force it was agreed that maintaining the 200 mm subbase layer thickness was most appropriate.

A summary of the properties of the imported subgrade layer are presented in Table 3.3.

Table 3.3: Summary of key properties of imported subgrade material

Property	Value	Test Method
Moisture content (%)	15.69	Nuclear density meter (NDM) testing in accordance with AS 1289 1.1, – 1.2.1(6.4), 2.1.1, 5.7.1, & 5.8.1
Field dry density (t/m³)	1.80	
Estimated CBR (%) for stabilised clay layer[1]	9.46	Dynamic Cone Penetrometer (DCP) testing in accordance with AS 1289 6.3.2
Estimated CBR (%) for natural clay layer[2]	22.53	
Estimated Modulus (MPa) for stabilised clay layer	94.6	Calculated as per equation 2 in Austroads (2017b)[3]
Estimated modulus (MPa) for natural clay layer	150[4]	

1 *This CBR is estimated from the average CBR calculated for the DCP results above a depth of 350 mm.*
2 *This CBR is estimated from the average CBR calculated for the DCP results at, and below, a depth of 350 mm.*
3 *Estimated Modulus: Modulus (MPa) = 10 x CBR (as per equation 2 in Austroads 2017b), calculated using the respective CBR value for stabilized clay of natural clay layer.*
4 *This modulus value has been limited to a maximum of 150 MPa as per the guidance in Austroads (2017b).*

In terms of the uniformity of the subgrade, the variation in moisture content, field dry density, and FWD deflection across the pavement area was assessed to determine the most appropriate offsets to locate the experimental lanes.

3.2.3 Unbound granular basecourse

Haulage costs, including the distance between source quarries and the ALF site, was a factor in selecting the basecourse material for the project. Based on previous experience, several quarry sources available within 30 minutes of the site were considered. The critical consideration for the selected material was whether the aggregate was both representative of the Australian network, and whether it would suitably deform within the specified loading period for the project.

Taking into account both of these factors, and previous experience, the source material for the granular basecourse was selected to be a good quality, 20 mm, Class 3, Hornfels crushed rock from Boral's Lysterfield quarry, located 20 minutes from the ALF site. A Class 3 crushed rock is high quality upper subbase material suitable for heavy duty unbound granular pavements. It may also be used as a base layer for lightly-trafficked roads.

The key properties, including optimum moisture content (OMC) and maximum dry density (MDD), of this material are provided in Table 3.4, the particle size distribution (PSD) is listed in Table 3.5, whilst the grading curve is shown in Figure 3.4.

Table 3.4: Summary of key properties of the selected basecourse material (20 mm class 3 crushed rock)

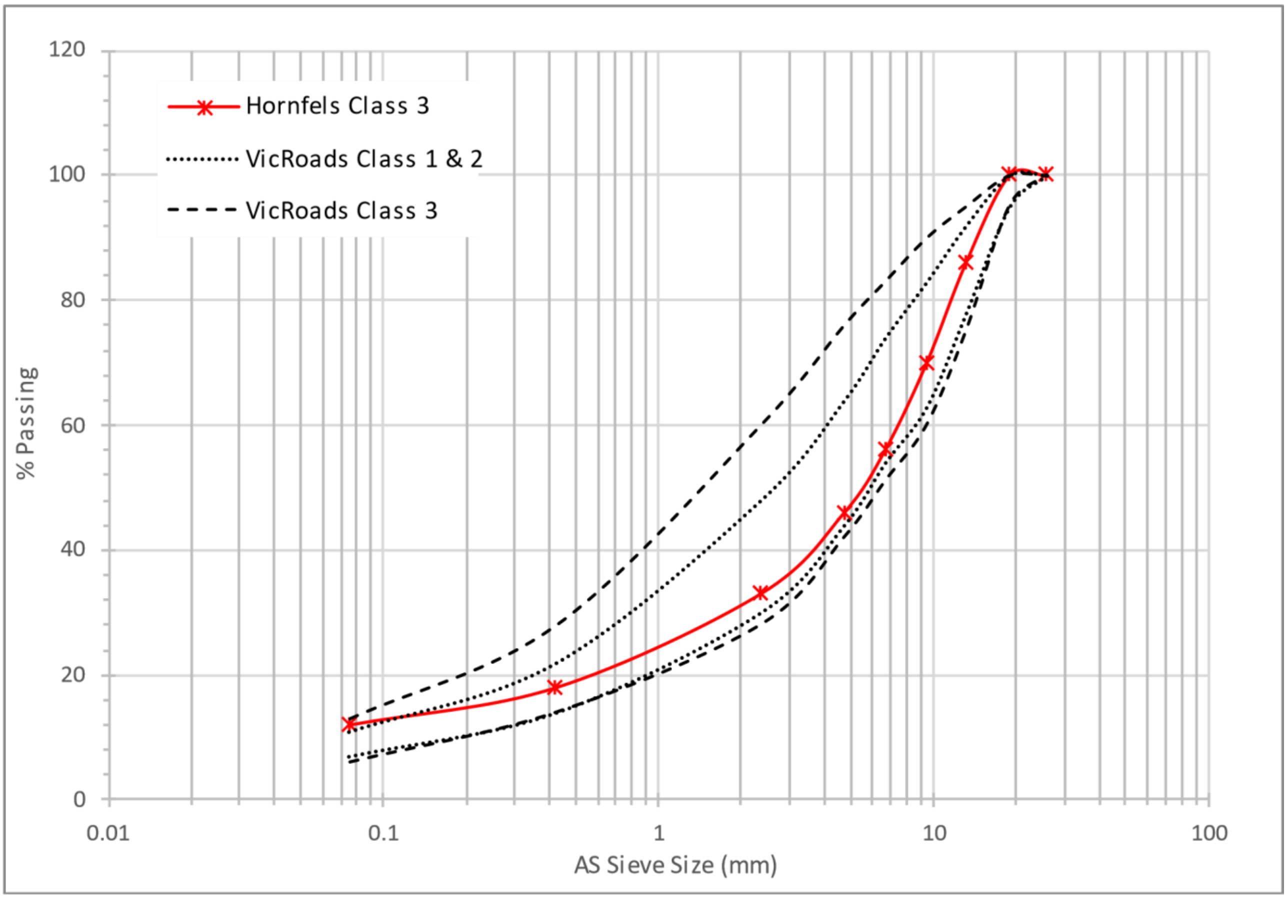
Property	Value[1]	Requirement[2]	Test Method
Modified OMC (%)	5.5	–	AS 1289.5.2.1
Modified MDD (t/m³)	2.33	–	AS 1289.5.2.1
Liquid Limit (%)	23	Max. 35	AS 1289.3.1.1
Plastic Limit (%)	15	–	AS 1289.3.2.1
Plasticity Index (PI)	8	Max. 10	AS 1289.3.3.1
Permeability (m/s)	3×10^{-8}	–	AS 1289.6.7.2
Unsound particles (%)	3	Max. 10	AS 1141.30.1
Marginal & unsound particles (%)	5	Max. 20	AS 1141.30.1

1 As provided by the supplier.
2 The provided requirements are given as examples for material conformance, and have been sourced from the requirements specified by VicRoads (2013).

Table 3.5: PSD of granular basecourse (20 mm Class 3 crushed rock)

AS Sieve (mm)	% Passing	VicRoads (2017) Requirement (Class 3)	
		Lower limit	Upper Limit
26.0	100	100	100
19.0	100	95	100
13.2	86	75	95
9.5	70	60	90
6.7	56	–	–
4.75	46	42	76
2.36	33	28	60
0.425	18	14	28
0.075	12	6	13

Figure 3.4 PSD (Grading curve) for granular basecourse (Hornfels 20 mm Class 3 crushed rock)



Specification reference: VicRoads (2013) & VicRoads (2017).

3.2.4 Prime and sprayed seal

Primer selection

To ensure a successful application of the sprayed seal to the basecourse, a primer seal was applied before the sprayed seal was laid. For this project, an emulsion prime from Primal was selected. The primer was first trialled in small patches to determine an appropriate application rate, as shown in Figure 3.5. This trial indicated that an application rate of 1.0 L/m^2 was optimal.

Figure 3.5 Primer trial patches

Note: Trial patches are annotated with the sprayer application rate (noted above each patch, in L/m^2).

Spray sealing

The sprayed seal was chosen to reflect that which is typically used on the Australian road network and would have a high level of performance (i.e. not show distress over the course of the experiments, which were focused on the performance of the granular layers and not on the of the seal). As such, the selected spray seal was a 10/5 double/double with a high bitumen content emulsion (HBCE) to provide a smooth and robust thin surfacing suitable for accelerated pavement testing, due to the ease of measuring surface.

The emulsion was a Class A 10 mm aggregate from Western Quarries, whilst the aggregate was a Class A 5 mm aggregate from Mawsons Concrete & Quarries which conformed to VicRoads (2021). The following application rates were adopted:

- First seal binder application rate: 0.80 L/m^3
- First seal aggregate spread rate: 140 m^2/m^3
- Second seal binder application rate: 0.50 L/m^3
- Second seal aggregate spread rate: 225 m^2/m^3

4. Pavement Construction

Construction, including site preparation, commenced in February 2021 and was completed mid-September 2021. The preparation and construction of the test site was managed by ARRB.

4.1 Key Considerations

4.1.1 Indoor construction

In undertaking the indoor construction process the following was considered:

- space allowances for the mobility of the construction plant
- increased time allowances for pavement dry-back to compensate for the lack of direct sunlight and reduced airflow across the pavement

- selection of an emulsion seal in place of a cutback bitumen seal to mitigate workplace health and safety concerns regarding fuming, and potential practical issues with the evaporation of volatiles in time for trafficking given the reduced airflow throughout the testing building.

4.1.2 Uniformity

To ensure meaningfully comparable outcomes from each of the test scenarios across the different locations distributed along the three experimental lanes (Figure 3.2), it was critical that the pavement was constructed in a uniform manner as much as practically possible. As such, pavement layer thickness, levels, moisture content, density, and deflection were monitored throughout construction.

4.2 Overview of Construction

The construction involved preparation, placement, and assessment of the test materials. An overview of the construction is listed in Table 4.1.

Table 4.1: Overview of construction activity schedule

Construction stage	Commencement	Conclusion
• Site preparation	03/02/2021	26/03/2021
– Kerb & channel placement & curing	01/03/2021	04/03/2021
– Removal of existing cement-treated pavement material (i.e. down to a remaining ~350 mm of stabilised clay material) & levelling of pre-existing subgrade	04/03/2021	26/03/2021
• FWD testing and level measurements of the pre-existing subgrade/stabilised clay layer	Conducted: 26/03/2021	
Construction of concrete tank (including 7-day curing time)	29/03/2021	05/04/2021
Placement, compaction, & levelling of imported sandy silty clay subgrade	16/06/2021	21/06/2021
• Testing of imported subgrade layer	22/06/2021	16/07/2021
– FWD testing	Conducted: 22/06, 30/06 & 16/07/2021	
– Nuclear Density Meter (NDM) testing	Conducted: 23/06 & 02/07/2021	
– Dynamic Cone Penetrometer (DCP) testing	Conducted: 23/06, 02/07 & 05/07/2021	
– Checking layer levels	Conducted: 24/06 & 01/07/2021	
Construction stage	**Commencement**	**Conclusion**
Placement, compaction, & levelling of unbound granular basecourse (20 mm Class 3 crushed rock)	05/07/2021	07/07/2021
Dry-back period for basecourse	07/07/2021	31/08/2021
• Testing of base layer	05/07/2021	06/09/2021
– FWD testing	Conducted: 16/07 & 06/09/2021	
– NDM testing	Conducted: 05/07/2021 (initial 100 mm) & 07/07/2021 (full basecourse)	
– Checking layer levels	Conducted: 06/07/2021	
– Ball Penetrometer testing	Conducted: 06/09/2021	

Surface priming (and primer trial) & spray sealing	Primer trial conducted: 02/09/2021 Surface priming conducted: 07/09/2021 Spray sealing conducted: 13/09/2021	
• Testing of sealed pavement	17/09/2021	08/10/2021
– FWD testing	Conducted: 17/09, 23/09, 01/10 & 08/10/2021	

4.2.1 Site & pre-existing subgrade preparation

Prior to the commencement of pavement construction, the ALF site was prepared for the new pavement. Over the course of March 2021, the existing pavement was milled back and excavated to a depth of approximately 600 mm from the surface level. This removal left an approximately 350 mm thick layer of cement-stabilised clay subgrade, over which the new pavement would be constructed. Once exposed, the subgrade was levelled in preparation for subbase construction.

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

As already discussed, the test program required three lanes to be constructed which spanned to the edge of the test facility. Surrounding concrete walls and required drainage 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 shown in Figure 4.1.

Figure 4.1 Test pavement subgrade and surrounding concrete walls

4.2.2 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 to reach a level 200 mm below the pavement surface. Once placed, this subgrade was compacted and trimmed to ensure the target level was met. Uniformity in layer moisture content and density was also assessed and confirmed to be sufficiently uniform before construction proceeded further.

4.2.3 Basecourse construction

The basecourse material was placed to a depth of 200 mm (i.e. meeting the pavement surface level). This was done with two lifts, each 100 mm thick. The basecourse layer was then compacted and levelled. Quality testing of the moisture content, layer density, and FWD deflection testing of the basecourse was undertaken, and dry-back of the material was monitored before construction proceeded further. The basecourse material was a standard Class 3 quarry crushed rock material of used for subbase and/or base layer for lightly trafficked road. This material would be of relatively high quality compared to the materials that might be available and used for part of the rural road network.

4.2.4 Surface priming & spray sealing

Once sufficient dry-back of the basecourse had occurred (i.e. a target moisture ratio of ~80% OMC) the surfacing for the pavement was applied.

As mentioned in Section 3.2.4, 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 that an application rate of 1.0 L/m^2 was most appropriate.

Following the primer trial, on 7 September 2021, the emulsion primer was applied to the test pavement surface on 13 September 2021. The double coat sprayed seal was applied as per the seal design for the project: a 10/5 double/double using a HBCE from Primal with spray and aggregate spread rates as outlined in Section 3.2.4.

A view of the test pavement after the application of the sprayed seal is shown in Figure 4.2.

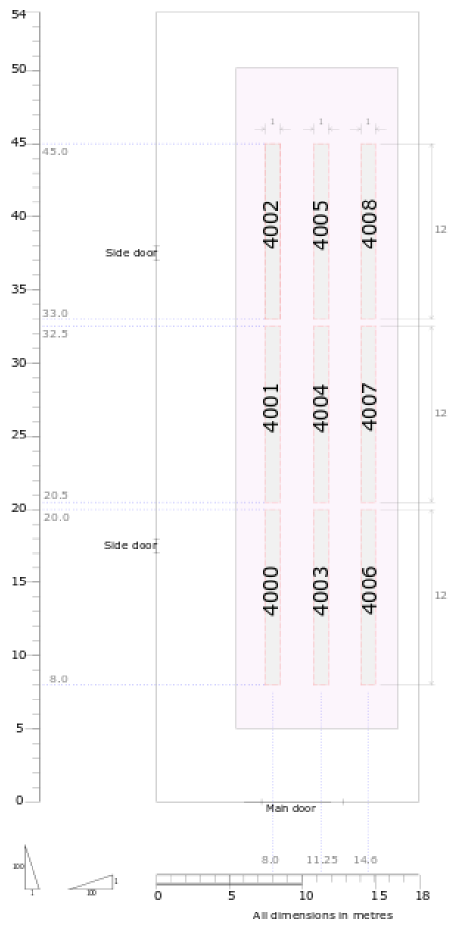
After the completion of the pavement surfacing, the construction was assessed and evaluated to determine the quality of the test pavement. This assessment is described in Section 6.2.

Figure 4.2 Test pavement after application of sprayed seal

4.3 Pavement Test Layout

Following the completion of the pavement the final layout was spray painted as per the layout shown in Figure 4.3.

Figure 4.3 Final pavement layout



5. Monitoring of Pavement Response and Performance

During the accelerated pavement loading, pavement condition assessments were conducted before the testing commenced, at regular intervals during the trafficking, and once the testing was complete.

The experiment monitoring methods included the following:

- Falling Weight Deflectometer (FWD) to measure pavement deflection; before, at regular intervals during and after testing, as described in Section 5.1.
- Transverse profilometer to measure surface profile and pavement surface deformation; before, at regular intervals during and after testing as described in Section 5.2.
- Sand volumetric method to measure texture depth before and after testing as described in Section 5.3.
- British Pendulum testing to measure skid resistance before and after as described in Section 5.4.
- Moisture content testing using the NDG to measure moisture content before and after testing as described in Section 5.5.

5.1 Deflection Testing

The FWD was utilised throughout trafficking, with testing conducted in accordance with AGAM-T006-11 in both the trafficked (in the wheel path) sections of each lane, as shown in Figure 5.1. The pavement surface vertical deflection were 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 (or 566 kPa with a 150 mm plate radius) when post-processing.

Figure 5.1 FWD at the ALF site

5.2 Transverse Profilometer Testing

The pavement surface deformation was regularly monitored using both automated profile measurements and visual inspections.

The surface profile of the trafficked area of each test lane was monitored using an automated transverse profilometer (TP) in accordance with AGAM-T009-16. These profiles were collected for each trafficking period and were taken at every half-metre along each test pavement, resulting in 22 transverse profile measurements in each test lane.

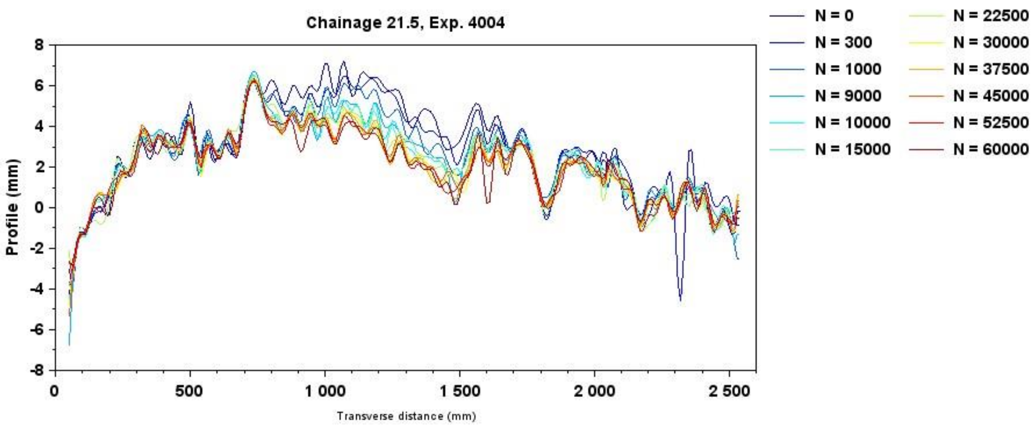
The TP is equipped with both ultrasonic and high-precision laser sensors to collect the transverse profile data. Two additional lasers are fitted at the front and rear to guide and position the TP while collecting data. Figure 5.2 shows the TP system in operation at the ALF site.

Figure 5.2 Transverse profilometer at ALF site

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 data was measured at shorter time intervals for the first 15 000 cycles for each lane (at 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 approximately every 7,500 cycles of loading until the trafficking was completed.

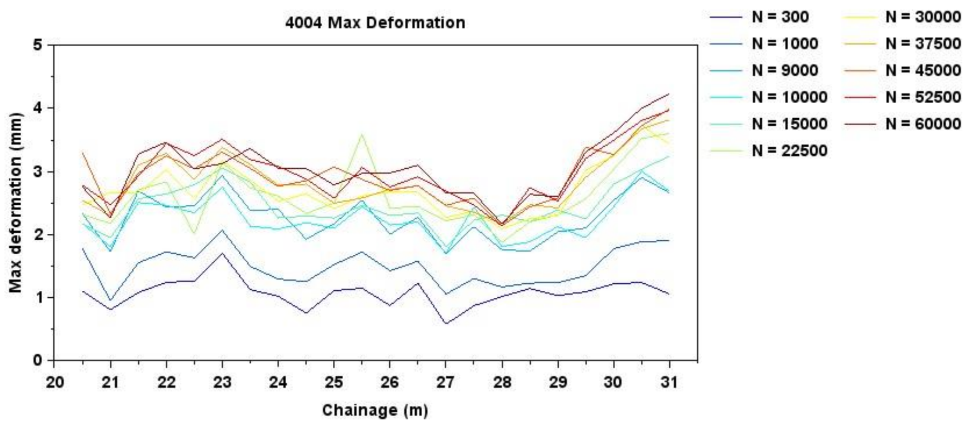
Figure 5.3 shows an example of the raw profile data for one test lane at one specific chainage. Different lines in this Figure demonstrate the measured profile across the width of the test lane after the given number of loading cycles. After conducting the data processing and analysis, the pavement surface deformation at each chainage was calculated using the measured profile data for each lane. For this, the profiles measured after 300 loading cycles were used as a reference, and the surface deformation was obtained using the difference between the reference profile and the profile after each interval during trafficking.

Figure 5.3 Example raw profile data



The deformation data (the downwards movement of the pavement surface in the central trafficked area) at different transverse distances at each chainage was then averaged and considered as the mean deformation for that specific chainage. Figure 5.4 illustrates an example of the calculated mean deformation at different chainages. Different lines in this Figure show the change in the surface deformation along the test pavement section at different loading cycles. As mentioned above, the deformations were calculated relative to the reference profile (measured after 300 cycles).

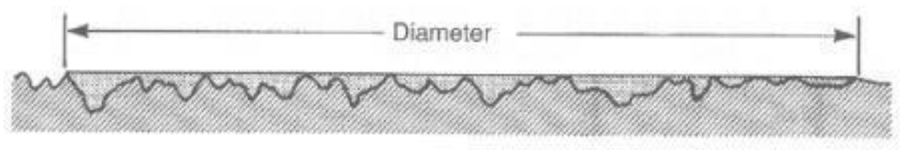
Figure 5.4 Example mean surface deformation



5.3 Sand Patch Texture Testing

The sand patch method involves a volumetric approach to determine the texture depth of the pavement. It is applied to the surface at different locations on the test bed. A known volume of fine-grained sand is spread on the pavement into a circle and the average diameter of the sand is measured at a number of locations, as shown in Figure 5.5. 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). This testing was undertaken before and after the pavement was trafficked to identify the changes caused by the trafficking. The test method utilised for the sand patch method was AGPT-T250-08.

Figure 5.5 Sand patch test



Source: Austroads (2009).

5.4 Skid Resistance Testing

British Pendulum Testing was undertaken to measure the skid resistance of the pavement at different locations on the test bed. Testing was conducted both before and after the pavement was trafficked. Testing of the freshly constructed pavement was conducted in accordance with *AS 4586-2013: slip resistance classification of new pedestrian surface materials*. Once the pavement was trafficked, testing was conducted in accordance with *AS 4663-2013: slip resistance measurement of existing pedestrian surfaces* was utilised.

5.5 Non-destructive Moisture Content Testing

Moisture content testing was undertaken using a NDG after trafficking. Testing was conducted in using non-destructive nuclear gauge testing in back-scatter mode for moisture content uniformity assessment across all testing sites. Data were collected for each trafficked lane at 1 metre intervals and calibrated based on results conducted on material removed at the ends of the ALF site.

6. Experiment Plan and Monitoring

6.1 Details of accelerated Pavement Testing Program

6.1.1 Trafficking program

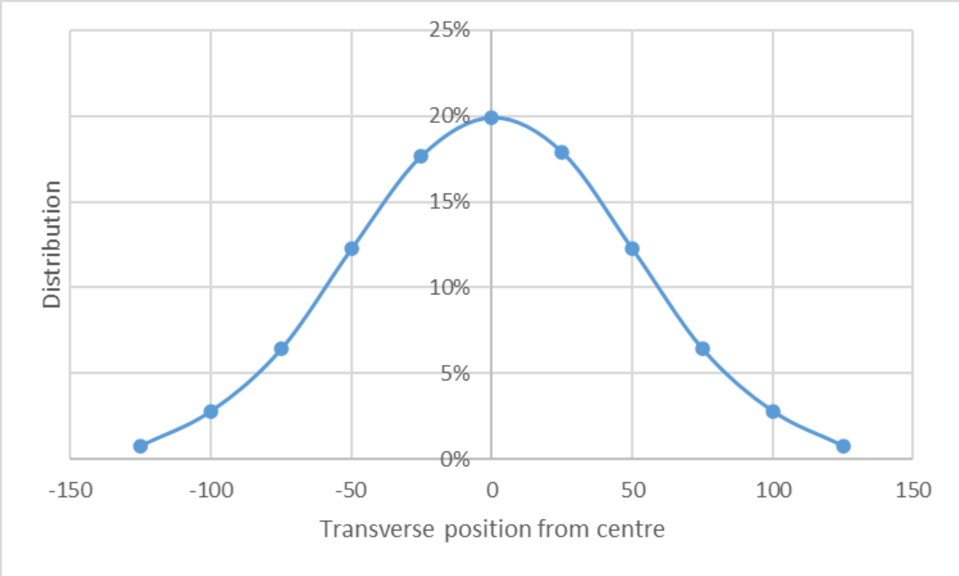
Pavement testing consisted of the application of a minimum of 52,500 cycles of load to each test pavement in sequence allowing for monitoring of the deformation change during testing. Loading was regularly interrupted to measure the pavement surface profile (i.e. when 0, 300, 1,000, 9,000, 10,000, 15,000, 22,500, 30,000, 37,500, 45,000 and 52,500 cycles are reached). If loading was extended the measurements were conducted after approximately every 7,500 cycles of loading until the trafficking was completed.

6.1.2 Transverse distribution of loading

The traffic loading was applied using the ALF trolley fitted with the relevant tyres being tested. To simulate realistic trafficking patterns, the load was distributed across the width of the pavement as shown in Figure 6.1. This was achieved by wandering the load transversely across the lane. For the first 500 cycles, the load was applied in a uniform rectangular distribution, after which point the loading was distributed as per Figure 6.2. A pseudo-normal distribution of transverse locations, covering a 1 m wide trafficked area was applied. The load was incrementally shifted transversely by 125 mm (relative to its previous location) every 50 cycles.

Figure 6.1 Transverse distribution of loading

Figure 6.2 Transverse distribution of load for the first 500 cycles



6.2 Pre-testing Deflection Measurements

Prior to testing commencing, FWD measurements were taken to assess pavement response and evaluate the pavement uniformity after the priming and sealing of the surface. Testing was performed on the 1, 8 and 12 October 2021. As the pavement surface was freshly sealed there were loose aggregates on the surface which can potentially affect the deflection readings and introduce variability. The average of the three sets of measurement was used to select the location of the experiments, i.e. sections with similar pavement response (mean pavement deflection).

The results of the testing are presented in Appendix A.1.

Deflection data collected on the centreline of each test section was used to calculate the average deflection as defined on the proposed pavement layout (Figure 4.3). The measured deflection values are summarised in Table 6.1. The Standard Deviation of the mean maximum deflection (d0) was considered to ensure that the test sites were suitable uniform.

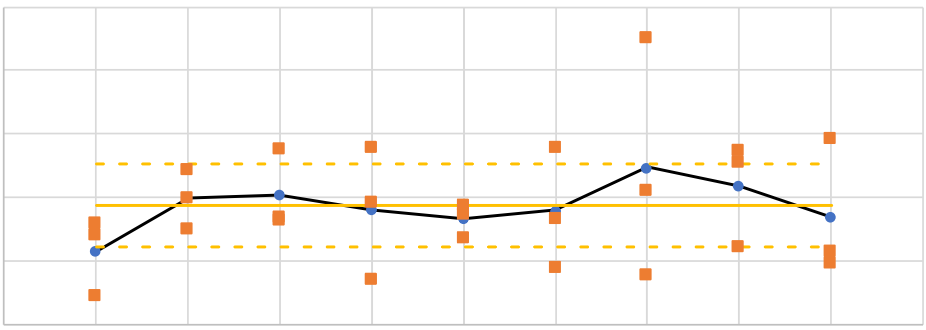
Table 6.1: Maximum deflection measured for candidate experiments

Experiment	Offset (m)	Chainage (m)		Date	Maximum deflection d0 (µm)				Mean (µm)	Deviation from mean
		Start	Finish		Mean	Std Dev.	Min	Max		
				01/10/2021	653	7.5	643	661		
				08/10/2021	652	6.8	644	660		
4000	8.0	8.0	20.0	12/10/2021	647	9.8	636	666	651	-0.5%
				01/10/2021	655	6.0	649	666		
4001	8.0	20.5	32.5	08/10/2021	653	6.0	645	659	655	+0.1%
				12/10/2021	657	12.4	643	676		
				01/10/2021	659	7.7	644	667		
4002	8.0	33.0	45.0						655	+0.1%

				08/10/2021	654	5.6	647	662		
				12/10/2021	653	8.9	642	667		
				01/10/2021	659	5.2	649	663		
4003	11.3	8.0	20.0	08/10/2021	655	3.1	649	658	654	+0.0%
				12/10/2021	649	7.4	639	659		
				01/10/2021	654	6.0	648	663		
				08/10/2021	652	6.5	643	659		
4004	11.3	20.5	32.5	12/10/2021	654	8.6	644	668	653	-0.1%
				01/10/2021	659	6.3	651	667		
4005	11.3	33.0	45.0	08/10/2021	650	9.9	639	666	654	-0.1%
				12/10/2021	653	6.5	642	661		
				01/10/2021	656	3.8	651	661		
				08/10/2021	649	6.2	641	660		
4006	14.6	8.0	20.0	12/10/2021	668	8.2	654	675	657	+0.5%
				01/10/2021	658	6.2	647	664		
4007	14.6	20.5	32.5	08/10/2021	651	5.9	645	661	656	+0.2%
				12/10/2021	659	10.8	649	674		
				01/10/2021	651	7.2	641	662		
				08/10/2021	650	8.3	638	660		
4008	14.6	33.0	45.0	12/10/2021	660	12.8	645	679	653	-0.1%

The mean maximum deflection (d0), based on the experiment number and the date tested, are shown in Figure 6.3. The orange points show the maximum deflections based on the three sets of data, 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 most of the mean maximum deflections were within 0.5% of the mean.

Figure 6.3 Summary of mean maximum deflection prior to trafficking commencing



The test site of 4012 was measured prior to selection of a re-test of a tyre, the measured deflection is noted to be more variable, refer Table 6.2. As the sites had already been tested, the deviation from the mean is based on previously calculated mean.

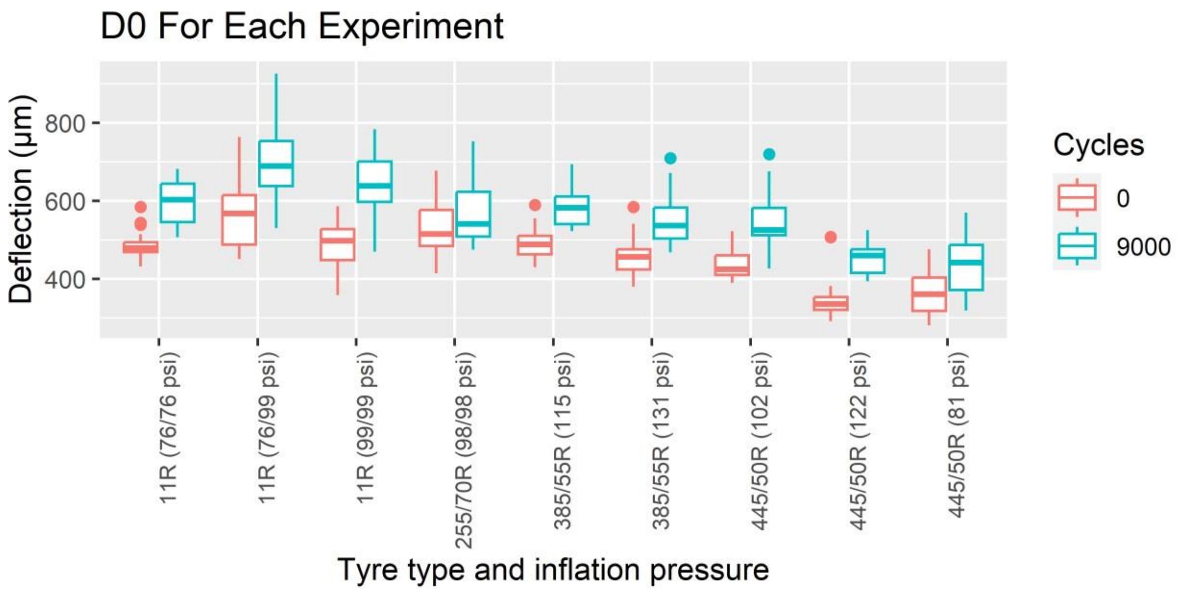
Table 6.2: Maximum deflection measured for additional experiment

Experiment	Offset (m)	Chainage (m)		Date	Maximum deflection d0 (µm)				Mean (µm)	Deviation from mean
		Start	Finish		Mean	Std Dev.	Min	Max		
4012	12.9	27.0	39.0	29/03/2023	507	50.4	455	609	488	-25.5%
				21/04/2023	468	46.9	390	592		

6.3 Deflection During Bedding-in (0 to 9,000 cycles)

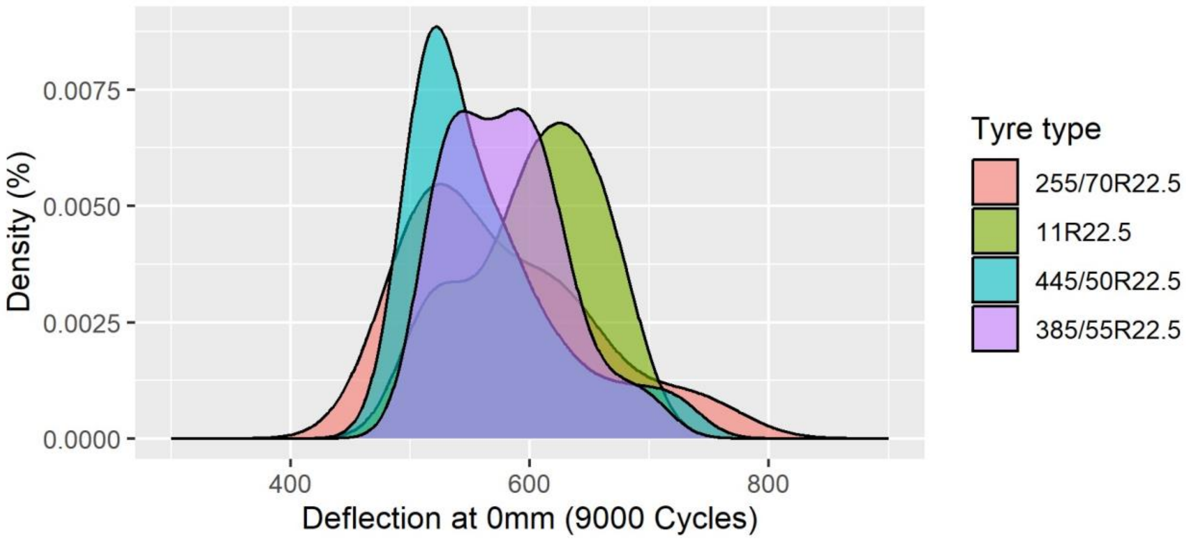
The maximum deflection (d_0) both prior to the ALF trafficking commencing and after 9,000 cycles is shown in Figure 6.4. The deflection measured prior to testing commencing varied between the test sites, but the variability was less and remained relatively consistent until 9,000 cycles.

Figure 6.4 Maximum deflection d_0 for each experiment



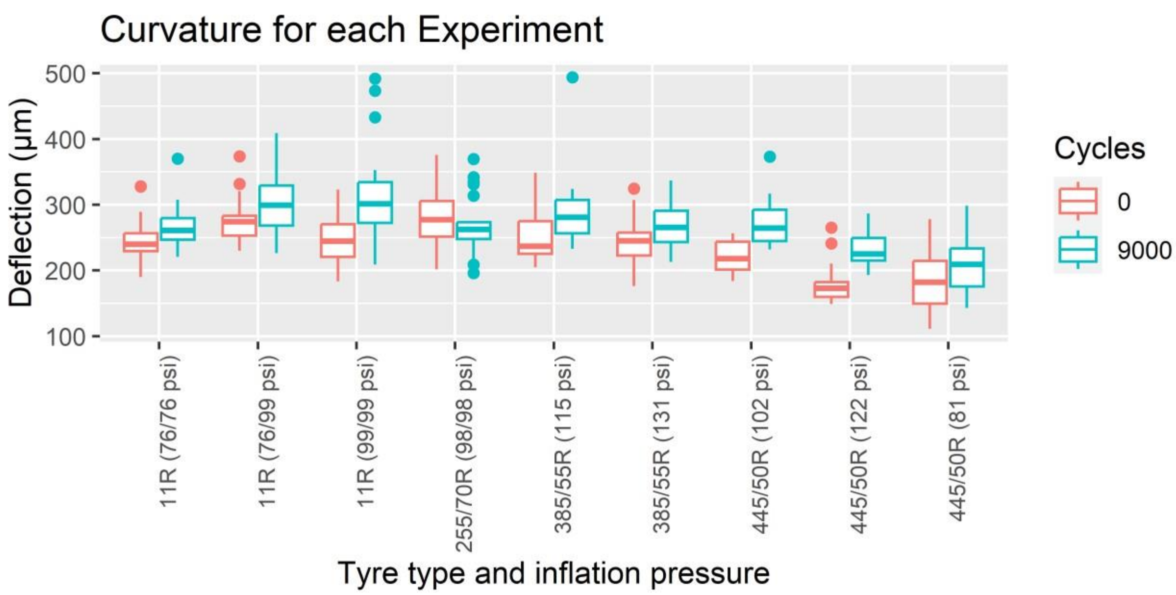
The density of the maximum FWD deflections (d_0) after 9,000 cycles is provided in Figure 6.5. This shows that the test section used for the 445/50R22.5 tyres testing had a tighter distribution of deflection than the other experiments. This means that the deflection on this site was more consistent with, on average, less deflection occurring than the sites used for testing with the other tyres.

Figure 6.5 Deflection density – Maximum deflection d_0 at recommended tyre pressures



The pavement surface curvature (d_0–d_{200}) results are provided in Figure 6.6. They show a similar variation as the maximum deflection, with minimal change at 0 and 9,000 cycles.

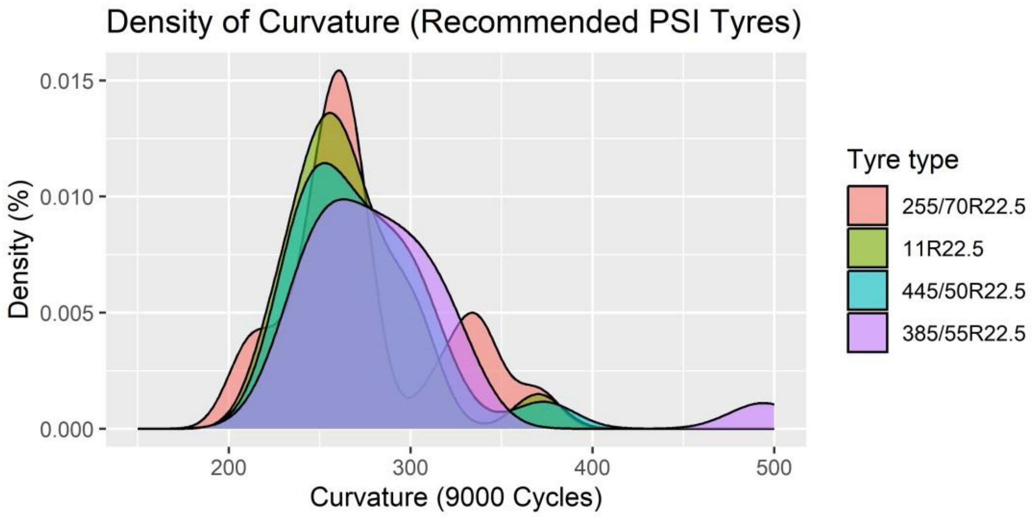
Figure 6.6 Pavement curvature d_0-d_{200} for each experiment



The density of the curvature for the recommended inflation pressures is provided in Figure 6.7. This shows that all the sites had relatively similar peak curvature values.

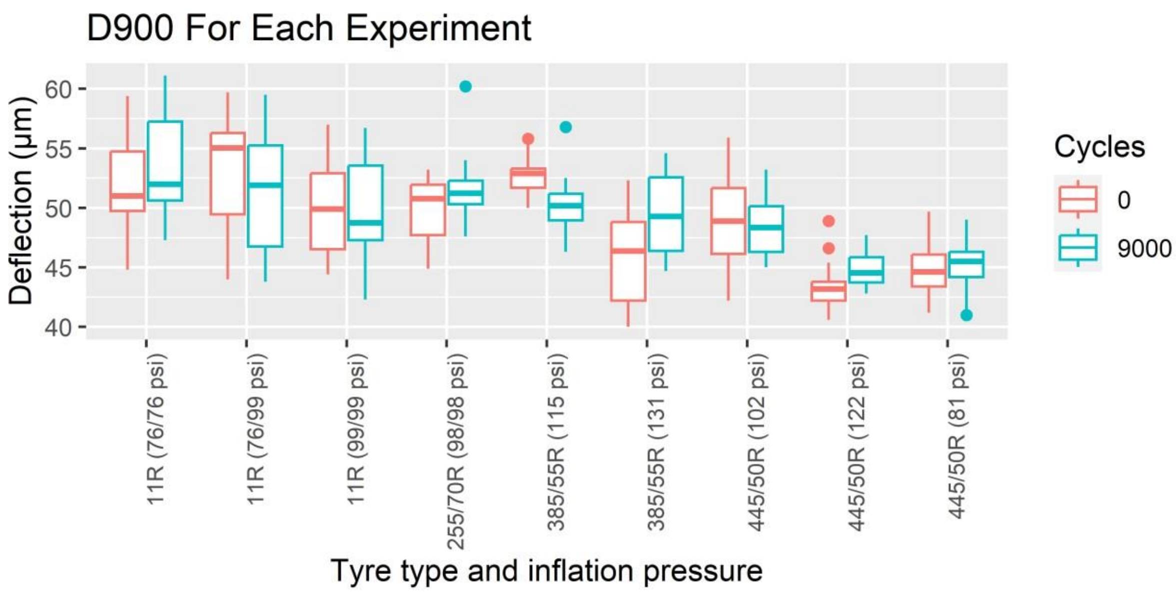
6.7 Curvature density Curvature d_0–d_{200} for tyres at recommended pressure

Figure –



The deflection parameter related to the subgrade property/stiffness is typically the deflection measured 900 mm away from the load (d_{900}), is shown in Figure 6.8. This shows there was minimal change between the deflection at 0 and 9,000 cycles.

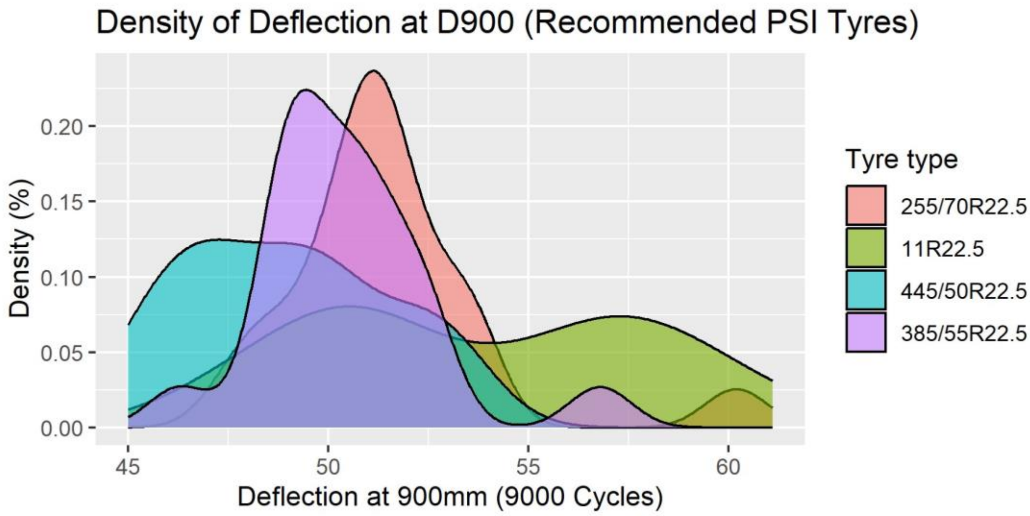
Figure 6.8 Deflection d_{900}



The density of the deflection d_{900} based on the tyres with recommended pressures are provided in Figure 6.9. Deflection d_{900} ranged between 55±10 µm.

6.9 Deflection density d_{900} for tyres at recommended pressure

Figure –



6.4 Moisture Content Testing

The moisture content of the pavement was measured using the NDG after testing, and the results are summarised in Table 6.3 and Figure 6.10. It was found that the moisture content in section 4003 (test 6) as shown in grey (Table 6.3) was over 5%, higher than the other sites. The ratio of moisture content to the OMC of the base material was 90% which would result in higher deformation of the pavement layer under loading compared with the other sites. As a result, the results at this location are only provided for completeness and should be considered with care.

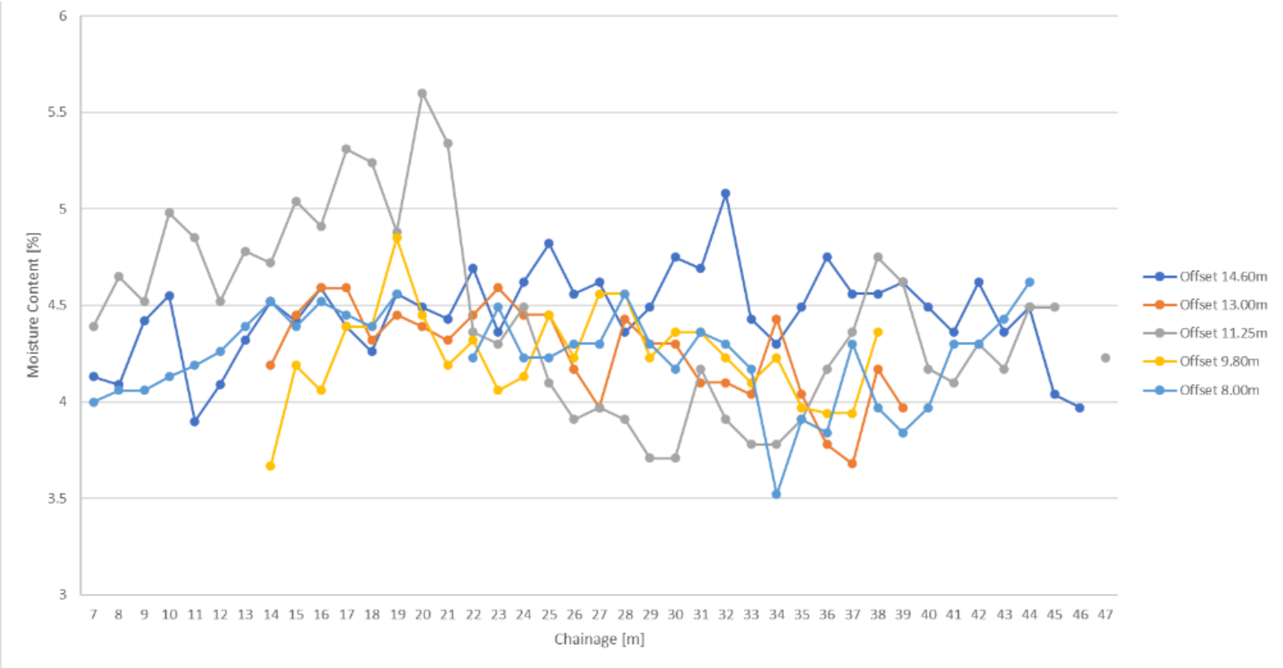
Table 6.3: Summary of moisture content testing after trafficking

Chainage (m)	Offset (m)				
	14.6	13	11.25	9.8	8
7	4.13	–	4.39	–	4.00
8	4.09	–	–	4.06	4.65
9	4.42	–	–	4.06	4.52
10	4.55	–	–	4.13	4.98
11	3.90	–	–	4.19	4.85
12	4.09	–	–	4.26	4.52
13	4.32	–	3.67	4.39	4.78
14	4.52	4.19	4.19	4.52	4.72
15	4.42	4.45	4.06	4.39	5.04
16	4.59	4.59	4.39	4.52	4.91
17	4.39	4.59	4.39	4.45	5.31
18	4.26	4.32	4.85	4.39	5.24
19	4.56	4.45	4.45	4.56	4.88
20	4.49	4.39	4.19	-	5.60
21	4.43	4.32	5.34	4.32	-
22	4.69	4.45	4.36	4.06	4.23

Figure –
23 4.36 4.59 4.30 4.13 4.49

Chainage (m)	Offset (m)				
	14.6	13	11.25	9.8	8
24	4.62	4.45	4.49	4.45	4.23
25	4.82	4.45	4.10	4.23	4.23
26	4.56	4.17	3.91	4.56	4.30
27	4.62	3.97	3.97	4.56	4.30
28	4.36	4.43	3.91	4.23	4.56
29	4.49	4.30	3.71	4.36	4.30
30	4.75	4.30	3.71	4.36	4.17
31	4.69	4.10	4.17	4.23	4.36
32	5.08	4.10	3.91	4.10	4.30
33	4.43	4.04	3.78	4.23	4.17
34	4.30	4.43	3.78	3.97	3.52
35	4.49	4.04	3.91	3.94	3.91
36	4.75	3.78	4.17	3.94	3.84
37	4.56	3.68	4.36	4.36	4.30
38	4.56	4.17	4.75	3.67	3.97
39	4.62	3.97	4.62	–	3.84
40	4.49	-	4.17	–	3.97
41	4.36	-	4.10	–	4.30
42	4.62	-	4.30	–	4.30
43	4.36	-	4.17	–	4.43
44	4.49	-	4.49	–	4.62
45	4.04	-	4.49	–	–
46	3.97	-		–	–
47	–	-	4.23	–	–

Figure 6.10 Variation in moisture content by location



6.5 Contact Pressure Distribution Measurements

6.5.1 Methodology

The contact pressure distribution of each tyre was measured with the assistance of Goodyear Australia and O'Brien Traffic using ARRB's pavement surface wear measurement trailer and an electronic pressure sensor pad (X-Sensor) loaned by Goodyear. Two tests were undertaken utilising the sensor:

1. Each tyre's footprint at varying loads and inflation pressures.
2. Each tyre's footprint under the ALF load and inflation pressures.

Figure 6.11 Field engineers from O'Brien Traffic and Goodyear recording tyre contact pressure distribution

The X-Sensor model IX500:256.256.16 was utilised for this test. It consists of a 406 mm x 406 mm pad with a contact sensor resolution of 1.6 mm. It provides 65,536 individual pressure readings across its surface.

The X-Sensor's X3 Pro v6.0 software package visually displays the footprint pressure distribution by way of a heat-map. It also calculates footprint pressure characteristics including area and pressure distribution profile. Data was also analysed using the raw sensor outputs.

The results of the pressure distribution for the tyres are summarised in Table 6.4, while the pressure heat maps for individual tyres are shown in Figure 6.12. 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, as represented by a concentration of red.

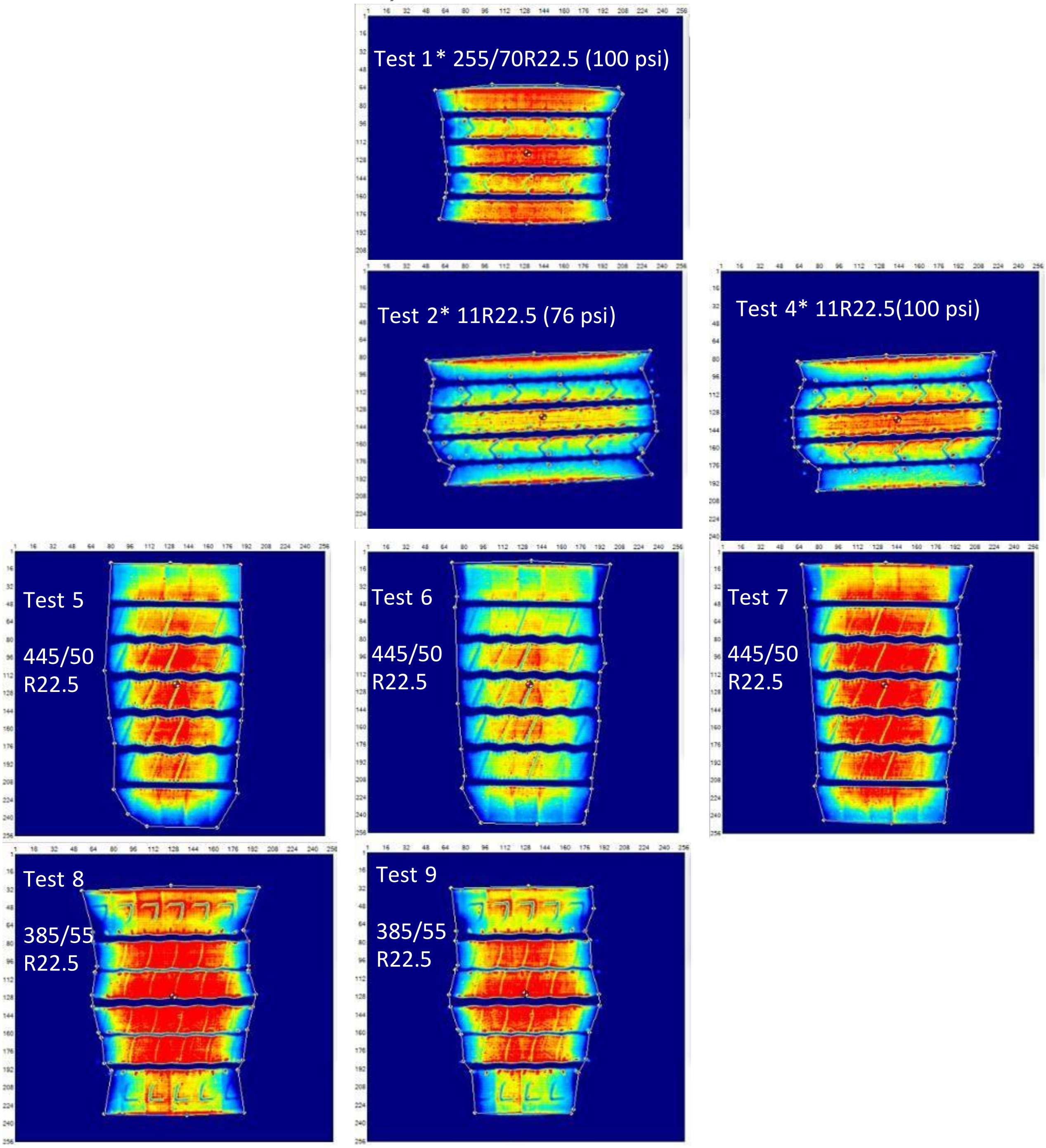
Table 6.4: Summary of pressure and area of tyres

Test number	Tyre size	Tyre inflation pressure	Area (mm^2)	Contact pressure (kPa)	Vertical force (t)
1	255/70R22.5	689 kPa (100 psi)*	40040	800.27	3.2675
2	11R22.5	524 kPa (76 psi)*	50250	617.49	3.1640
3	11R22.5	–	–	–	–
4	11R22.5	689 kPa (100 psi)*	44782	679.61	3.1033
5	445/50R22.5	689 kPa (100 psi)	60614	709.33	4.3844
6	445/50R22.5	558 kPa (81 psi)	66555	599.36	4.0675
7	445/50R22.5	841 kPa (122 psi)	67573	826.54	5.6954
8	385/55R22.5	903 kPa (131 psi)	59906	912.25	5.5725
9	385/55R22.5	792 kPa (115 psi)	51130	822.89	4.2903

* Testing is for single tyre configuration.

Figure 6.12 Tyre pressure heat map – measured under individual tyres

Under inflated	Recommended pressure (ALF load)	Over inflated



* Testing is for single tyre configuration.

Additional tests were undertaken for the dual 11R22.5 tyres. The results showed that the area under a single tyre was not equivalent to the dual tyres, as shown in Table 6.5. Figure 6.13 shows the contact pressure heat map based on the dual 11R22.5 tyres. The tabulated results are for tyres mounted on the ALF rig;

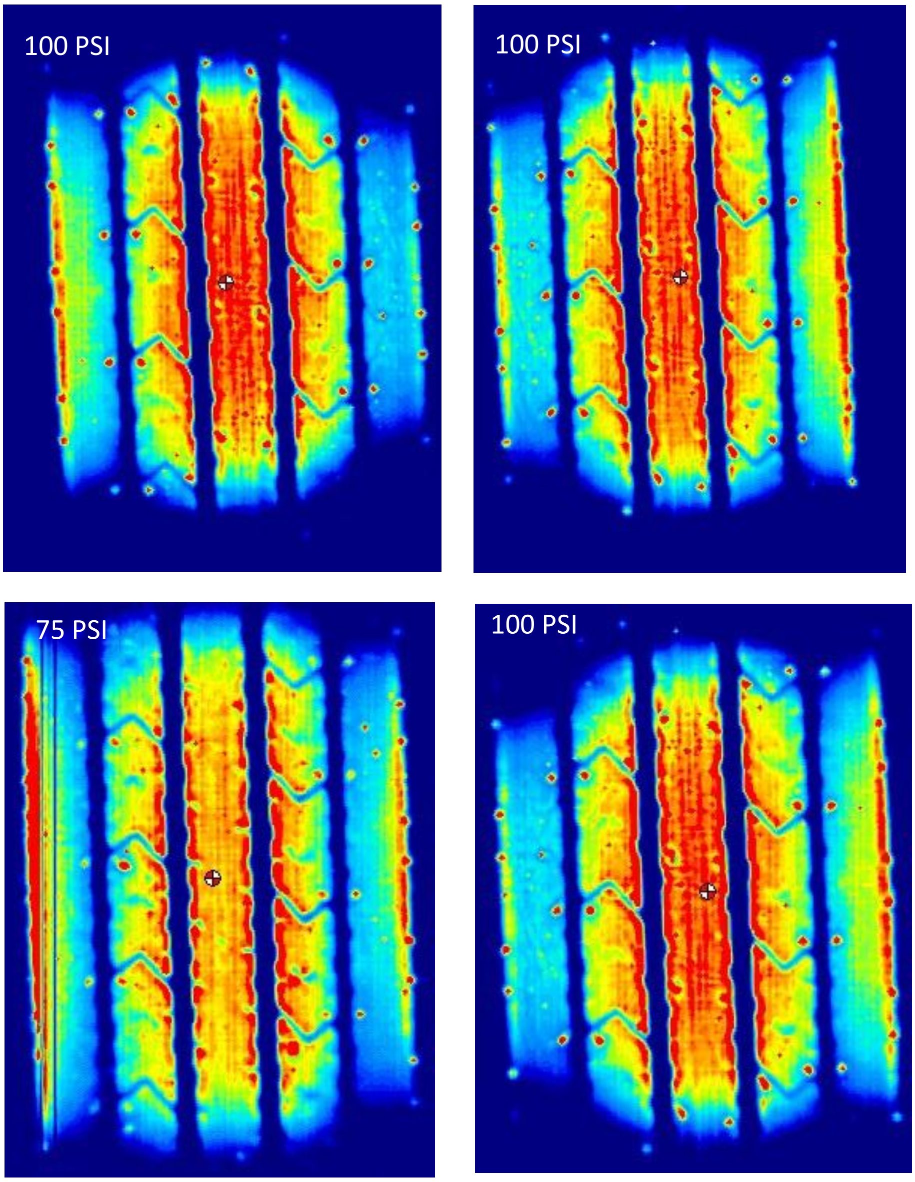
'airbag side' and 'drive side' refers to the two tyres in the dual set. The results are shown in Figure 6.14.

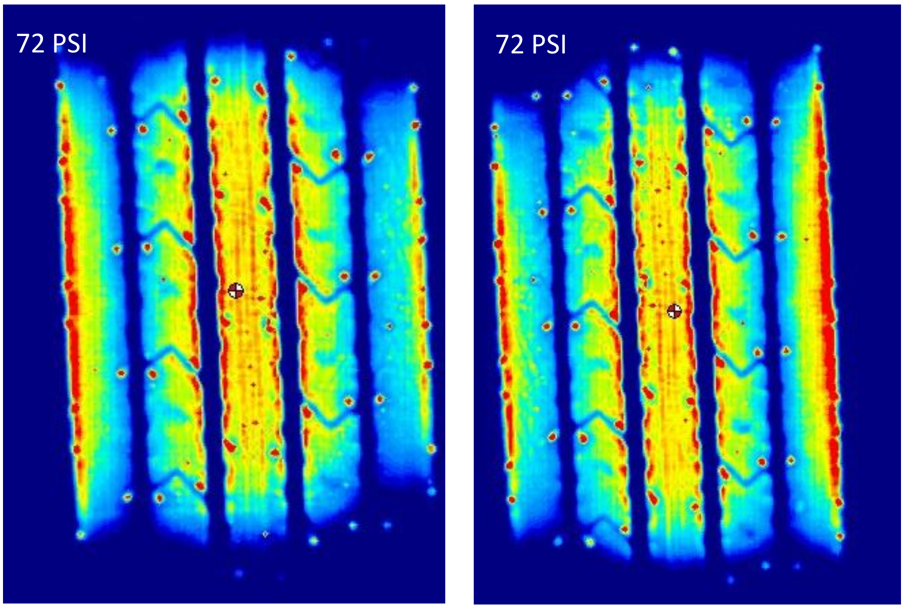
Table 6.5: Distribution of load based on tyre pressure - 11R22.5 dual assembly

Drive side	Airbag side	Total Area (mm^2)

Inflation pressure (psi/kPa)	Load (t)	Contact pressure (kPa)	Area (mm²)	Inflation pressure (psi)	Load (t)	Contact pressure (kPa)	Area (mm²)	
100/689	1.870	775	31956	100/689	2.250	790	35716	67672
75/517	2.040	729	40111	100/689	2.100	784	34007	74118
72/496	1.870	696	37582	72/496	2.250	716	42134	79717

Figure 6.13 Tyre pressure heat map - Dual 11R22.5





Note: Footprints are not to scale.

In addition to testing the contact pressure and contact area of the 11R22.5 tyre, the distribution of the load was tested, and the results are shown in Table 6.6. This shows the tyre pressure, the load share (i.e. share of 4t load from ALF) and the impact the change in tyre pressure has on the load-carrying capacity (LCC) of the tyres, based on the allowable mass of the tyres for the inflation pressure. The tests showed that, with equal inflation pressures in both tyres, there was a higher load on the airbag side tyre compared to the tyre on the drive side (see Figure 6.14). This is likely due to the ALF being a cantilevered axle with the airbag provided to add load. This influences the load share on the tyres, which changes as the inflation tyre pressures decrease, putting more load onto the external tyre. The tyre pressure distribution is critical, with the differential inflation pressures impacting the load sharing of the tyre and the load capacity which the tyres can safely carry. This is an important finding as the NHVR enforcement activity, based on personal communication with NHVR, showed that 27% of the tyres had a 5% or greater difference in pressure, while 31% of tyres (all inner tyres) could not be measured.

The tests showed that a reduction of 172 kPa (25 psi) in the airbag side tyre resulted in a load increase of 8% on the other dual tyre, while a reduction of 345 kPa (50 psi) resulted in a 28% increase in the load on that tyre.

Table 6.6: Distribution of load based on tyre pressure - 11R22.5

Airbag side				Drive side			
Inflation pressure (psi/kPa)	Load change	Tyre LCC (t)	% of LCC	Inflation pressure (psi/kPa)	Load change	Tyre LCC (t)	% of LCC
100/689	**100%**	2.452	91%	100/689	**100%**	2.452	79%
90/620	**98%**	2.255	97%	100/689	**102%**	2.452	81%
80/551	**94%**	2.052	101%	100/689	**107%**	2.452	85%
75/517	**92%**	1.949	105%	100/689	**108%**	2.452	86%
70/482	**87%**	1.844	105%	100/689	**114%**	2.452	91%
60/413	**82%**	1.630	112%	100/689	**121%**	2.452	95%
50/345	**75%**	1.409	118%	100/689	**128%**	2.452	101%

Note: Loads in bold are measured loads, while loads non-bold are calculated.

LCC: load-carrying capacity.

Figure 6.14 ALF configuration reference image for load distribution

6.5.2 Summary of Findings – Contact Pressure Distribution

A summary of the findings of the contact pressure distribution work is as follows.

- The wide single tyres have a wider hotspot than the dual tyres.
- The total footprint area increases as the inflation pressure decreases.
- The over-inflated 11R22.5 tyres had a more rounded imprint than the same tyre with the recommended pressure.
- The wider tyres had a more consistent shape when overinflated.
- The tread of the wider tyres was less supported and distorted to conform to the pavement.
- The differences in tyre pressure influenced the load-sharing distribution of the tyres in the dual wheel assembly.
- The lower pressure tyres have a reduced recommended load-carrying capacity.

It is noted that the values identified during the testing of the contact pressure differ from the results reported in Austroads (2008), in particular for the 385/55R22.5 tyres. This difference may be due to a number of reasons, including the difference in the design of the tyres. The width and contact stress of the tyres, using the same method reported in Austroads (2008) is shown in Table 6.7.

Table 6.7: Static contact stress and width

Test number	Tyre Size	Inflation pressure (kPa/psi))	Contact width (mm)	Contact Stress (kPa)
1	255/70R22.5	689 (100) both	189 x 2	877
2	11R22.5	524 (76) both	185 x 2	660
3	11R22.5	524 (76) for inner tyre 689 (100) for outer tyre	185 x 2	713
4	11R22.5	689 (100) both	185 x 2	698
5	445/50R22.5	689 (100)	371	801
6	445/50R22.5	558 (81)	369	758
7	445/50R22.5	841 (122)	371	864

8	385/55R22.5	903 (131)	309	1031
9	385/55R22.5	792 (115)	309	963

7. Loading Test Program

To quantify the performance of the next generation wide load base tyres compared with typical dual tyres required the selection of representative next generation wide load base tyres, as well as typical dual tyres. The tyres which were selected for testing are shown in Figure 7.1.

Figure 7.1 Model, size, section width and configuration of the tyres used for testing

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

To understand the effect of the tyre size, as well as the different tyre pressures, the test program was constructed as per Table 7.1. The tyres utilising the pressures recommended by manufacturers, based on loading, are identified in bold. The locations of the respective test segments on the ALF site are shown in Figure 4.3.

Table 7.1: Test program

Test no.	Load (kN)	Section	Tyre size	Tyre configuration	Inflation	Inner pressure (kPa)	Outer pressure (kPa)
1	**40**	**4006**	**255/70R22.5**	**Dual**	**Recommended**	**675**	**675**
2	**40**	**4007**	**11R22.5**	**Dual**	**Recommended**	**525**	**525**
3	40	4008	11R22.5	Dual	Mismatch	525	682.5
4	40	4005	11R22.5	Dual	Over inflated	682.5	682.5
5	**40**	**4004**	**445/50R22.5**	**Single**	**Recommended**	**700**	**NA**
6	40	4003	445/50R22.5	Single	Under inflated	560	NA
7	40	4000	445/50R22.5	Single	Over inflated	840	NA
8	40	4001	385/55R22.5	Single	Over inflated	900	NA
9	**40**	**4002**	**385/55R22.5**	**Single**	**Recommended**	**790**	**NA**
10	**40**	**4012**	**445/50R22.5**	**Single**	**Recommended**	**700**	**NA**

Note: Test 10 is a re-test of test number 5 funded by the NTRO/ARRB.

When comparing the results with Austroads (2008) it is noted that the 445 tyres tested in the Austroads project were different from the 445/50R22.5 tyres tested as part of this project: 445/65R22.5 tyres were tested in the Austroads project which, as the naming convention suggests, have an aspect ratio of 65 as opposed to 50, which will impact the footprint of the tyres and the load which is transferred to the pavement. Additionally, the pavement used in the testing was different from the pavements tested in the current trial, which will wear at a different rate.

8. Results and Analysis

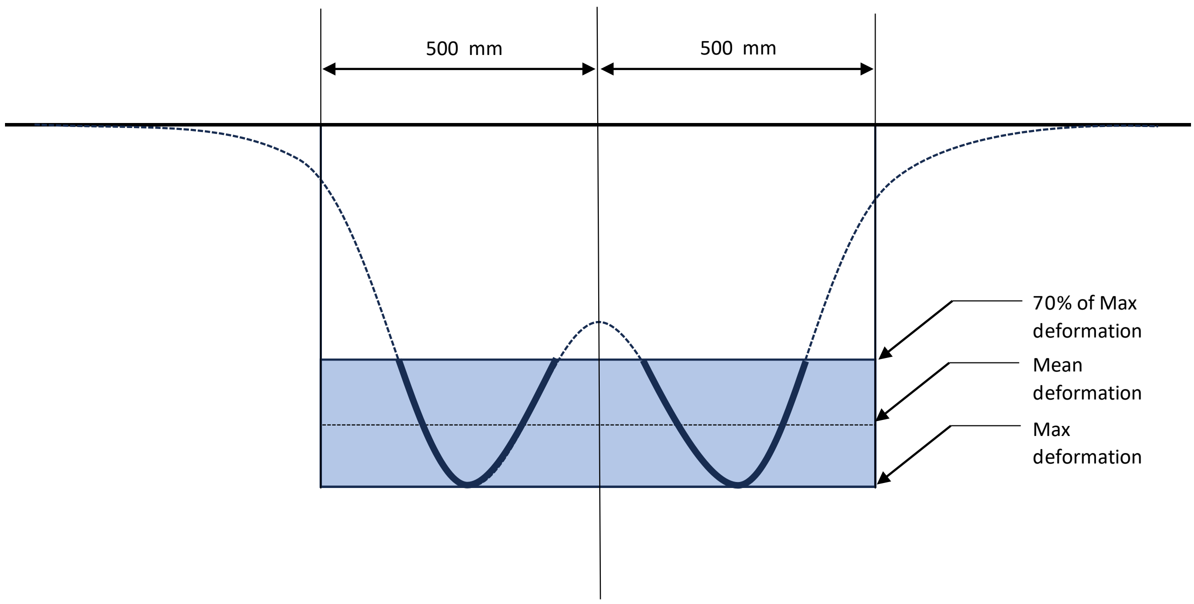
This section provides a summary of the results of the tyre testing, based on metrics relating to pavement wear.

8.1 Pavement Wear Metrics

The metrics used for quantifying pavement wear were as follows:

- Total deformation
  - The total deformation is the overall mean of the mean deformation at the selected chainages. It is calculated as the average value of the mean of the highest 30% deformation on each side of the trafficked area centreline and within the trafficked area (refer Figure 8.1). The deformation was measured using the transverse profilometer.
- Deformation rate
  - The rate at which the deformation occurs is calculated from the slope of the deformation between 9,000 and 52,500 ALF cycles, based on the measurements taken using the transverse profilometer.
- Pavement surface deflection parameters – Maximum deflection
    - The maximum deflection is the deflection which occurs at the location of the load pulse (D_0) transferred from a loading plate utilising the FWD. It is an indicator of vertical stress.
    - Curvature
    - The curvature is the maximum deflection (D_0) minus the deflection at an offset of 200 mm from the load pulse (D_{200}), i.e. Curvature = D_0-D_{200}. It is an indicator of tensile strain at the base of bound (asphalt or cemented) layers.
    - The deflection at a distance of 900 mm from the load (D_{900}) is indicative of the subgrade modulus (and hence CBR).
- Surface texture
  - The average texture depth of the pavement surface is measured using the sand patch method. This is determined by measuring the area covered by a standard volume of sand, as per the volumetric method.
- Surface friction
  - The surface friction properties were measured under dry and wet conditions utilising the British pendulum test.

Figure 8.1 Total deformation diagram



When comparing the results obtained under ALF loading, the maximum number of cycles chosen for comparison was 52,500. This number of cycles was chosen as this was a common number of cycles between all the tests.

The tyre-related factors considered during the analysis were: 1) tyre pressure and 2) tyre size (section width). The deformation rate was selected as the definitive metric to compare the pavement wear caused by the tested tyres and to quantify the effects of these two factors.

Details of the measured deflections are presented in Appendix A.1 and Appendix A.2 as follows:

- Appendix A.1 Deflection after sealing and before trafficking
- Appendix A.2 Deflections measured during ALF trafficking

Details of the analysis of the deflection data are presented in Appendix A.3.

8.2 Pavement Wear Results

To understand the impact of the effects of tyre pressure on the granular pavements, testing was conducted with the tyres at their recommended inflation pressures but also under- and over-inflated. The analysis of these tests did not provide the expected results. This is thought to be due to the small amount of total deformation measured after 52,500 load cycles was too small to allow any distinction to be made between the results of the tests in terms of variations in tyre pressure.

The comparison of the effect of different tyre configurations was therefore mainly based on the deformation rate (mm/cycles) measured during the experiments.

8.2.1 Deformation rate

The measured deformation rate was calculated based on the slope of the deformation curve between 9,000 and 52,500 cycles using data measured at 0.5 m intervals and assuming a linear relationship.

The results are presented in Appendix B. Owing to the high moisture content of the site tested in test number 6, this data was excluded from the analysis. Outliers (i.e. data outside the range of ±1.5 times the interquartile range (IQR) from the mean as well as chainages where the deformation rate deviated from the average over the entire test section) were excluded from the datasets.

To take account of the variability in the test pavement response (i.e. deflection), the measured deformation rates were adjusted based on the calculated adjusted structural number (SNP), using the method outlined in Appendix C. The average deformation rate and adjusted deformation rates are shown in Table 8.1 and Figure 8.2. The Figure shows the measured deformation rate, with one standard deviation above and below the mean shown in grey.

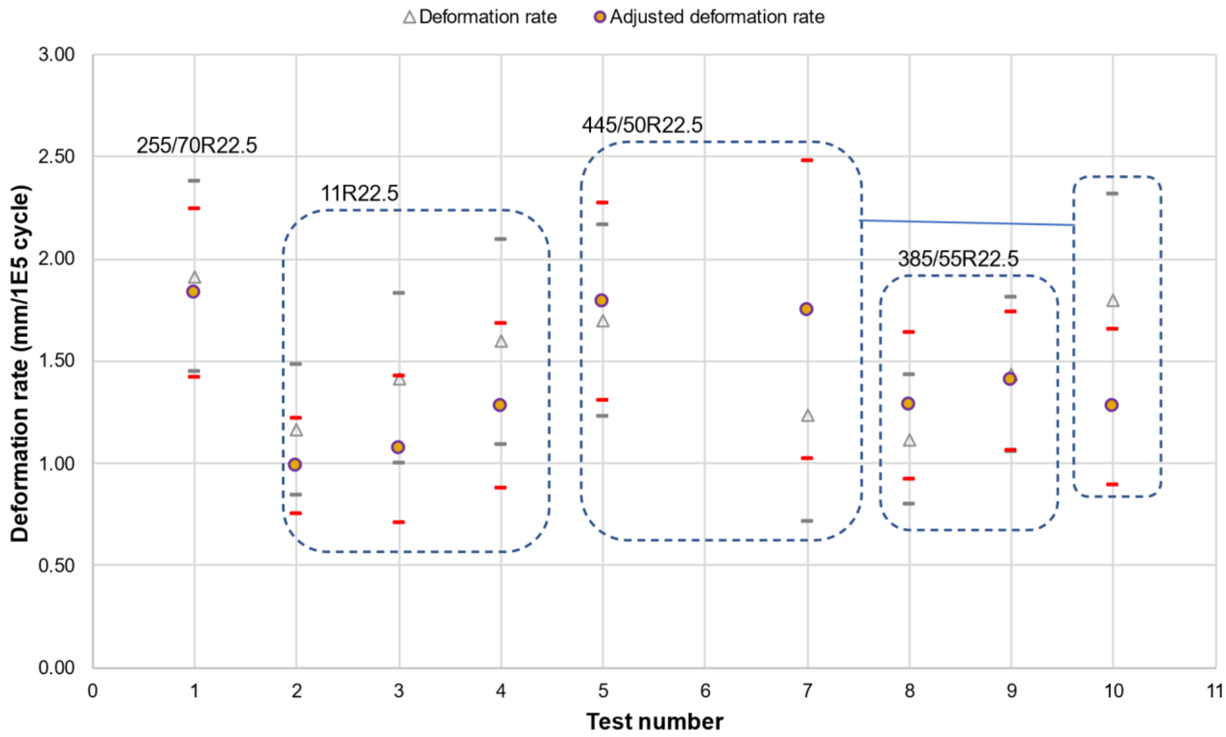
After adjusting the deformation rate using the adjusted structural number, the deformation rates were considered more comparable as they were adjusted to an average pavement condition for all tyre configuration.

Table 8.1: Adjusted deformation rate

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

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

Figure 8.2 Deformation rate against adjusted deformation rate



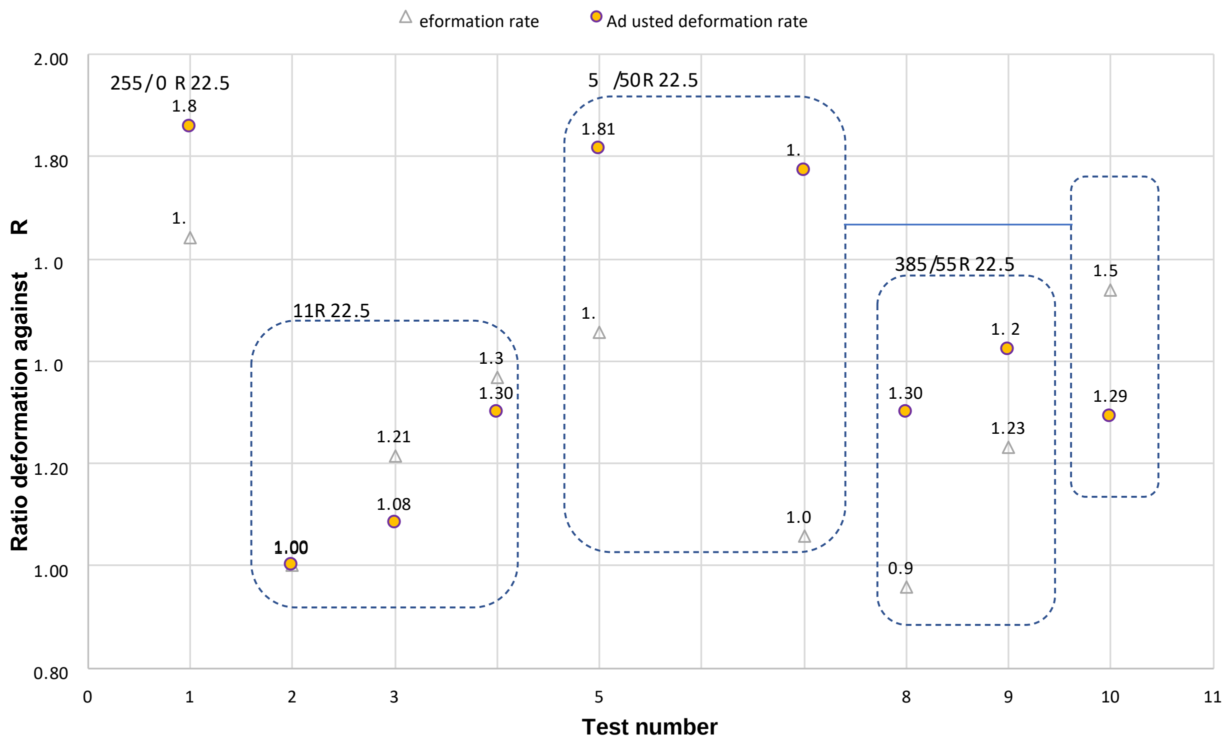
The results show that inflation pressure had a significant effect on the deformation under the dual 11R22.5 tyres, with the deformation rate increasing as pressure increased. However, no statistically significant results were obtained for the wide single tyres. The most damaging case for the 11R22.5 tyre was when overinflated 100 psi (700 kPa)). Enforcement activity conducted by the NHVR found that it is common for 11R22.5 dual tyres to be inflated to 100 psi (700 kPa), based on personal communication with NHVR; hence this test scenario was included to represent what is currently occurring in practice.

When comparing the deformation rate results representative of common practice for the 11R22.5 dual tyres at 99 psi (682 kPa) with the 445/50R22.5 at 102 psi (703 kPa) and the 385/55R22.5 at 115 psi (792 kPa) the differences were too small for any trend to be identified.

In summary, the use of over-inflated 11R22.5 dual tyres resulted in increased relative pavement wear. However, the differences in the results for the wide single tyres 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 (see Section 6.5) which showed less variation in contact patch area and peak pressure than the dual tyres.

Figure 8.3 shows the ratio of the deformation rate, and the adjusted deformation rate, under the wide single tyres compared with the dual tyres with recommended pressure.

Figure 8.3 Ratio of deformation of wide single tyres and 11R22.5 dual tyres

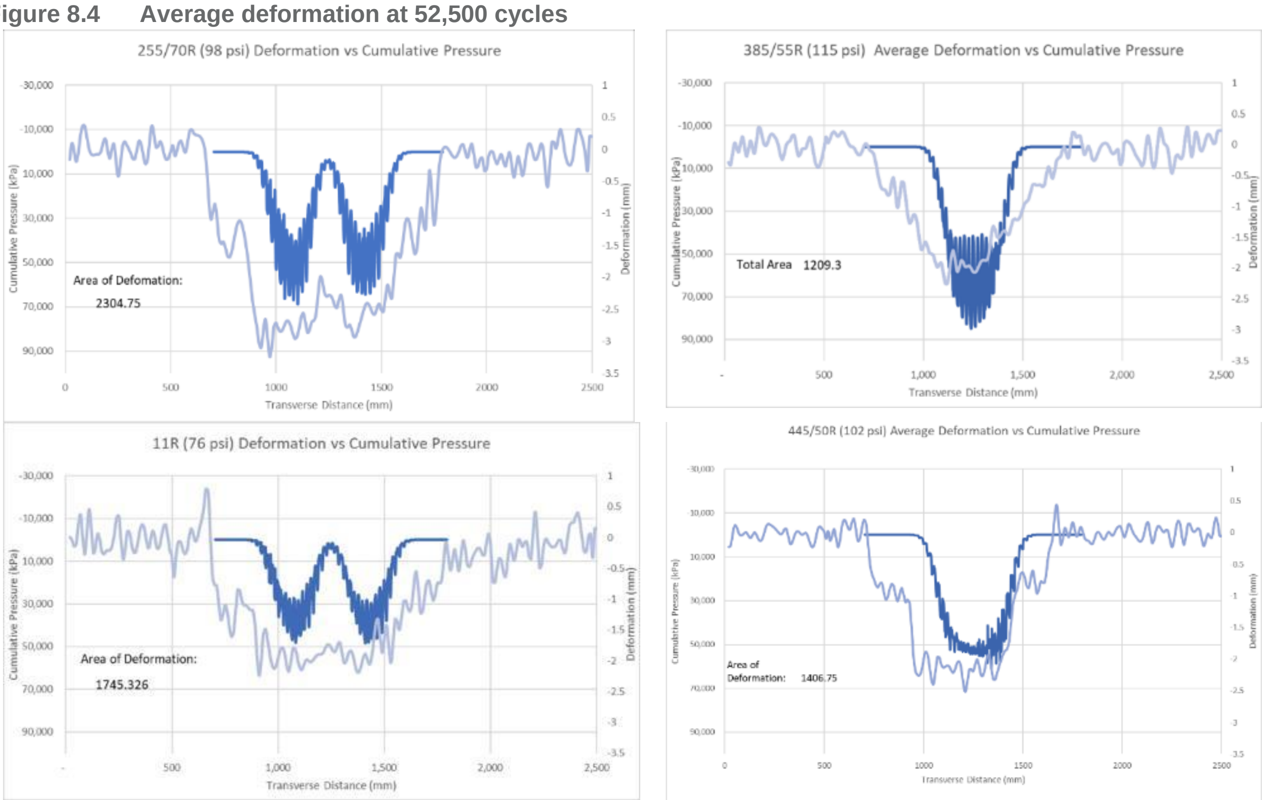


8.2.2 Transverse deformation profile analysis

This section examines the effects of tyre size on observed performance under loading at the recommended tyre pressures. A comparison of the average deformation for all the chainages (i.e. transverse profile), area of deformation, and cumulative tyre pressure (i.e. the cumulated contact stress calculated from the tyre pressure measurements during a full lateral wandering phase, including a distribution of 300 positions (i.e. 300 cycles)) is provided in Figure 8.4.

The average deformation in relation to the wheel path for the width of the test pavement after 52,500 ALF cycles is shown in light blue, whilst the cumulative pressure on the pavement, as identified from the contact pressure distribution testing, is shown in dark blue. The cumulative pressure shows the cumulated contact stress calculated from the tyre pressure measurements during a full lateral wandering phase. It can be seen when comparing the average deformation profile for each of the different tyres that the depth and width of the deformation relative to the cumulated tyre pavement contact stress. Generally, the deformation under the dual tyres is spread over a wider area than the single wide tyres. Comparing the deformation of the 11R22.5 and the 445/50R22.5 tyres, the 445/50R22.5 tyre has a smaller area of deformation. It is noted that while the 445/50R22.5 tyre has a smaller area of deformation, the maximum deformation is larger and occurs over a narrower area than that under the 11R22.5.

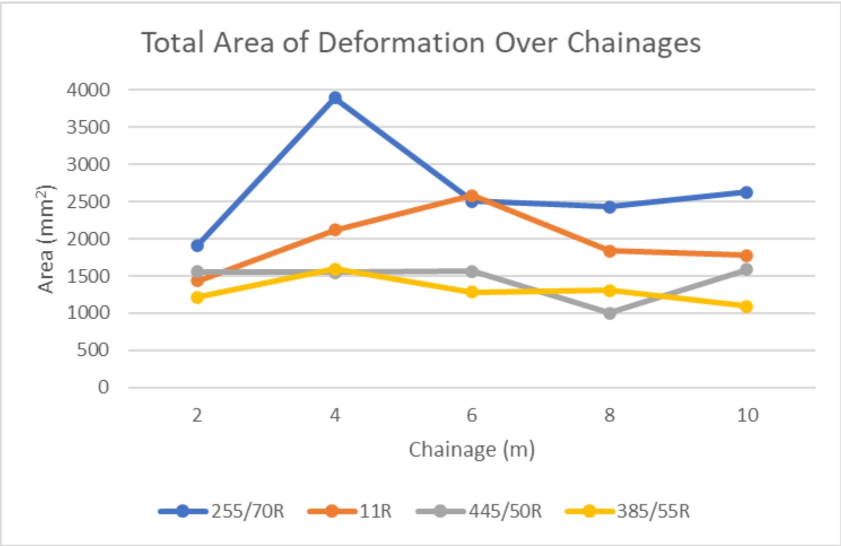
Figure 8.4 Average deformation at 52,500 cycles



As shown in Figure 8.5, the total area of deformation varies along the length of the test pavement. The effect of the wide tyres remains relatively consistent along the distance, while the effect of the dual tyres is more variable. Additionally, the dual tyres generally generated a larger area of deformation than the wide single tyres.

In summary, the wide single tyres generated a narrower rut than the dual 11R22.5 tyres, and the rut depth was slightly lower. However, there was very little difference in the rut depth between all tyre sizes.

Figure 8.5 Area of deformation based on chainage



8.2.3 Total deformation

The results after 52,500 cycles of ALF loading, based on the average deformation between 9,000 and 52,500 cycles at all the measured chainages are shown in Table 8.2. The average total deformation and standard deviation at each recorded cycle is shown in Appendix B.

Table 8.2: Total deformation

Test no.	Section ID	Tyre Size	Inflation pressure (kPa (psi))	Total deformation (mm)
1	4006	255/70R22.5	675 (98) for both tyres	4.13
2	4007	11R22.5	525 (76) for both tyres	3.43
3	4008	11R22.5	525 (76) for inner tyre; 682.5 (99) for outer tyre	3.04
4	4005	11R22.5	682.5 (99) for both tyres	3.27
5	4004	445/50R22.5	700 (102)	2.95
6	4003	445/50R22.5	560 (81)	3.20
7	4000	445/50R22.5	840 (122)	2.37
8	4001	385/55R22.5	900 (131)	1.86
9	4002	385/55R22.5	790 (115)	2.82
10	4012	445/50R22.5	700 (102)	3.34

Note: High moisture content identified during Test 6.

Based on the results, the highest average total deformations were observed on sites trafficked with the dual 255 tyres. There is minimal difference between the average total deformation results for the 11R22.5 and the 445/50R22.5 tyres. The standard deviations for the 11R22.5 tyres were also higher than the wider tyres (see Appendix B). In other words, the results for the 11R22.5 tyres tended to vary more across all deformation measurements than the results for the 445/50R22.5 tyres.

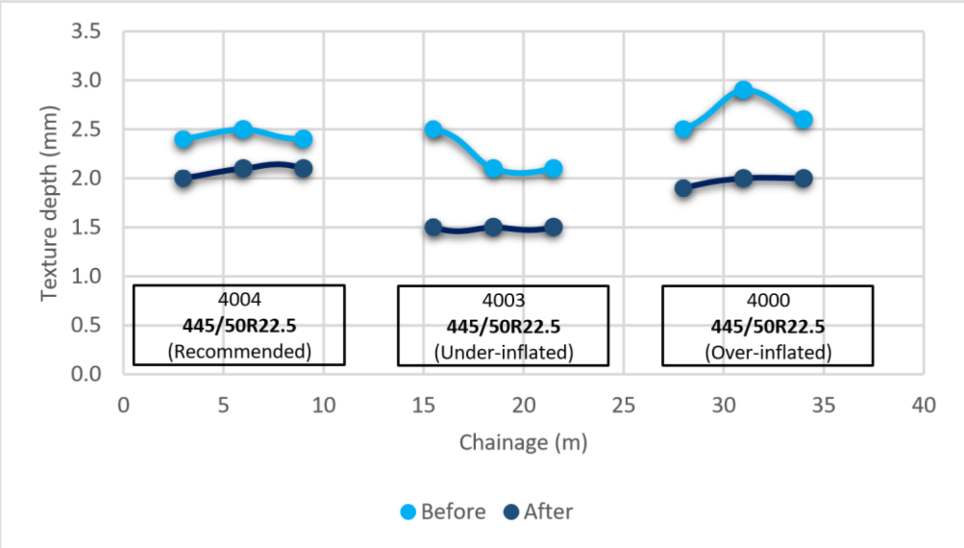
8.3 Surface texture

Texture depth was measured on all the pavements at three locations before and after trafficking. The results for the 445/50R22.5 tyres, 11R22.5 tyres, the 385/55R22.5 and 255/70R22.5 tyres are shown in Figure 8.6 Figure 8.7 and Figure 8.8 respectively.

The results suggest that the 385/55R22.5 super single tyres caused the smallest change in texture depth, with the ultra-wide 445/50R22.5 tyres showing a relatively large difference in change to texture depth for the under-inflated and over-inflated tyres, with only the recommended 102-PSI test showing results comparable with the 385/55R22.5 super single tyres, albeit still with the worse performance. The results for the dual tyres were the worst, with large differences in texture depth, except for the over-inflated 11R22.5 tyres which were comparable with the ultra-wide tyres at 102 PSI.

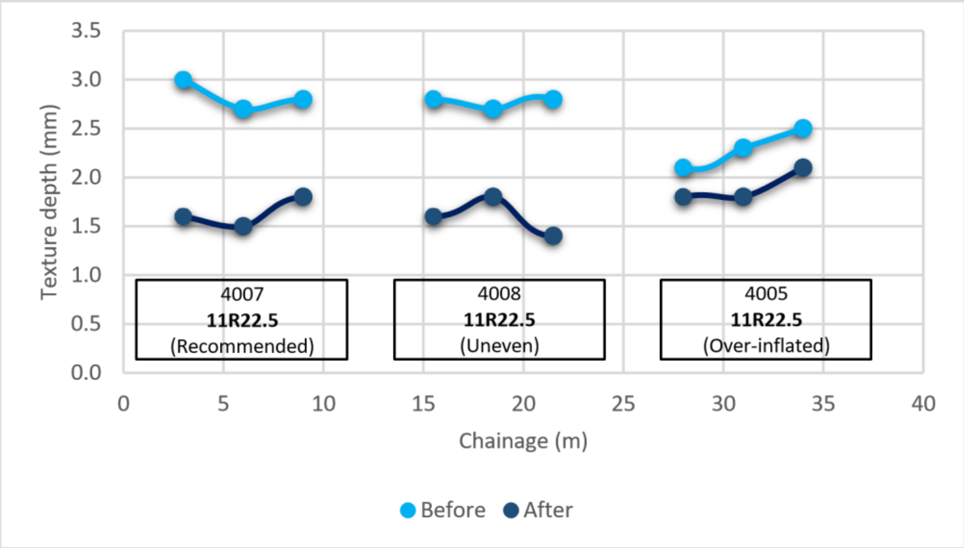
These measurements are an indication of the degree to which the tyres 'smoothed out' the road surface during the experiments. The implication of faster reductions in texture depth is that more frequent resurfacing of a road would be required in order to maintain it at a level of surface texture sufficient to maintain safe levels of friction.

Figure 8.6 Texture depth for 445/50R22.5 tyres measured before and after testing



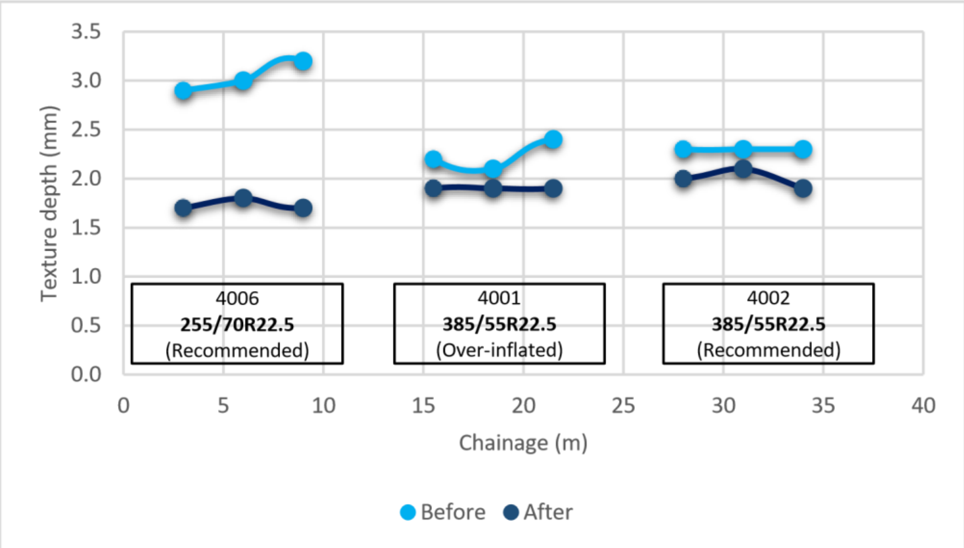
The 445/50R22.5 tyres generated the smallest reduction in surface texture when inflated to the recommended pressure. Over- and under-inflation produced greater reductions in surface texture.

Figure 8.7 Texture depth for 11R22.5 tyres measured before and after testing



At the recommended inflation pressure, and when unevenly inflated, the 11R22.5 tyres caused a larger reduction in surface texture than the 445/50R22.5 tyres. The reduction in texture was smaller when the tyres were over-inflated, but the initial texture depth was lower, suggesting that the initial texture depth has a bearing on how much the tyres will affect the texture depth.

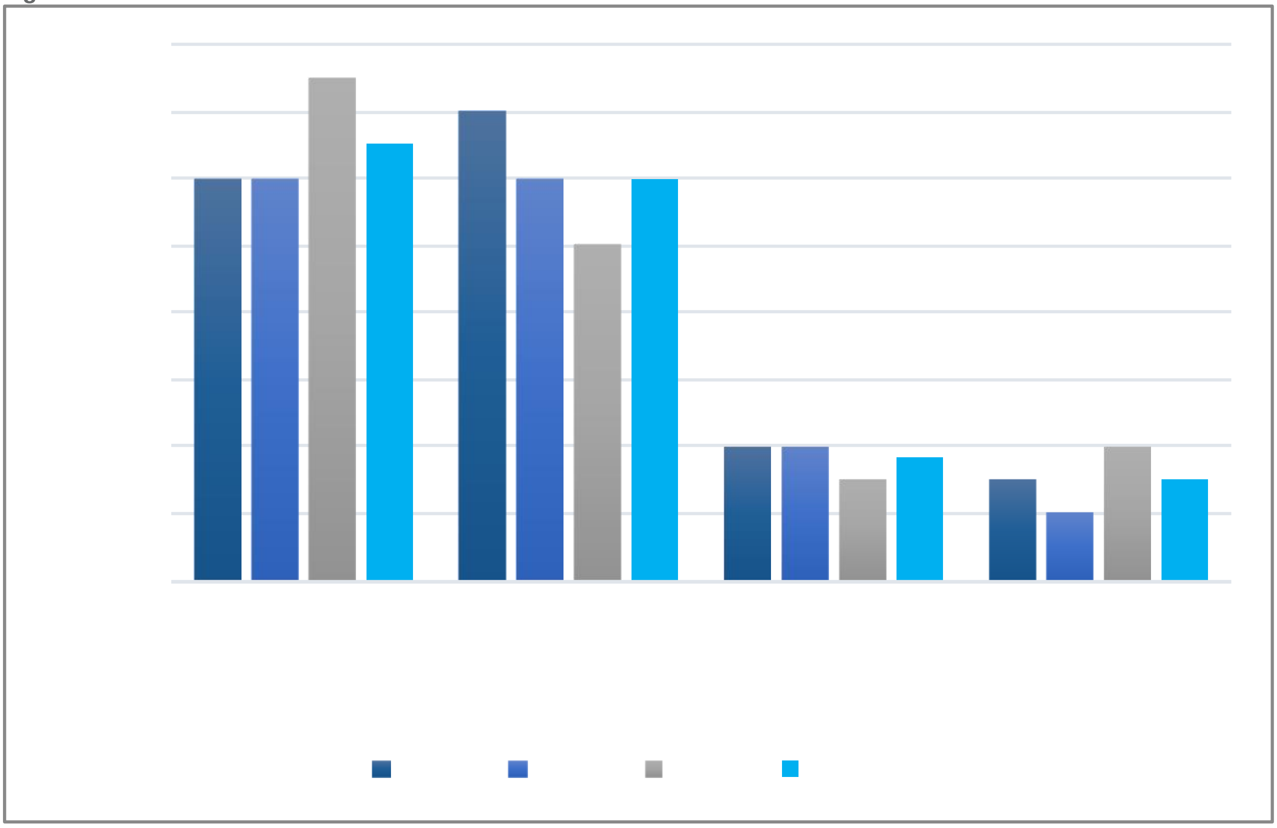
Figure 8.8 Texture depth for 225/70R22.5 and 385/55R22.5 tyres measured before and after testing



In summary, in terms of texture loss, the 255/70R22.5 tyres were the worst, with a mean reduction in texture depth of 1.3 mm. The 385/55R22.5 tyres performed the best with both recommended and over-inflated tyres inducing virtually no change in texture depth. It is noted that the texture depth was low prior to testing commencing.

8.9 Comparison of average decrease in sand texture depth between tested tyres

Figure



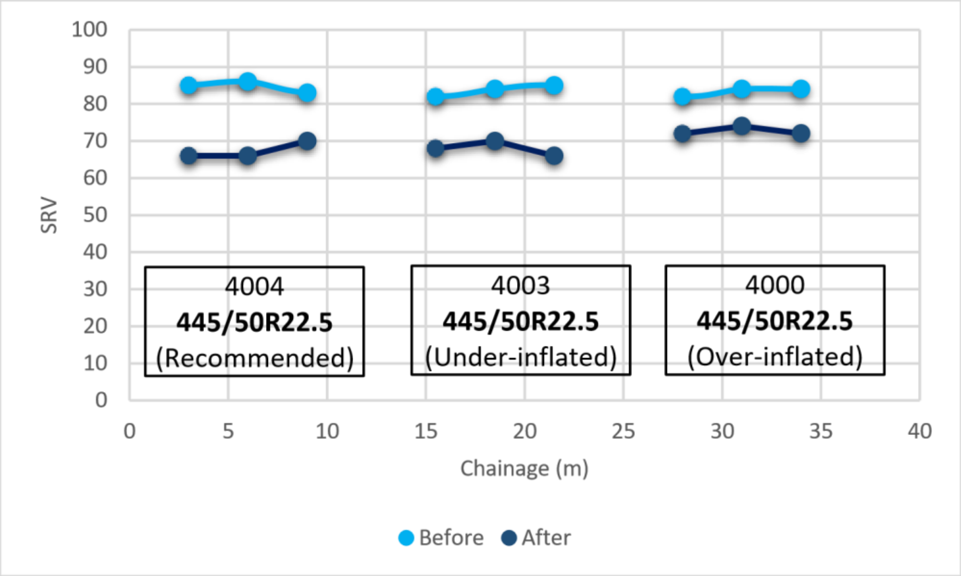
Overall, the 445/50R22.5 and 385/55R22.5 tyres performed significantly better than the 255/70R22.5 and 11R22.5 tyres. This suggests that wide single tyres have a significantly smaller effect on road surface texture than the tested dual tyres. A decrease in texture depth means that the surface stones are being re-oriented or removed, which in turn means that the tyres create a flatter road surface, which effects the surface drainage of the pavement. A satisfactory level of surface texture allows the vehicle's tyres to have better contact with the surface aggregate in the presence of water. This is also closely related with the skid resistance of the surface; however, it is not a direct relationship and the aggregate properties (i.e. microtexture and polishing resistance) play a large role in the pavement surface friction characteristics as discussed in the next section.

8.4 Skid resistance

The changes in Skid Resistance Value (SRV) of the pavement surface during testing are shown in Figure 8.10, Figure 8.11, and Figure 8.12. A larger change in SRV indicates that the tyre has worn the surface to a greater extent with a resulting reduction in skid resistance. However, there was only a small difference between the tyres overall, with the 255/70R22.5 and the 11R22.5 tyres having less of an effect on SRV than the wide single tyres.

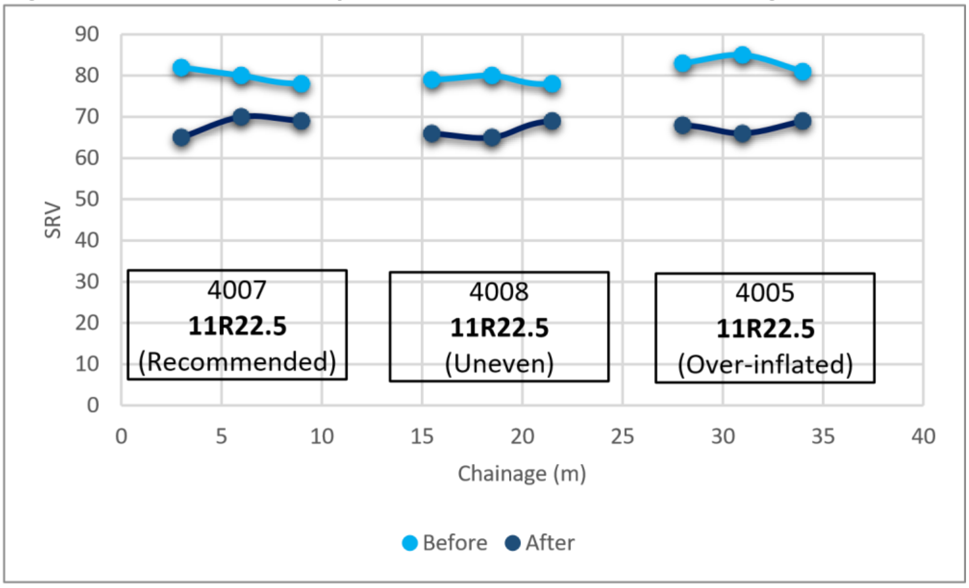
8.10 SRV for 445/50R22.5 tyres measured before and after testing

Figure



The 445/50R22.5 tyres generated an approximately 17% reduction in skid resistance over the course of the experiment for both the recommended and under-inflated tyre, with an average SRV loss of 20% and 19% respectively. The over-inflated tyre, however, caused a comparatively low SRV loss of 13%.

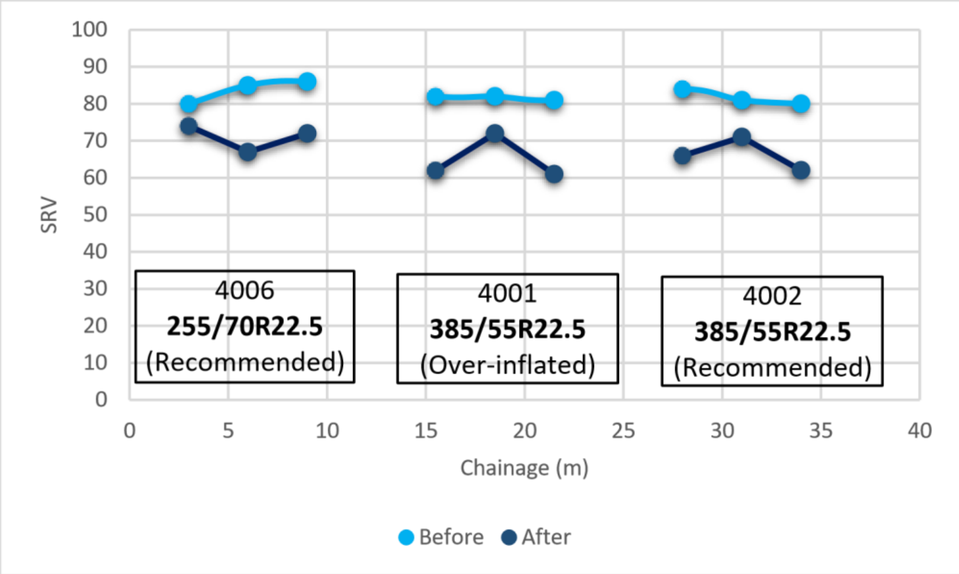
Figure 8.11 SRV for 11R22.5 tyres measured before and after testing



Reductions in SRV differed slightly across the 11R22.5 tyres but final values were similar. The reduction in SRV with the over-inflated tyres was greatest, with a SRV difference of 18%, compared with 15% and 16% for both the tyres at recommended pressures and the unevenly inflated tyres respectively. This is a comparatively better result than the 445/50R22.5 tyres.

8.12 SRV for 255/70R22.5 and 385/55R22.5 tyres measured before and after testing

Figure



The measurements taken along the test sections involving the 385/55R22.5 tyres produced the most varied results, with a reduction of 20% in the SRV for recommended pressure, and 19% for over-inflated tyres. There was a similar variation along the test section used for the 255/70R22.5 tyre, with an SRV difference of 15%.

Figure 8.13 Comparison of decrease in SRV between tested tyres

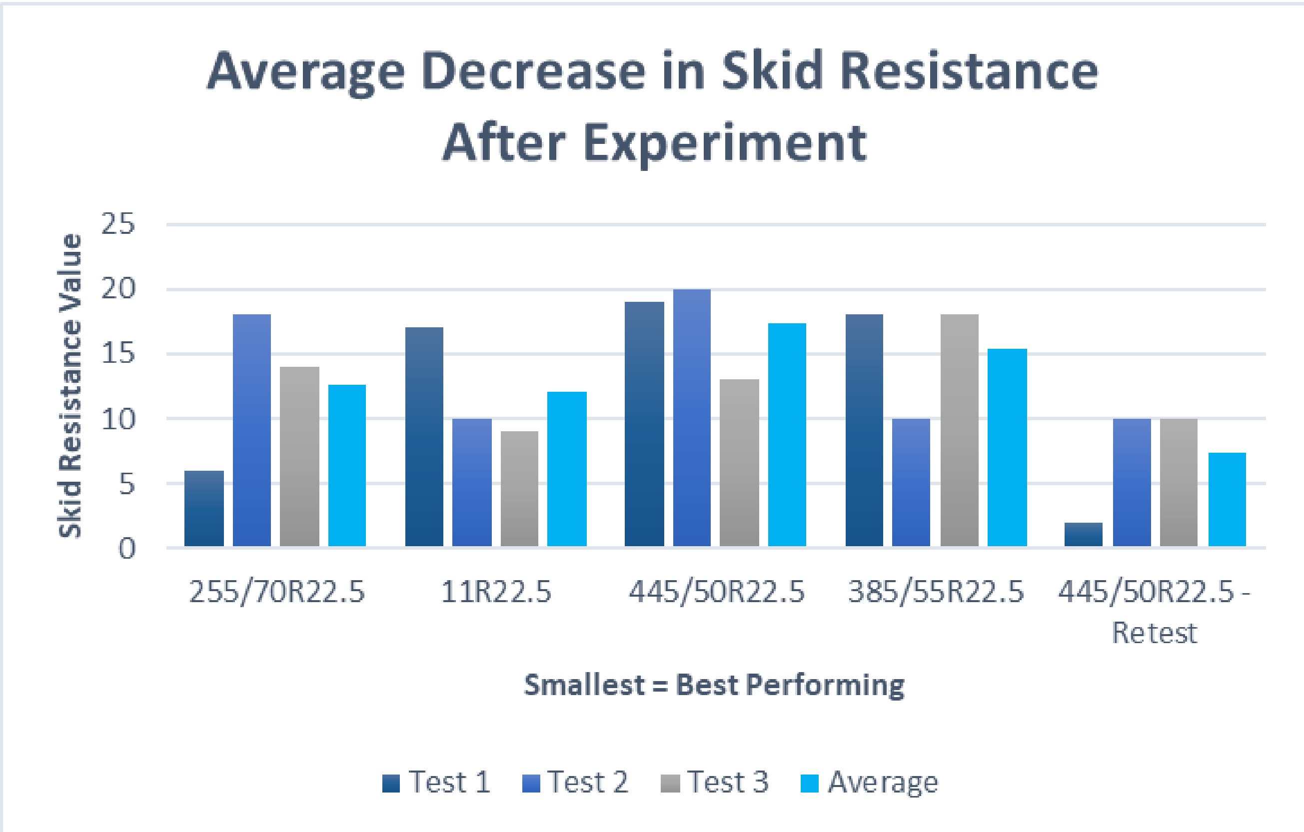


Figure 8.13 shows the average reduction in skid resistance for each tyre at their recommended pressures. It is apparent that both wide single tyres tended to have larger differences in SRV than the dual tyres. It is

Figure

important to note that, as the measurements were taken in the centre of the lane, the wide tyres trafficked this section of the pavement more than the dual tyres due to the gap between the two tyres in the dual set being located in the centre of the test area. It is noted that, while surface texture is related to skid resistance, it is not the only contributing factor, with the microtexture of the aggregate also playing a role.

9. Discussion

The Australian road network covers a vast area with road connections through urban areas, regional areas and remote locations. In urban areas, road pavements, including motorways and heavy vehicle routes, are typically composed of thick asphalt or concrete, while the majority of road pavements in regional and rural areas are unsealed gravel roads. Over 90% of the regional and rural sealed roads are composed of a sprayed sealed surface and an unbound granular base. This includes major highways and heavy vehicle freight routes. This low-cost all-weather pavement has generally performed well under the prevailing heavy vehicle freight task. It was for this reason that this 'typical' Australasian pavement type was selected for this study.

Wide single and ultrawide single tyres have been available for decades internationally. Many studies including the COST 334 study undertaken by the European Union in the late 1990s (European Commission Directorate General Transport 2001) and similar studies in the USA have 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. These overseas heavy duty pavement structures are more representative of urban heavy-duty asphalt or concrete pavements in Australasia. However, it should be noted that what is considered a 'thick' heavy duty asphalt pavement in Australasia would be considered a 'thin' asphalt pavement in Europe, the USA and Asia.

There have not been substantial studies of the relative performance of sprayed seal unbound granular pavements for new generation of ultrawide single tyres compared with dual tyres. This is an area of primary interest in Australasia as it is a barrier to the adoption of ultrawide single tyres in Australasia.

Early limited studies in Australia during the 1980s using a response-to-load approach on 385/65R22.5 wide single tyres indicated an increased relative pavement wear of up to five times compared with dual tyres. This work set the precedent for load restrictions on the use of wide single tyres on heavy vehicles in Australasia. It also resulted in a lack of desire on the part of road owners to further study the impacts of wide tyres on road wear.

However, the development of ultrawide single tyres, including the 445/65R22.5 super single tyre, in the early-2000s led to the wide adoption of single tyre configurations across Europe and the USA (resulting from studies such as COST 334). A range of benefits were established, including lower rolling resistance leading to reduced fuel consumption, greater lateral stability due to the wider tyre tracking and increased pay load due to the reduced number and tare weight of wheels for single versus dual wheel configurations.

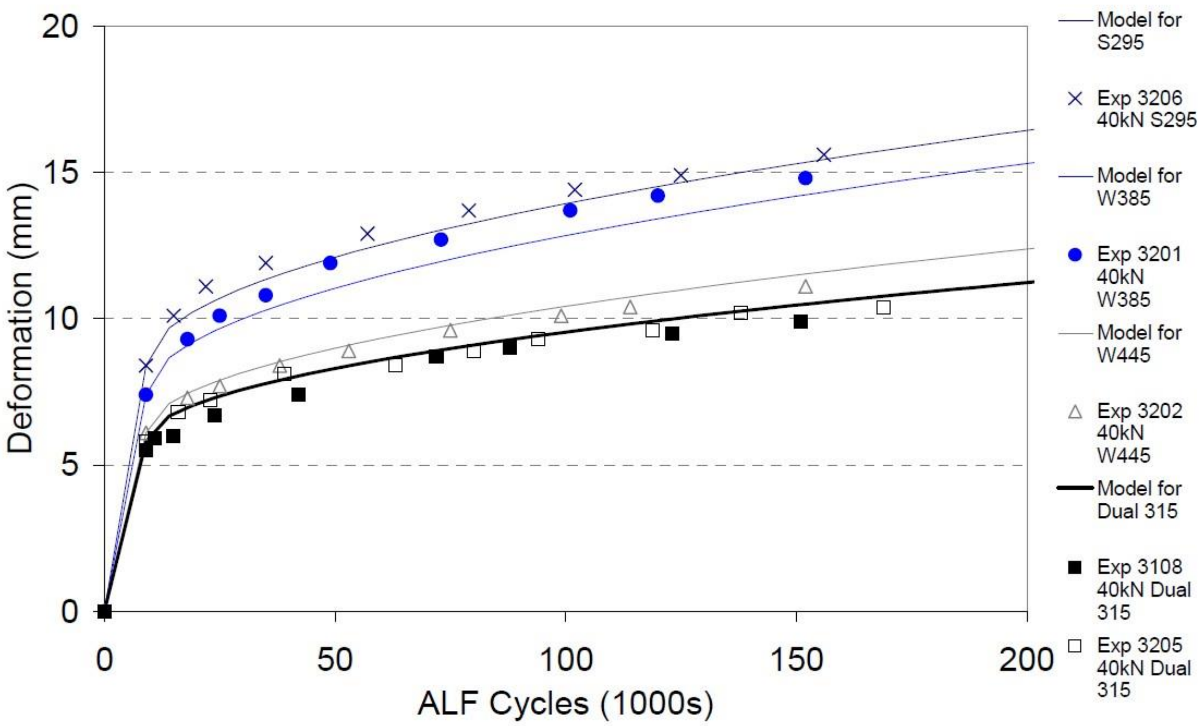
The major gap in knowledge remained the relative pavement wear of these new ultrawide super single tyres compared with dual tyres on Australasian sprayed seal surfaced unbound granular pavements.

The ARRB ALF is a full-scale pavement test facility designed to simulate long-haul heavy vehicle loading and to quantify pavement wear under controlled conditions. The ALF has been in use since 1984 and many studies of pavement and materials performance have been conducted. As such, the ALF provides a means to gain a better understanding of the relative wear of wide single and dual tyre configurations on different pavement structures. It provides a much-improved comparison as compared to the simpler response-to-load approach used earlier.

One impediment for the use of the ALF has been the lack of interest and research investment to address the ultrawide single tyre versus dual tyre comparative performance issue. This is because road agency innovation funding has been prioritised on materials and pavement performance under dual tyre loading only. Proposals to investigate the relative performance of ultrawide single tyres compared with dual tyres have not been prioritised by transport agencies/asset owners as mentioned above.

Only one limited study, part-funded by road agencies and part-funded by a tyre supplier, has been conducted in the early 2000s (Austroads 2008). The key results of this study are shown in Figure 9.1.

Figure 9.1 ALF deformation data for different tyre configurations based on deformation model



This study provided solid evidence that the pavement wear for the 445/65R22.5 tyre was very similar to the conventional dual tyres, noting that the ALF dual tyres used were a larger 315/80R22.5 tyre, not the more common 11R22.5 dual tyre size. The ALF trafficking was undertaken at a full axle load of 8 tonne (40 kN half axle) in all cases.

With the low prioritisation and lack of investment in this topic over many years it was with great enthusiasm that ARRB took up the opportunity to again use the ALF to determine the relative wear of a range of single tyre sizes in partnership with the TIC, NHVR and other stakeholders. A typical Australian sprayed seal surfaced unbound granular pavement design was adopted for the experiment design which involved a range of wide single tyres compared against standard 11R22.5 dual tyres. One additional parameter was added, this being the tyre inflation pressure which had been a fixed value for the earlier experiments.

Significant effort was put into the design and construction of a uniform sprayed seal-surfaced unbound granular test pavement which could accommodate the required number of experiments to complete the test matrix of tyre configurations and tyre inflation pressures. Preliminary works involved excavation of the entire site and the construction of a concrete tank lining the test pavement area to isolate this from external moisture changes. This was done at ARRB’s CAPEX cost as an improvement to its ALF test facility in support of this study. A select clay subgrade was carefully constructed in the test tank and this was dried to a uniform moisture content and target CBR value. It should be noted that, as a natural material, there was some variability in the clay subgrade.

The granular material was brought in, mixed and compacted then dried back prior to sealing. A heavy-duty seal design was placed to complete the test pavement construction and extensive assessment and measurements were made across the whole pavement area. A key issue was pavement uniformity which would allow the best chance for a direct comparison of pavement wear for each tyre type and tyre inflation pressure – each ALF experiment has to be conducted on a separate test pavement area.

A key issue was pavement uniformity, particularly a uniform, consistent moisture content across the entire test pavement area as this is required for valid rut performance comparisons. It is well established that variations or changes in moisture content (and compacted density, material grading, plasticity and subgrade support) in sprayed sealed granular pavements can have a significant influence on performance under traffic loading. Project stakeholders would have observed first hand pavement deterioration of this pavement type in wet weather conditions.

While the test pavement was constructed from a manufactured crushed rock material, it is still subject to variations in grading, thickness, compacted density, clay subgrade support and moisture content – even though it was sealed and in a concrete isolation tank inside the fully enclosed ALF shed. Some of this potential non-uniformity of the test pavement areas can be accounted for through the extensive pavement assessment data collected, particularly the FWD deflection measurements conducted regularly in the lead up to, and during, each ALF experiment as well as moisture content and compacted density testing.

In terms of the ALF loading, this is very well controlled with the axle load achieved using steel weights on an airbag swing arm suspension system with wheels driven at a uniform speed of 20 km/h along the 12 m test pavement. A consistent lateral wander program was incorporated so that a normal distribution traffic pattern was applied across 1 m width of the test pavement. Due to the available budget, only 50,000 8 tonne (40 kN half axle load) load cycles could be applied during each ALF experiment. This resulted in rutting of the order of 4 mm to 5 mm for each experiment which is quite low compared to the earlier study (Austroads 2008) which involved 150,000 cycles per experiment resulting in rutting in the order of 10 mm to 15 mm as shown in Figure 10.1.

Table 9.1 compares the 2007 and 2023 tests, with the deformation rate for the 2007 tests determined using a similar method to that used in 2023. It should be noted that the tests in 2007 should be considered relative to each other and not compared against the 2023 tests, as the pavements and tyre configurations varied.

Table 9.1: Comparison of 2007 and 2023 test programs

Year	Experiment (Site)	Tyre configuration	Inflation pressure kPa (psi)	ALF load cycles	Deformation at 52,500 cycles (mm)	Deformation at 9000 cycles (mm)	Deformation rate (mm/cycle)
2007-08	1 (3108)	315/80R22.5 dual	760 (110)	151,000	–	5.5	–
2007-08	2 (3201)	385/60R22.5 wide single	760 (110)	151,600	12.0	7.4	10.51×10^{-5}
2007-08	3 (3202)	445/65R22.5 wide single	760 (110)	152,400	8.9	6.1	5.90×10^{-5}
2007-08	4 (3205)	315/80R22.5 dual	760 (110)	169,000	7.8	5.8	4.68×10^{-5}
2007-08	5 (3206)	295/80R22.5 single steer	760 (110)	156,000	12.4	8.4	8.74×10^{-5}
2022-23	1 (4006)	255/70R22.5 dual	675 (98) for both	67,500	4.13	3.24	1.91×10^{-5}
2022-23	2 (4007)	11R22.5 dual	525 (76) for both	52,500	3.43	3.02	1.17×10^{-5}
2022-23	3 (4008)	11R22.5 dual	525 (76) for inner 682.5 (99) for outer	52,500	3.04	2.45	1.42×10^{-5}
2022-23	4 (4005)	11R22.5 dual	682.5 (99) for both	75,000	3.27	2.53	1.60×10^{-5}
2022-23	5 (4004)	445/50R22.5 wide single	700 (102)	60,000	2.95	2.27	1.70×10^{-5}

2022-23	6 (4003)	445/50R22.5 wide single	560 (81)	60,000	3.20	2.26	2.17×10^{-5}
2022-23	7 (4000)	445/50R22.5 wide single	840 (122)	52,500	2.37	1.77	1.24×10^{-5}
2022-23	8 (4001)	385/55R22.5 wide single	900 (131)	60,000	1.86	1.34	1.12×10^{-5}
2022-23	9 (4002)	385/55R22.5 wide single	790 (115)	67,500	2.82	2.25	1.44×10^{-5}
2022-23	10 (4012)	445/50R22.5 wide single	700 (102)	200,000	3.34	2.45	1.80×10^{-5}

Although the level of rutting observed from the most recent testing is low when compared to the 2007 tests, the ALF data set is considered valid and representative as the shape of the rut development fitted in well with the expected rut development (high initial rutting followed by a uniform linear, flatter, long-term rut development). This was further validated by running two additional experiments out to 200,000 ALF cycles and comparing the linear, flatter, long-term rut development which was consistent with the lower (50,000 cycle) experiments.

A significant issue that was identified in the data set was that the 445/65R22.5 tyre experiments produced an unexpected result. These 445/65R22.5 experiments conducted at different inflation pressures generated moderate pavement wear in the form of rutting but the magnitude of this rutting was higher than would be expected relative to the dual tyres and the 385/65R22.5 single tyre. Much effort has been applied to investigate the reasons for this and to potentially correct for this in terms of variability between the test pavements. However, while this investigation of the performance data is continuing and the ALF is available, the ARRB project team decided to repeat this experiment for the 445/65R22.5 tyre. The results of this repeated test were included in the analysis.

It is normal practice in laboratory studies to complete testing in 'triplicate'. Further, achieving statistical significance at a 95% confidence level generally requires sample sizes of six or more, in this case there has only been one ALF experiment per tyre configuration. This full scale accelerated loading experiment design (sample size of one) is a function of the effort required per experiment, including the time and cost for each ALF experiment. There is always the risk that the sample size of one ALF experiment per tyre configuration may deliver an outlier or unexpected result which does not align with the trend of the associated test results.

The need to undertake additional ALF experiments to boost the sample size is not unexpected and this requirement has been used in the past, including for the earlier work published in 2008 (see the repeat for the 315/80R22.5 dual tyre experiment in Austroads (2008).

Overall, this TIC/NHVR ALF study of wide single tyres is adding significant new performance data which is expanding the state of knowledge in Australasia. Encountering unexpected or inconsistent results from this type of experimental work is common: if the results were known in advance, then there would not be a huge benefit in undertaking the study. The ARRB team has ensured a valid and robust result under the available time and budget constraints to achieve the new knowledge sought, acknowledging that there is a need to build positively on the knowledge base which has taken such a long time to populate in this subject area.

10. Conclusions

Wide single and ultrawide single tyres have been available for decades internationally, based on the results of many studies including the COST 334 study, 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 in place of dual tyre configurations has occurred in Europe and the USA. However, there have not been significant studies of the relative performance of sprayed seal unbound granular pavements subjected to ultrawide single tyre with dual tyre loading which isa barrier to the adoption of ultrawide single tyres here.

The aim of this project was to compare the pavement wear effects of sprayed seal unbound granular pavements subject to wide single tyre with dual tyre loading.

Overall, the results suggest that the level of pavement wear from all of the tyre configurations tested was similar. However, some differences that merit attention as now discussed.

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 both the dual tyres and single tyres were within a similar range (within the variability of the experiment). The deformation rate of the 255/70R22.5 dual tyres was the highest.
- 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 did not correlate with deformation rate, with other contributing factors including contact patch area, shape and pressure distribution.

Profile of pavement rutting

- The peak value of the rut profile (over 3 mm) under 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 11R22.5 tyre sets generated rutting that was wider and deeper than the rut produced by the wide single tyres. However, the difference in rut depth between the 11R22.5 and the wide single tyres was small and it may be insignificant. More experimental 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 on pavement wear.
- It is clear from the comparison of the rutting profiles that the dual tyres and single tyres wear different areas of the pavement. This is because dual tyres traffic a wider transverse path, whilst the wide single tyres traffic a narrower path in the centre of the trafficking lane, an area less trafficked by dual tyres. It is expected that if trafficked over the same pavement section, both dual tyres and wide single tyres would result in a more evenly dispersed lateral wear pattern.
- It should also be noted that the traversing profile of ALF (which can be varied) was narrower than what is applied in practice. This traversing profile was selected to concentrate the loading and increase the amount of deformation.

Inflation pressure

- Based on the deformation rates, inflation pressure was found to have a significant effect on wear for the dual 11R22.5 tyres, but not for wide single tyres. The most damaging option for the 11R22.5 was when it was over-inflated. This 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 (689 kPa) with the 445/50R22.5 tyres 102 psi (703 kPa) and the 385/55R22.5 tyres at 115 psi (792 kPa),

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 mm/cycle 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 would imply that wide single tyres can operate at a wider range of inflation pressures, with no discernible difference in pavement wear. The findings are not aligned with the COST 334 conclusion and could be further investigated. However, this observation 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) when compared with dual tyres.

Effect on pavement wear

- A hypothesis to explain the small differences in rutting observed for all tyres is that the variations due environment factors, pavement construction and measurement tolerance had a greater impact on pavement wear (approximately 0.000012 mm/cycle) than the (small) differences associated with variations in tyre configuration.
- Significant effort was put into the design and construction of a uniform sprayed seal-surfaced unbound granular pavement, such that the pavement would be representative of common (good) construction practice and aligned with previous pavement designs used for testing, e.g. by Austroads (2008). It could be expected that the use of accelerated loading would allow the relative performance under the different tyre types to be identifies sooner than what would be expected in practice. However, the total deformation was only 3-4 mm for the dual tyres and 2-3 mm for the single tyres.
- The test conditions were well controlled, protected from the elements, sealed and protected from moisture ingress by underground surrounding concrete walls inside the fully enclosed ALF shed. Despite this, the variations in the test environment and subgrade natural variability 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 have a greater influence on field performance.
- The 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 need to be clarified by determining the load equivalency for each tyre. Further trafficking would also be recommended, perhaps on a weaker pavement to corroborate the finding.

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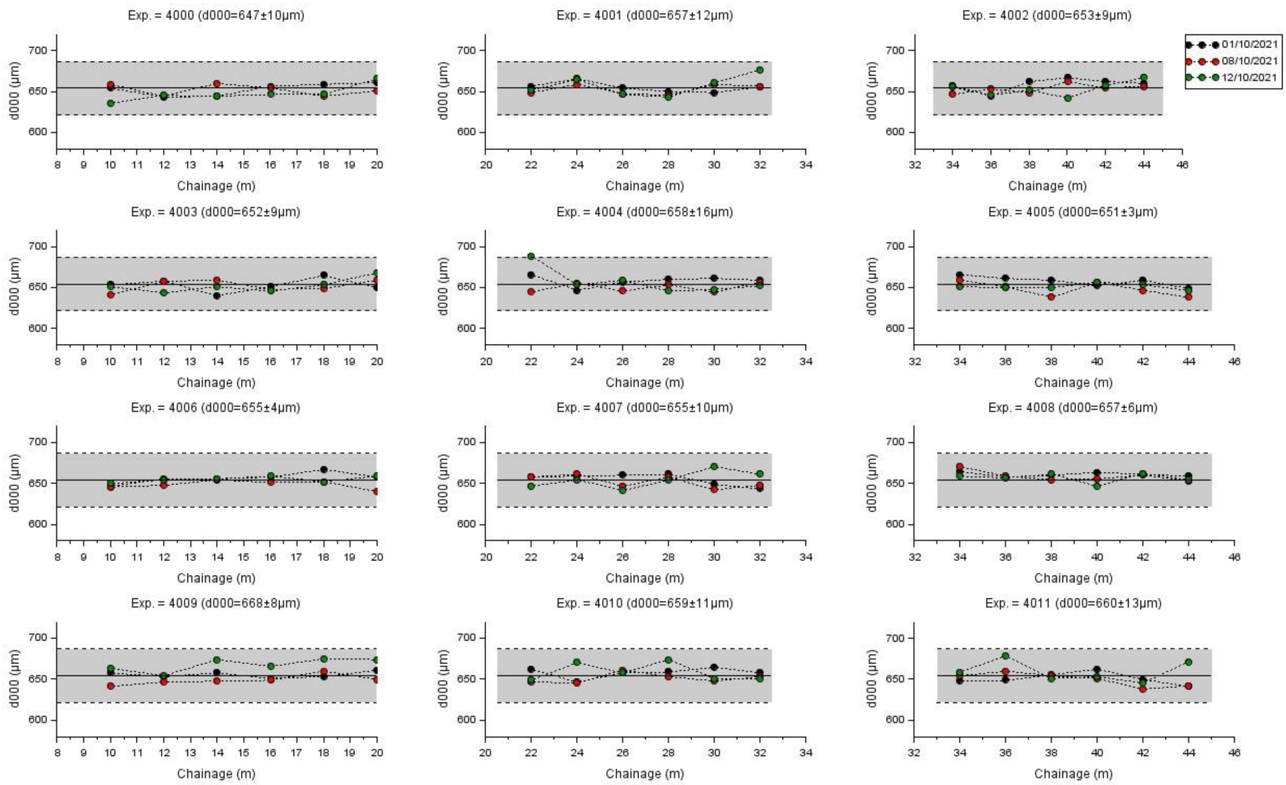
AGAM-T006-11: *Pavement deflection measurement with a falling weight deflectometer (FWD)*.

AGAM-T009-16: *Pavement rutting measurement with a laser profilometer*.

Appendix A Results of Deflection Testing

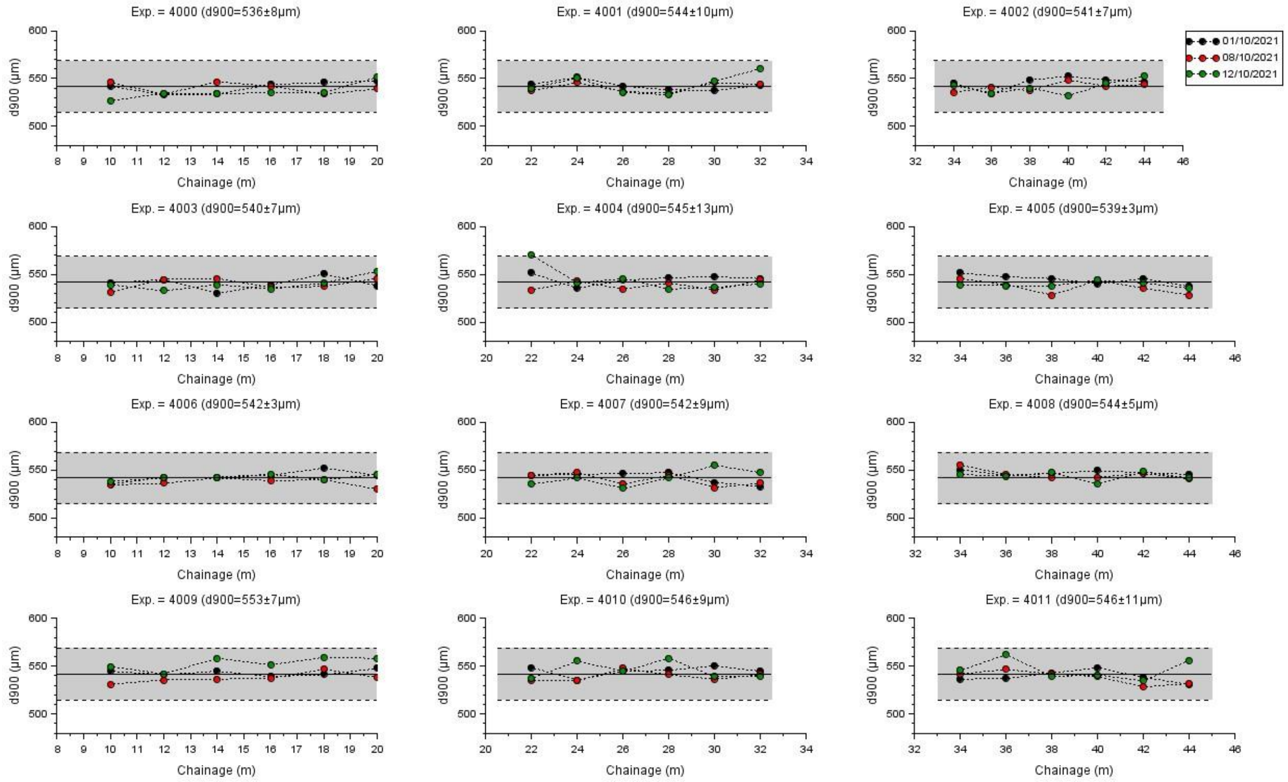
A.1 After Sealing and Before Trafficking

Figure A.1: Maximum deflection d0 (normalised to 40 kN)



Note: Grey areas represent the overall mean deflection for all experiments ± 5%

Figure A.2: Deflection d900 for geophone offset 900 mm (normalised to 40 kN)



Note: Grey areas represent the overall mean deflection for all experiments ± 5%

A.2 Deflections Measured during ALF Trafficking

Table A.1: Falling Weight Deflectometer data: test 1 (experiment 4006)

Load	Chainage		Temperature (°C)		Load	Deflection (µm)								
Cycle	Site	Experiment	Surface	Air	(kPa)	0	200	300	450	600	900	1200	1500	1800
0	8	0	14.7	13.3	556.0	520.2	234.0	154.6	102.1	74.1	51.0	37.6	32.3	27.1
0	8.5	0.5	14.6	13.2	573.0	438.6	234.0	158.4	104.6	75.5	50.8	38.8	33.0	27.6
0	9	1	14.5	13.1	567.0	542.6	236.3	156.2	99.7	73.1	48.7	37.3	31.6	26.3
0	9.5	1.5	14.4	12.9	556.0	499.7	222.5	149.3	99.0	70.7	47.4	36.5	31.1	25.8
0	10	2	14.4	12.8	550.0	467.8	218.5	143.6	94.6	69.8	46.9	35.6	29.4	25.5
0	10.5	2.5	14.5	12.7	548.0	414.5	212.9	146.8	95.1	71.4	49.3	35.3	29.4	25.1
0	11	3	14.5	12.5	553.0	498.8	220.9	150.6	97.9	71.7	46.6	36.0	30.3	25.3
0	11.5	3.5	14.3	12.3	560.0	422.6	204.0	141.2	95.1	68.6	45.7	38.9	31.5	26.6
0	12	4	14.2	12.3	545.0	428.3	192.9	130.7	89.6	66.3	44.9	36.3	29.7	24.9
0	12.5	4.5	14.2	12.2	544.0	485.7	215.9	143.4	89.7	66.2	46.1	35.5	30.2	25.3
0	13	5	14.1	12.1	605.0	484.0	259.2	166.6	109.6	74.9	52.1	39.9	36.0	28.4
0	13.5	5.5	14.1	12.0	597.0	592.7	247.7	167.8	106.4	79.0	51.7	39.1	32.9	27.7
0	14	6	14.1	12.0	599.0	548.7	263.1	168.8	108.5	79.6	53.2	40.5	33.6	28.4
0	14.5	6.5	14.1	11.9	591.0	511.0	249.1	159.3	99.8	74.7	51.5	39.1	31.8	27.4
0	15	7	14.1	11.9	597.0	571.8	252.8	165.0	105.0	76.3	52.0	39.9	33.9	29.1

0	15.5	7.5	14.1	11.8	581.0	503.7	246.0	164.1	104.8	75.9	52.5	40.7	34.4	28.7
0	16	8	14.1	11.8	605.0	596.4	277.4	169.8	105.3	76.5	53.2	41.6	35.1	29.0
0	16.5	8.5	14.1	11.8	603.0	632.1	301.3	184.1	104.5	75.6	52.2	41.7	35.3	29.6
0	17	9	13.9	11.7	597.0	676.9	301.3	191.0	109.0	76.0	50.1	45.0	35.7	35.0
0	17.5	9.5	13.8	11.8	593.0	575.5	298.8	188.3	107.8	74.6	51.8	40.6	35.4	29.6
0	18	10	13.7	11.8	592.0	581.8	278.3	171.9	104.6	73.7	50.8	41.4	34.2	28.5
0	18.5	10.5	13.6	11.9	592.0	576.8	272.5	167.5	101.0	70.4	49.4	41.8	36.7	30.8
9000	8	0	16.4	15.5	576.0	504.9	258.1	170.1	108.5	77.2	54.0	40.4	33.8	29.1
9000	8.5	0.5	16.1	15.5	562.0	474.7	278.5	189.7	114.6	78.4	52.0	40.9	34.3	27.1
9000	9	1	16.1	15.4	564.0	549.1	274.5	187.2	111.0	82.2	52.3	39.6	33.3	27.6
9000	9.5	1.5	16.1	15.4	566.0	533.3	266.7	181.0	115.0	77.7	50.1	39.6	31.5	24.3
9000	10	2	16.1	15.3	551.0	505.0	262.7	175.3	110.1	78.8	51.0	35.4	32.7	28.5
9000	10.5	2.5	16.2	15.3	588.0	489.6	276.5	181.3	111.9	76.9	53.7	38.9	30.3	31.4
9000	11	3	16.2	15.3	547.0	517.8	253.5	169.5	105.8	78.8	48.4	34.4	30.4	25.4
9000	11.5	3.5	16.2	15.3	561.0	496.1	243.3	166.3	103.9	75.7	48.8	38.3	32.0	27.8
9000	12	4	16.2	15.2	580.0	519.4	267.7	168.2	106.4	75.8	51.8	38.6	32.6	27.7
9000	12.5	4.5	16.2	15.2	575.0	527.8	265.2	174.9	107.5	74.0	51.0	38.4	34.3	30.3
9000	13	5	16.1	15.1	568.0	501.4	292.7	186.0	113.5	77.7	50.9	38.7	32.6	30.9
9000	13.5	5.5	16.1	15.0	562.0	625.7	290.9	194.6	115.6	79.7	50.9	38.6	33.1	27.4
9000	14	6	16.0	15.0	568.0	579.6	326.8	200.9	120.5	86.4	53.4	37.0	36.7	31.2
9000	14.5	6.5	16.1	15.0	558.0	527.2	299.9	183.0	107.8	75.4	51.5	40.3	32.2	27.5
9000	15	7	16.0	15.0	583.0	594.0	280.2	185.8	110.0	77.9	53.4	41.3	35.0	28.0
9000	15.5	7.5	16.0	15.0	576.0	556.8	305.5	203.9	107.9	82.7	51.2	42.8	32.0	28.5
9000	16	8	16.0	15.0	579.0	663.2	332.2	207.5	109.2	81.3	60.2	40.1	42.3	29.1
9000	16.5	8.5	16.0	15.0	557.0	752.7	382.9	230.4	113.2	75.3	52.2	41.9	35.0	29.0
9000	17	9	15.9	15.0	552.0	711.6	369.7	219.0	114.1	69.3	49.8	39.2	33.8	28.7
9000	17.5	9.5	15.9	15.0	557.0	628.7	366.5	228.9	113.7	73.2	47.6	42.0	32.5	27.2
9000	18	10	16.0	15.0	553.0	627.3	359.2	211.8	113.1	72.9	50.1	39.9	34.1	27.9
9000	18.5	10.5	16.0	15.1	589.0	614.6	344.5	208.5	111.3	72.8	51.3	41.4	36.6	27.6
75000	8	0	27.4	30.5	529.0	541.2	292.7	183.2	105.1	74.2	50.6	37.8	31.6	26.2
75000	8.5	0.5	27.0	30.5	536.0	518.1	303.4	199.9	115.5	78.4	51.1	37.7	30.5	27.4
75000	9	1	26.9	30.5	546.0	580.7	294.8	193.9	110.2	74.6	51.7	32.8	30.5	22.9
75000	9.5	1.5	27.1	30.5	546.0	575.2	291.4	188.8	108.9	74.3	44.1	38.9	28.3	26.1
75000	9.5	1.5	27.1	30.5	546.0	575.2	291.4	188.8	108.9	74.3	44.1	38.9	28.3	26.1
75000	10	2	27.1	30.5	561.0	543.0	293.5	189.4	112.2	75.6	49.0	37.2	29.1	25.4

75000	10.5	2.5	27.2	30.5	557.0	491.8	297.8	187.1	114.2	78.6	43.6	34.8	28.6	23.2
75000	11	3	27.2	30.5	559.0	533.6	274.8	179.4	108.9	74.7	55.0	31.6	25.9	24.5
75000	11.5	3.5	27.2	30.4	554.0	512.3	261.5	166.3	101.7	71.5	47.7	34.8	24.0	20.0
75000	12	4	27.2	30.4	550.0	548.6	290.2	174.2	102.6	71.4	47.6	37.6	31.5	26.5
75000	12.5	4.5	27.0	30.4	530.0	561.4	269.4	176.5	99.7	68.8	49.0	36.1	29.8	27.1
75000	13	5	27.2	30.4	540.0	536.3	311.7	199.5	109.2	76.0	51.1	35.6	32.7	28.0
75000	13.5	5.5	27.1	30.5	528.0	643.3	314.6	195.4	111.7	72.9	48.3	37.4	30.3	25.5
75000	14	6	27.0	30.6	552.0	617.5	335.0	212.5	111.3	78.2	51.1	38.0	31.4	25.0
75000	14.5	6.5	27.2	30.6	542.0	557.8	323.2	196.9	108.7	72.7	49.3	38.5	30.1	25.9
75000	15	7	27.0	30.7	553.0	611.9	307.1	196.5	107.8	74.5	50.8	40.1	32.8	27.0
75000	15.5	7.5	27.2	30.9	529.0	568.5	308.1	193.3	106.7	73.7	53.9	37.2	29.1	19.9
75000	16	8	27.3	31.0	519.0	653.5	331.8	192.0	102.3	70.7	43.3	38.3	31.5	26.0
75000	16.5	8.5	27.1	31.2	536.0	737.4	375.5	219.9	103.4	69.5	48.9	38.6	33.7	27.4
75000	17	9	27.3	31.4	535.0	721.7	382.5	217.2	99.8	68.6	52.4	34.6	30.6	24.5
75000	17.5	9.5	27.4	31.6	501.0	729.5	364.8	207.4	99.7	61.5	43.4	37.4	31.9	26.3
75000	18	10	27.0	31.8	543.0	665.9	387.2	224.0	107.6	65.7	50.0	39.0	32.4	26.9

Table A.2: Falling Weight Deflectometer data: test 2 (experiment 4007)

Load	Chainage		Temperature (°C)		Load	Deflection (µm)								
Cycle	Site	Experiment	Surface	Air	(kPa)	0	200	300	450	600	900	1200	1500	1800
0	20.5	0	26.7	28.8	531.0	482.4	260.3	167.6	97.6	69.9	48.4	39.5	37.7	28.9
0	21	0.5	26.4	28.9	529.0	469.7	222.5	153.3	96.3	74.9	50.8	39.8	35.3	28.9
0	21.5	1	26.5	28.9	523.0	474.8	231.6	157.0	101.2	77.3	50.3	39.8	33.8	28.6
0	22	1.5	26.4	28.9	529.0	468.5	223.0	146.9	99.4	72.7	49.9	38.6	33.5	29.4
0	22.5	2	26.2	29.0	536.0	439.7	209.8	145.9	91.2	72.8	49.7	38.8	34.4	28.7
0	23	2.5	26.2	29.0	537.0	432.4	211.3	143.6	91.6	70.4	48.3	39.0	33.9	28.7
0	23.5	3	26.2	29.0	529.0	544.1	216.3	142.7	87.5	69.9	44.8	37.3	33.9	29.3
0	24	3.5	26.2	29.1	534.0	481.3	217.5	145.9	90.4	66.5	47.1	39.1	33.4	28.3
0	24.5	4	26.1	29.1	533.0	476.3	240.6	152.4	90.5	71.0	48.1	34.5	39.7	27.3
0	25	4.5	26.1	29.1	531.0	495.2	251.6	164.9	101.2	77.1	50.8	37.2	34.7	24.5
0	25.5	5	26.1	29.2	529.0	584.1	255.8	168.4	103.9	76.2	50.6	40.1	33.9	29.5
0	26	5.5	26.0	29.2	536.0	509.6	250.0	172.4	114.6	84.0	52.2	42.0	35.4	29.4
0	26.5	6	26.1	29.3	530.0	538.3	249.0	166.8	112.2	82.0	54.5	40.8	34.0	30.1
0	27	6.5	26.0	29.4	542.0	514.3	251.5	171.5	114.9	84.8	55.2	42.8	36.3	29.6
0	27.5	7	26.1	29.5	532.0	490.0	254.1	174.5	114.8	83.1	55.2	43.1	36.0	29.0

0	28	7.5	26.3	29.6	536.0	473.9	244.9	172.8	115.8	87.0	54.8	43.7	37.4	30.8
0	28.5	8	26.3	29.8	534.0	482.2	242.0	171.3	113.7	87.6	59.4	44.3	35.8	28.7
0	29	8.5	26.4	29.8	535.0	462.0	245.5	172.5	109.2	84.7	55.3	42.6	33.4	28.6
0	29.5	9	26.6	30.0	535.0	448.2	258.4	171.0	107.7	82.3	54.9	41.5	34.8	28.6
0	30	9.5	26.6	30.1	542.0	431.5	233.7	160.4	104.0	80.9	53.0	41.7	37.2	28.8
0	30.5	10	26.7	30.3	534.0	471.4	235.0	158.0	97.7	76.1	52.5	43.4	36.0	26.8
0	31	10.5	26.7	30.5	539.0	483.5	243.9	161.6	101.6	74.3	51.2	42.9	37.1	27.7
9000	20.5	0	22.6	22.2	555.0	540.2	268.2	170.3	99.8	71.2	51.9	41.0	34.1	29.6
9000	21	0.5	22.5	22.2	549.0	517.2	263.1	173.0	102.8	73.5	51.6	41.6	35.4	30.3
9000	21.5	1	22.5	22.3	547.0	527.3	282.7	180.7	110.7	76.9	52.1	41.5	35.6	29.0
9000	22	1.5	22.4	22.3	536.0	506.6	274.3	174.1	101.6	72.6	51.0	40.4	34.3	28.8
9000	22.5	2	22.6	22.3	559.0	516.0	272.2	167.0	97.4	67.5	50.5	42.7	37.6	30.7
9000	23	2.5	22.7	22.4	539.0	527.5	274.3	168.4	100.4	72.3	50.0	40.5	34.8	29.4
9000	23.5	3	22.6	22.5	527.0	681.5	311.4	179.9	92.3	62.9	47.3	38.9	34.0	27.9
9000	24	3.5	22.7	22.5	537.0	574.6	298.8	187.3	99.5	65.6	47.8	39.5	34.4	29.1
9000	24.5	4	22.6	22.6	540.0	603.9	342.1	201.3	105.6	68.4	50.4	39.3	33.7	29.0
9000	25	4.5	22.5	22.6	542.0	645.2	380.4	229.2	117.9	75.2	51.3	41.7	35.7	28.9
9000	25.5	5	22.4	22.6	534.0	676.1	368.5	233.0	123.2	78.2	49.2	38.2	32.6	30.1
9000	26	5.5	22.4	22.7	544.0	640.3	371.6	243.3	140.9	88.9	54.6	42.9	36.0	30.2
9000	26.5	6	22.6	22.8	543.0	663.7	361.5	241.7	136.5	89.8	59.4	41.8	36.5	30.8
9000	27	6.5	22.7	22.9	547.0	649.5	362.6	238.2	139.7	92.4	57.8	44.5	37.1	31.6
9000	27.5	7	22.6	23.0	548.0	650.1	389.7	240.2	134.4	89.3	61.1	40.7	39.8	32.0
9000	28	7.5	22.7	23.1	552.0	593.8	347.4	233.2	135.8	93.3	58.8	45.0	38.0	29.1
9000	28.5	8	22.5	23.3	543.0	624.8	344.3	224.8	133.7	96.9	55.8	39.7	38.1	31.8
9000	29	8.5	22.8	23.4	553.0	612.6	365.8	228.9	132.6	91.1	56.8	43.8	40.1	31.1
9000	29.5	9	22.6	23.7	551.0	602.9	375.9	237.9	128.3	85.9	57.4	45.5	38.2	33.2
9000	30	9.5	22.6	23.8	555.0	561.4	340.7	216.5	127.0	84.3	57.7	45.0	36.2	31.4
9000	30.5	10	22.6	24.0	550.0	623.6	326.2	208.9	115.1	79.8	56.4	44.5	36.3	30.2
9000	31	10.5	22.5	24.2	531.0	592.2	333.4	208.0	112.6	74.2	51.0	41.0	36.4	30.7
52500	20.5	0	26.7	27.1	565.0	525.0	261.7	165.2	100.2	74.7	51.9	40.6	33.1	29.9
52500	21	0.5	26.5	27.1	567.0	520.1	260.4	172.6	100.8	81.2	47.5	41.7	39.1	34.9
52500	21.5	1	26.6	27.2	564.0	540.9	292.9	186.6	107.5	84.0	53.2	43.9	40.5	21.6
52500	22	1.5	26.6	27.2	558.0	549.2	280.9	182.4	105.3	74.9	53.6	41.5	34.5	30.0
52500	22.5	2	26.6	27.2	563.0	539.1	275.9	172.1	98.2	71.6	52.0	44.0	40.1	26.6
52500	23	2.5	26.6	27.3	561.0	575.9	296.8	182.1	101.7	70.7	50.7	41.0	36.5	30.7
52500	23.5	3	26.5	27.3	561.0	711.2	336.7	200.0	95.5	66.3	51.2	42.1	36.9	31.2

52500	24	3.5	26.5	27.4	567.0	616.5	326.1	200.0	103.3	68.4	51.6	41.0	36.2	31.3
52500	24.5	4	26.3	27.4	563.0	623.6	358.7	203.7	107.1	69.0	49.5	39.4	35.1	31.0
52500	25	4.5	26.5	27.5	562.0	668.6	388.6	240.8	120.5	74.8	51.2	42.5	37.2	30.9
52500	25.5	5	26.6	27.5	537.0	685.8	374.3	231.6	120.9	78.8	52.7	38.7	36.4	29.8
52500	26	5.5	26.5	27.6	561.0	678.9	405.0	260.0	139.9	89.5	54.5	42.1	36.9	32.1
52500	26.5	6	26.5	27.7	555.0	704.6	378.6	245.8	138.5	90.0	56.7	42.4	36.0	31.9
52500	27	6.5	26.5	27.7	559.0	674.2	390.5	242.8	141.6	90.4	56.9	45.1	36.9	31.5
52500	27.5	7	26.5	27.8	567.0	683.7	398.7	256.3	138.6	93.2	59.0	44.1	35.2	33.2
52500	28	7.5	26.6	27.8	565.0	621.2	356.9	237.5	139.0	93.9	60.0	45.2	39.0	33.3
52500	28.5	8	26.6	27.9	571.0	654.8	362.2	245.8	140.1	96.4	59.3	45.6	39.1	33.0
52500	29	8.5	26.7	28.0	564.0	633.9	378.6	236.5	136.0	92.1	59.0	44.9	38.8	32.6
52500	29.5	9	26.7	28.1	569.0	632.7	393.2	248.8	135.8	86.2	58.2	44.4	39.3	31.1
52500	30	9.5	26.5	28.1	564.0	606.9	357.4	229.8	130.2	86.4	57.3	44.0	36.4	31.9
52500	30.5	10	26.5	28.2	563.0	639.9	356.5	221.2	119.9	85.1	57.1	41.2	36.5	28.7
52500	31	10.5	26.5	28.3	540.0	598.7	348.3	207.7	118.3	77.0	52.8	46.2	35.6	29.9

Table A.3: Falling Weight Deflectometer data: test 3 (experiment 4008)

Load	Chainage		Temperature (°C)		Load	Deflection (µm)								
Cycle	Site	Experiment	Surface	Air	(kPa)	0	200	300	450	600	900	1200	1500	1800
0	33	0	26.4	27.4	576.0	568.1	299.4	188.3	118.0	77.7	56.3	44.9	36.2	32.7
0	33.5	0.5	26.4	27.4	572.0	625.4	342.4	205.6	118.3	80.1	55.1	44.4	37.8	31.6
0	34	1	26.5	27.3	571.0	748.9	375.1	221.4	121.6	82.6	55.0	45.5	38.1	31.8
0	34.5	1.5	26.5	27.4	569.0	763.5	432.0	254.2	131.7	84.0	55.5	44.3	37.3	32.4
0	35	2	26.5	27.3	576.0	679.2	358.5	225.2	124.3	84.2	56.2	43.3	37.6	32.1
0	35.5	2.5	26.4	27.3	571.0	635.3	353.6	205.9	118.1	82.8	55.9	47.7	38.5	32.8
0	36	3	26.2	27.3	565.0	578.6	311.8	196.8	118.6	83.3	57.9	45.7	38.3	32.0
0	36.5	3.5	26.3	27.2	561.0	568.1	298.9	187.2	112.1	85.0	59.2	44.7	37.6	31.4
0	37	4	26.0	27.2	575.0	595.3	318.8	183.3	105.5	81.9	59.7	46.5	38.8	32.3
0	37.5	4.5	26.1	27.2	571.0	616.3	333.5	191.1	102.2	74.7	56.7	45.8	39.0	32.7
0	38	5	26.1	27.1	567.0	554.2	314.3	194.8	111.8	82.8	57.5	43.6	33.7	31.7
0	38.5	5.5	26.0	27.0	576.0	609.8	299.1	176.0	99.9	74.7	55.4	46.6	42.7	32.6
0	39	6	26.0	27.0	577.0	556.1	270.1	166.6	95.2	77.3	52.1	45.7	45.4	20.3
0	39.5	6.5	26.0	26.9	582.0	568.6	286.0	166.2	94.0	70.7	53.5	42.3	36.6	30.5
0	40	7	25.6	26.7	583.0	492.1	259.0	158.3	89.7	66.1	49.8	40.5	34.7	29.4
0	40.5	7.5	25.6	26.7	583.0	486.2	255.4	154.4	91.5	67.8	49.6	40.9	36.2	31.0
0	41	8	25.6	26.6	576.0	486.3	247.5	145.6	85.2	66.6	49.4	41.0	34.0	28.1
0	41.5	8.5	25.6	26.6	586.0	525.7	250.4	146.9	83.5	62.5	47.0	39.2	33.0	28.4

0	42	9	25.5	26.6	546.0	485.1	211.6	120.7	73.5	60.9	49.2	37.5	32.2	23.9
0	42.5	9.5	25.4	26.6	564.0	450.5	220.9	123.0	74.9	58.5	44.0	36.9	33.3	28.8
0	43	10	25.3	26.6	563.0	452.0	190.5	121.9	75.2	59.1	45.1	36.3	31.6	27.2
0	43.5	10.5	25.3	26.6	569.0	453.5	203.6	125.0	81.0	59.7	45.3	38.2	32.8	27.4
9000	33	0	27.0	26.4	548.0	641.8	312.1	189.9	103.8	74.2	53.5	42.9	36.8	31.3
9000	33.5	0.5	27.0	26.4	543.0	730.1	409.9	237.5	117.3	76.5	53.8	42.1	36.3	27.5
9000	34	1	27.0	26.4	538.0	914.0	505.2	294.2	136.6	80.4	52.3	42.9	37.4	30.7
9000	34.5	1.5	26.9	26.4	535.0	925.4	613.8	351.7	149.2	77.0	49.9	41.4	36.0	29.9
9000	35	2	26.9	26.3	543.0	841.9	470.2	302.6	143.2	87.0	48.1	43.9	39.4	29.6
9000	35.5	2.5	26.9	26.3	549.0	774.6	479.3	281.7	138.5	79.3	55.4	41.9	36.8	29.0
9000	36	3	26.9	26.2	549.0	700.6	417.0	257.6	131.5	84.0	56.5	45.4	33.0	30.2
9000	36.5	3.5	26.9	26.2	557.0	678.1	411.1	239.2	124.8	85.4	59.5	46.1	39.7	33.1
9000	37	4	26.9	26.1	573.0	704.5	406.7	230.6	114.1	77.3	59.5	50.0	42.5	33.2
9000	37.5	4.5	26.9	26.1	560.0	773.2	436.6	243.7	119.7	82.5	54.8	42.7	37.8	33.2
9000	38	5	26.9	26.0	568.0	714.4	465.2	268.3	127.9	79.2	57.9	45.7	38.1	31.6
9000	38.5	5.5	26.9	26.0	577.0	760.6	410.7	235.0	112.5	72.4	56.0	45.6	39.6	32.6
9000	39	6	26.9	25.9	563.0	694.9	366.5	214.5	107.4	73.3	54.1	43.5	37.6	29.6
9000	39.5	6.5	26.9	25.8	561.0	683.8	376.2	217.9	99.6	66.0	51.5	42.6	36.7	31.1
9000	40	7	26.9	25.8	558.0	642.9	359.2	210.7	95.1	62.0	48.5	41.7	35.3	29.3
9000	40.5	7.5	26.9	25.7	568.0	599.8	359.9	206.4	103.6	67.2	47.8	41.5	37.9	34.9
9000	41	8	26.9	25.8	540.0	587.0	325.9	186.3	92.2	60.3	45.6	38.5	33.8	27.9
9000	41.5	8.5	26.9	25.8	560.0	641.7	340.9	189.2	89.9	56.9	46.4	38.9	33.1	27.8
9000	42	9	26.8	25.8	550.0	636.4	305.0	169.4	81.4	55.4	44.9	37.3	32.8	27.9
9000	42.5	9.5	26.7	25.8	554.0	542.3	315.8	184.6	87.6	58.6	43.8	37.6	32.5	28.7
9000	43	10	26.7	25.8	560.0	542.1	270.4	162.1	84.8	58.3	44.5	40.5	33.5	27.7
9000	43.5	10.5	26.6	25.7	564.0	530.2	278.9	157.2	88.1	62.3	45.6	37.9	33.0	27.3
52500	33	0	34.8	35.6	555.0	647.7	328.0	196.4	108.5	80.3	52.9	43.9	38.3	32.1
52500	33.5	0.5	34.9	35.6	545.0	746.1	413.9	242.7	122.6	79.3	51.9	42.6	37.8	28.3
52500	34	1	35.0	35.6	547.0	943.1	532.2	299.5	138.1	81.5	51.3	47.7	40.0	31.3
52500	34.5	1.5	35.0	35.6	541.0	969.3	596.4	346.8	147.5	74.3	50.9	45.3	37.5	30.5
52500	35	2	35.0	35.6	549.0	895.0	504.8	305.2	147.8	84.9	54.2	44.0	39.6	32.4
52500	35.5	2.5	34.9	35.7	552.0	832.7	511.3	292.5	136.5	83.6	56.0	45.4	37.9	31.9
52500	36	3	35.0	35.7	556.0	737.9	433.3	271.9	134.6	83.4	56.7	44.8	38.3	32.2
52500	36.5	3.5	35.0	35.8	537.0	706.3	411.8	236.4	119.4	82.5	57.1	45.4	37.9	31.8
52500	37	4	34.9	35.8	539.0	719.5	409.2	227.2	111.5	77.9	56.9	45.3	38.6	31.6
52500	37.5	4.5	35.0	35.8	535.0	761.4	418.0	240.8	113.7	76.2	55.9	45.6	38.4	31.8

52500	38	5	35.2	35.9	540.0	725.1	440.1	263.6	125.7	76.0	55.3	44.3	37.4	31.1
52500	38.5	5.5	35.0	35.9	540.0	760.1	402.8	221.5	102.9	69.1	53.0	43.4	36.6	30.1
52500	39	6	34.8	36.0	542.0	705.3	378.7	226.2	105.9	73.0	52.6	42.2	37.2	30.1
52500	39.5	6.5	34.8	36.0	544.0	704.9	386.4	217.4	97.5	65.4	50.3	42.7	37.5	29.1
52500	40	7	35.0	36.1	537.0	661.6	372.0	212.1	94.3	62.7	47.8	40.3	34.3	29.2
52500	40.5	7.5	34.8	36.1	540.0	624.8	337.4	199.8	96.8	63.7	47.7	39.8	35.1	28.3
52500	41	8	34.8	36.1	540.0	589.6	340.4	191.0	92.8	61.9	45.6	38.8	34.1	28.7
52500	41.5	8.5	35.0	36.6	550.0	656.4	346.9	185.1	96.1	62.9	44.4	34.1	31.1	26.2
52500	42	9	35.1	36.7	539.0	662.4	322.9	179.8	80.9	53.1	43.1	37.7	32.3	27.1
52500	42.5	9.5	35.0	36.9	533.0	555.4	314.8	175.9	86.9	56.5	43.1	36.6	32.3	27.6
52500	43	10	34.9	37.1	530.0	543.6	268.4	157.2	82.7	59.3	44.4	37.2	31.5	27.1
52500	43.5	10.5	34.8	37.3	536.0	534.7	283.0	162.8	88.7	61.9	44.6	37.0	31.7	28.0

Table A.4: Falling Weight Deflectometer data: test 4 (experiment 4005)

Load	Chainage		Temperature (°C)		Load	Deflection (µm)								
Cycle	Site	Experiment	Surface	Air	(kPa)	0	200	300	450	600	900	1200	1500	1800
0	33	0	29.4	26.7	549.0	521.9	262.9	152.5	89.4	65.3	47.3	38.6	34.0	26.9
0	33.5	0.5	29.4	26.7	551.0	586.0	294.1	163.2	86.2	64.4	46.6	37.8	32.2	27.1
0	34	1	29.7	26.9	543.0	527.4	237.7	149.2	87.9	66.2	53.7	40.7	24.7	22.3
0	34.5	1.5	29.8	27.0	535.0	497.0	266.0	161.7	96.7	69.4	46.0	36.4	33.2	24.6
0	35	2	29.9	27.2	534.0	559.3	288.1	183.9	110.2	77.5	53.1	33.8	32.8	25.8
0	35.5	2.5	29.8	27.3	533.0	566.6	298.2	187.2	121.5	90.3	57.0	37.3	30.5	23.8
0	36	3	29.7	27.4	545.0	548.0	277.1	177.8	116.1	85.0	54.9	41.2	33.9	27.1
0	36.5	3.5	30.0	27.6	548.0	544.4	221.6	189.0	111.8	80.5	54.9	42.2	35.5	28.2
0	37	4	30.3	28.1	545.0	525.5	260.3	167.1	111.1	80.1	53.5	41.7	34.8	29.2
0	37.5	4.5	30.4	28.2	539.0	500.2	263.7	157.3	100.2	76.0	52.3	40.5	34.1	30.1
0	38	5	30.5	28.3	551.0	428.4	233.4	151.8	100.7	76.3	51.8	40.0	34.4	28.5
0	38.5	5.5	30.3	28.4	542.0	464.5	239.9	149.4	95.4	71.6	51.1	37.6	26.1	28.4
0	39	6	30.5	28.5	558.0	457.1	218.0	134.3	88.7	68.9	51.9	39.2	32.0	26.9
0	39.5	6.5	30.5	28.6	553.0	514.7	226.7	135.8	84.6	66.4	49.0	39.4	33.7	29.5
0	40	7	30.4	28.8	556.0	444.7	247.3	140.0	74.0	60.4	47.1	38.9	33.1	27.2
0	40.5	7.5	30.4	28.9	546.0	471.0	229.5	126.4	71.8	68.7	45.1	35.4	32.0	27.2
0	41	8	30.3	29.0	555.0	498.6	244.0	131.9	74.3	63.5	47.6	38.1	32.9	26.0
0	41.5	8.5	30.6	29.2	552.0	459.1	211.1	120.4	70.5	57.0	46.5	38.5	31.8	24.3
0	42	9	30.6	29.3	561.0	389.7	192.8	106.1	70.3	48.0	50.8	43.8	38.6	28.2
0	42.5	9.5	30.5	29.5	534.0	392.4	173.0	104.2	70.0	56.7	44.4	36.7	31.9	27.1

0	43	10	30.5	29.7	539.0	377.9	189.6	123.5	73.1	56.7	44.4	37.0	31.5	26.5
0	43.5	10.5	30.8	29.7	545.0	358.6	175.6	113.8	77.7	60.2	45.4	37.4	32.4	27.5
9000	33	0	25.5	22.8	554.0	565.6	288.6	167.6	95.6	68.7	48.5	38.3	33.1	27.0
9000	33.5	0.5	25.5	22.9	556.0	699.4	376.7	195.0	92.8	69.6	47.3	38.4	32.7	27.0
9000	34	1	25.5	22.9	546.0	687.0	334.4	192.4	96.3	65.2	47.7	38.5	32.2	26.3
9000	34.5	1.5	25.5	23.0	541.0	678.4	376.7	223.3	111.2	75.9	47.3	37.0	32.8	24.3
9000	35	2	25.5	23.1	549.0	777.5	429.5	262.8	133.7	86.0	54.9	38.1	34.0	27.0
9000	35.5	2.5	25.5	23.1	539.0	783.5	461.5	276.5	138.6	85.1	53.4	40.8	35.1	28.5
9000	36	3	25.6	23.2	551.0	753.8	280.3	287.2	132.6	85.7	56.3	41.5	36.3	28.9
9000	36.5	3.5	25.9	23.6	556.0	709.1	275.8	248.4	129.6	82.6	53.6	47.2	37.9	29.2
9000	37	4	25.8	24.1	552.0	707.0	215.2	257.8	118.2	81.4	54.6	44.9	36.5	29.3
9000	37.5	4.5	26.2	24.5	543.0	701.3	387.8	230.9	122.9	83.7	56.7	41.5	36.1	29.4
9000	38	5	26.4	24.6	536.0	666.0	391.8	223.7	115.0	78.8	54.0	42.8	41.5	30.4
9000	38.5	5.5	26.2	24.7	546.0	614.2	347.5	204.3	108.7	71.5	52.0	40.8	34.4	28.0
9000	39	6	26.1	24.9	549.0	610.9	307.4	178.6	96.4	70.4	51.5	41.4	34.8	27.4
9000	39.5	6.5	26.3	25.0	551.0	663.3	325.1	173.5	92.3	66.4	48.6	39.3	33.8	28.3
9000	40	7	26.3	25.3	561.0	596.3	337.9	178.9	79.9	61.1	47.8	39.1	37.1	26.6
9000	40.5	7.5	26.4	25.4	551.0	600.3	312.9	157.8	73.6	58.8	51.6	38.6	35.6	26.8
9000	41	8	26.4	25.5	561.0	611.5	319.5	172.0	81.2	63.4	48.9	40.2	38.9	26.7
9000	41.5	8.5	26.3	25.7	543.0	603.3	302.3	151.8	73.0	56.4	46.6	39.8	31.8	26.3
9000	42	9	26.1	25.9	558.0	517.4	265.7	138.1	75.3	50.4	42.3	38.0	31.6	26.3
9000	42.5	9.5	26.1	26.0	560.0	520.9	249.3	133.6	74.8	57.9	45.9	38.5	32.8	27.6
9000	43	10	26.2	26.2	551.0	469.5	260.7	160.1	80.7	56.1	46.6	38.9	33.2	25.8
9000	43.5	10.5	26.2	26.3	565.0	475.4	244.4	151.6	84.1	70.4	45.6	37.2	33.2	27.3
52500	33	0	27.5	26.0	588.0	580.0	303.7	188.3	100.4	71.1	50.9	40.6	36.2	29.6
52500	33.5	0.5	27.5	26.0	580.0	695.0	374.5	201.7	94.3	70.5	50.0	40.9	36.3	29.1
52500	34	1	27.7	26.0	578.0	687.7	331.3	197.0	95.9	73.5	48.9	41.4	36.5	30.2
52500	34.5	1.5	27.7	26.0	569.0	682.6	375.6	227.3	114.2	77.9	51.0	39.8	40.3	24.8
52500	35	2	27.7	26.0	576.0	822.2	459.9	276.3	131.5	87.9	60.7	41.4	34.0	28.0
52500	35.5	2.5	27.8	26.1	573.0	848.6	483.7	293.9	142.1	87.3	62.2	38.3	38.8	29.5
52500	36	3	28.0	26.1	580.0	806.2	622.6	231.4	141.8	88.6	57.6	47.2	36.1	28.8
52500	36.5	3.5	28.0	26.3	574.0	754.8	327.2	268.0	133.0	83.8	57.4	45.6	38.2	30.7
52500	37	4	28.0	26.6	581.0	762.0	453.5	253.7	137.0	83.9	56.8	46.1	37.9	31.2
52500	37.5	4.5	28.1	26.8	564.0	757.5	405.5	238.7	119.1	86.5	54.0	41.0	35.6	27.6
52500	38	5	28.1	26.8	588.0	681.3	390.7	238.9	126.2	80.8	55.0	43.7	39.1	33.1
52500	38.5	5.5	28.0	26.9	582.0	667.8	387.6	232.8	118.1	77.0	54.6	46.2	38.2	27.9

52500	39	6	28.0	27.0	586.0	662.9	343.3	196.9	103.2	75.8	52.0	44.7	35.2	29.1
52500	39.5	6.5	28.0	27.1	589.0	715.7	368.8	202.1	100.6	68.2	52.7	43.9	38.4	30.2
52500	40	7	28.2	27.1	592.0	639.4	382.3	207.7	84.1	65.9	51.3	44.5	38.8	30.8
52500	40.5	7.5	28.0	27.2	590.0	644.7	333.4	181.4	83.7	64.9	50.8	41.3	36.3	30.1
52500	41	8	28.2	27.3	586.0	657.4	354.3	188.8	91.1	63.1	49.6	42.1	35.3	30.4
52500	41.5	8.5	28.4	27.3	594.0	660.6	362.4	190.6	93.4	67.8	51.3	38.9	35.4	29.0
52500	42	9	28.1	27.4	595.0	570.6	299.6	167.0	81.2	53.9	47.4	39.9	37.6	28.6
52500	42	9	28.1	27.4	595.0	570.6	299.6	167.0	81.2	53.9	47.4	39.9	37.6	28.6
52500	42.5	9.5	28.1	27.5	588.0	564.1	273.5	152.1	82.0	60.8	48.9	44.3	35.7	29.7
52500	43	10	28.0	27.6	583.0	513.0	298.2	179.3	88.8	60.3	50.3	41.6	35.9	29.8
52500	43.5	10.5	28.1	27.7	597.0	509.3	269.6	165.4	95.0	69.8	52.6	41.6	36.0	30.0

Table A.5: Falling Weight Deflectometer data: test 5 (experiment 4004)

Load	Chainage		Temperature (°C)		Load	Deflection (µm)								
Cycle	Site	Experiment	Surface	Air	(kPa)	0	200	300	450	600	900	1200	1500	1800
0	20.5	0	26.0	25.5	572.0	399.5	179.0	122.7	80.1	62.1	44.9	36.1	30.5	26.2
0	21	0.5	26.0	25.5	576.0	426.0	200.9	132.7	85.7	54.7	42.2	38.5	32.8	26.8
0	21.5	1	26.0	25.5	579.0	454.7	211.4	133.3	82.9	60.7	45.5	36.9	31.2	25.8
0	22	1.5	26.0	25.5	574.0	444.6	205.9	135.3	81.8	58.2	46.0	36.7	31.1	26.4
0	22.5	2	26.0	25.5	574.0	409.6	208.9	131.2	82.9	62.3	45.4	36.5	31.7	26.3
0	23	2.5	26.0	25.5	574.0	462.4	211.5	131.9	82.3	63.6	47.3	37.4	31.5	27.7
0	23.5	3	25.9	25.5	566.0	420.3	216.8	137.7	84.6	61.7	45.9	36.9	30.5	26.7
0	24	3.5	25.9	25.6	569.0	396.8	201.4	125.9	80.6	62.6	46.5	37.6	32.6	27.2
0	24.5	4	25.7	25.6	567.0	389.4	205.5	128.0	82.7	62.8	46.7	38.0	36.8	27.9
0	25	4.5	25.6	25.7	568.0	435.5	189.6	127.9	85.5	64.9	47.3	38.7	32.4	27.2
0	25.5	5	25.6	25.7	569.0	412.3	198.2	136.3	82.7	66.0	51.5	38.3	33.6	28.1
0	26	5.5	25.6	25.8	571.0	420.4	205.1	139.3	91.2	70.4	50.0	41.7	38.5	28.1
0	26.5	6	25.6	25.8	566.0	423.3	229.9	139.9	93.5	69.5	49.2	39.4	34.0	28.5
0	27	6.5	25.6	25.8	572.0	404.7	190.4	134.2	93.3	65.4	50.5	38.7	33.2	31.1
0	27.5	7	25.9	25.8	567.0	439.7	189.0	124.8	86.8	64.5	48.6	43.7	39.1	31.7
0	28	7.5	26.0	25.9	593.0	399.8	216.2	141.0	90.0	69.5	51.7	42.4	36.4	30.6
0	28.5	8	26.0	25.9	581.0	469.2	225.1	139.9	92.8	71.6	52.3	41.6	36.1	30.5
0	29	8.5	25.9	25.9	586.0	423.1	229.2	151.3	94.4	71.4	51.7	41.8	36.3	30.8
0	29.5	9	25.8	25.9	577.0	512.0	286.2	172.5	100.2	80.3	55.9	40.7	34.5	30.1
0	30	9.5	25.7	26.0	587.0	486.0	276.2	167.3	102.5	78.1	54.2	42.9	38.7	31.3
0	30.5	10	25.8	26.0	582.0	522.5	266.0	166.1	100.2	73.5	52.3	42.4	38.4	30.2

0	31	10.5	25.7	26.1	576.0	498.5	252.2	171.7	102.8	76.8	51.4	40.6	37.3	30.4
9000	20.5	0	28.8	29.3	569.0	426.0	191.7	128.7	81.0	61.5	45.7	36.3	31.5	26.3
9000	21	0.5	28.8	29.3	574.0	496.7	231.3	139.4	82.8	61.4	46.1	37.9	32.5	26.2
9000	21.5	1	28.8	29.3	570.0	553.0	259.8	151.4	81.5	57.8	45.0	37.5	31.7	27.2
9000	22	1.5	28.9	29.3	569.0	566.3	266.5	155.5	80.9	58.3	46.2	37.2	30.2	27.1
9000	22.5	2	28.8	29.3	568.0	507.8	264.6	155.1	83.2	60.5	45.8	38.2	33.2	28.0
9000	23	2.5	29.0	29.5	574.0	586.0	281.2	156.9	85.5	61.5	46.7	37.7	32.8	27.5
9000	23.5	3	29.0	29.5	564.0	572.8	293.1	174.4	89.1	64.1	46.6	37.9	33.1	27.5
9000	24	3.5	29.0	29.5	574.0	520.5	274.1	156.1	83.5	61.5	47.7	36.4	32.4	27.9
9000	24.5	4	29.0	29.5	570.0	520.4	276.5	161.8	88.7	64.1	47.5	39.2	33.7	28.4
9000	25	4.5	29.0	29.6	570.0	506.0	242.3	156.4	92.5	65.3	48.7	40.4	34.4	31.1
9000	25.5	5	29.0	29.6	572.0	513.7	275.4	162.8	87.9	64.8	49.9	40.5	35.2	29.7
9000	26	5.5	29.0	29.6	574.0	523.0	269.4	163.2	99.4	71.3	49.4	41.7	35.3	33.0
9000	26.5	6	29.0	29.6	560.0	521.2	285.4	177.5	101.2	71.2	49.6	40.9	34.9	28.8
9000	27	6.5	29.2	29.6	573.0	527.6	265.4	174.4	103.9	70.8	49.8	40.6	33.9	29.1
9000	27.5	7	29.4	29.6	568.0	511.7	243.7	144.4	98.9	64.0	46.1	43.1	33.3	32.2
9000	28	7.5	29.3	29.6	580.0	511.5	279.5	170.4	95.9	70.2	52.4	42.2	33.8	30.5
9000	28.5	8	29.3	29.6	572.0	584.8	286.3	168.3	99.4	71.8	53.2	42.5	37.0	30.3
9000	29	8.5	29.1	29.7	571.0	544.9	295.7	175.1	96.4	71.8	51.1	45.1	39.3	31.7
9000	29.5	9	29.3	29.7	568.0	634.2	345.1	195.1	107.7	80.3	52.7	41.8	36.2	31.5
9000	30	9.5	29.3	29.8	572.0	614.6	342.6	195.5	102.7	74.7	52.7	42.4	36.1	31.9
9000	30.5	10	29.3	29.8	570.0	719.2	346.1	205.3	101.0	64.9	48.0	43.5	36.1	28.0
9000	31	10.5	29.4	30.2	575.0	675.5	358.4	205.8	107.4	71.1	50.2	39.5	35.6	28.1
60000	20.5	0	24.8	21.3	598.0	374.6	178.2	119.6	78.2	60.0	45.2	36.5	31.3	26.0
60000	21	0.5	24.8	21.2	600.0	443.2	209.2	127.7	78.7	60.3	45.4	36.8	31.7	25.7
60000	21.5	1	24.9	21.1	591.0	521.6	243.4	139.7	78.0	58.1	45.9	37.3	33.5	28.1
60000	22	1.5	24.9	21.0	590.0	551.8	250.2	142.7	74.7	56.6	45.2	36.2	32.0	26.6
60000	22.5	2	25.0	21.0	585.0	518.6	259.5	146.8	79.5	59.5	45.3	37.4	32.1	30.4
60000	23	2.5	25.0	21.0	592.0	595.9	270.1	144.1	79.3	59.3	45.8	37.7	32.4	27.2
60000	23.5	3	24.9	20.9	576.0	568.5	282.4	155.5	81.2	58.6	46.0	38.0	32.4	26.7
60000	24	3.5	24.8	20.8	581.0	547.7	277.0	148.2	80.4	62.1	46.0	37.1	32.9	28.4
60000	24.5	4	24.8	20.8	578.0	511.1	262.7	150.9	84.0	61.4	47.4	38.3	33.3	28.1
60000	25	4.5	24.8	20.7	597.0	488.2	235.8	146.0	87.1	63.7	47.5	39.5	34.2	28.5
60000	25.5	5	24.8	20.7	592.0	480.7	241.6	147.9	82.0	64.4	48.6	39.9	33.4	28.8
60000	26	5.5	24.8	20.6	598.0	493.3	250.0	154.5	93.0	69.5	50.0	45.2	35.0	29.5
60000	26.5	6	24.8	20.6	582.0	511.6	275.4	162.2	96.5	69.6	51.2	40.0	33.4	28.8

60000	27	6.5	24.8	20.5	584.0	499.1	247.9	159.9	99.8	69.7	49.9	40.5	35.6	28.5
60000	27.5	7	24.9	20.4	569.0	502.4	222.3	139.9	87.8	65.0	51.8	43.9	36.5	30.0
60000	28	7.5	25.0	20.4	592.0	464.3	244.3	153.9	89.5	69.6	53.4	41.2	35.5	29.7
60000	28.5	8	25.0	20.3	578.0	560.9	268.0	153.9	95.3	69.3	51.6	42.6	35.7	29.5
60000	29	8.5	25.1	20.2	586.0	528.5	281.3	173.6	94.4	67.6	52.1	43.6	38.9	32.6
60000	29.5	9	25.0	20.2	582.0	605.8	337.1	189.8	102.2	71.8	52.2	41.5	36.9	29.2
60000	30	9.5	25.1	20.1	589.0	588.2	320.6	182.3	95.5	73.0	54.2	42.1	37.0	31.3
60000	30.5	10	25.1	20.0	570.0	659.0	309.0	177.5	91.4	65.8	51.6	40.4	34.9	29.8
60000	31	10.5	25.5	20.0	594.0	626.2	307.9	190.8	105.2	71.3	50.2	40.4	35.1	29.5

Table A.6: Falling Weight Deflectometer data: test 6 (experiment 4003)

Load	Chainage		Temperature (°C)		Load	Deflection (µm)								
Cycle	Site	Experiment	Surface	Air	(kPa)	0	200	300	450	600	900	1200	1500	1800
0	8	0	24.2	23.0	590.0	336.2	185.7	131.9	89.3	65.7	46.3	37.0	31.8	27.4
0	8.5	0.5	24.2	23.0	589.0	361.2	162.0	120.2	82.1	63.9	46.3	35.7	29.8	24.1
0	9	1	24.2	22.9	601.0	342.4	176.2	122.3	82.5	61.3	46.0	38.3	32.5	27.1
0	9.5	1.5	24.3	22.8	594.0	306.8	159.2	113.4	77.6	58.6	43.4	35.5	30.2	26.1
0	10	2	24.3	22.8	587.0	290.4	145.4	104.8	73.1	55.5	41.2	34.8	29.3	24.9
0	10.5	2.5	24.3	22.8	578.0	296.5	159.0	110.5	73.2	58.4	44.4	33.0	31.1	27.1
0	11	3	24.2	22.8	590.0	280.3	169.5	117.8	77.2	61.2	42.5	33.8	28.6	23.7
0	11.5	3.5	24.2	22.8	583.0	326.8	161.0	116.8	81.6	59.5	42.0	35.4	30.2	25.3
0	12	4	24.2	22.8	558.0	314.5	160.2	119.0	82.4	60.9	43.4	34.1	29.3	23.4
0	12.5	4.5	24.1	22.8	573.0	315.0	169.1	123.0	83.5	61.0	43.0	33.5	29.2	23.5
0	13	5	24.1	22.8	584.0	360.1	171.8	122.1	83.5	63.2	43.5	33.8	28.6	24.3
0	13.5	5.5	24.1	22.7	574.0	381.9	178.7	123.2	84.6	63.2	44.6	35.1	29.6	24.2
0	14	6	24.1	22.7	566.0	367.3	190.7	133.1	89.2	64.4	44.7	34.5	28.8	23.8
0	14.5	6.5	24.1	22.7	581.0	471.4	215.9	145.6	97.0	68.9	44.4	33.6	28.8	24.6
0	15	7	24.1	22.7	611.0	436.0	214.3	148.2	96.1	69.9	49.7	36.3	30.8	25.7
0	15.5	7.5	23.9	22.6	579.0	359.0	210.0	145.9	97.9	70.9	45.7	35.9	29.7	24.8
0	16	8	23.9	22.6	604.0	398.4	182.9	125.0	87.1	66.9	47.6	36.4	30.8	25.7
0	16.5	8.5	24.0	22.6	588.0	380.6	190.3	123.8	82.0	63.6	47.6	35.8	29.8	25.0
0	17	9	24.0	22.6	602.0	413.5	192.6	126.5	81.4	62.9	46.1	34.1	30.6	25.4
0	17.5	9.5	23.9	22.6	588.0	475.9	198.1	125.0	81.5	61.1	43.2	37.1	30.4	27.0
0	18	10	23.9	22.6	606.0	405.1	194.6	120.9	80.7	62.2	45.1	36.4	31.3	26.4
0	18.5	10.5	23.9	22.6	603.0	407.6	189.0	124.5	81.5	62.7	45.7	36.8	31.8	26.2
9000	8	0	24.0	21.5	583.0	335.9	182.6	130.6	87.6	64.8	46.0	36.9	33.2	27.8

9000	8.5	0.5	24.0	21.4	582.0	328.5	169.3	120.1	76.9	66.0	46.9	34.6	33.8	25.5
9000	9	1	23.9	21.4	585.0	320.3	177.5	117.6	75.2	58.0	44.1	34.8	29.8	26.3
9000	9.5	1.5	23.9	21.4	570.0	318.9	168.6	118.7	74.4	57.4	41.0	34.5	28.1	25.0
9000	10	2	23.7	21.4	577.0	370.5	179.6	120.0	76.8	57.1	42.7	35.3	31.6	28.2
9000	10.5	2.5	23.7	21.3	572.0	371.8	200.8	125.8	79.9	59.4	41.4	34.1	31.4	25.5
9000	11	3	23.8	21.3	587.0	358.6	196.1	142.4	86.1	61.6	43.0	35.2	30.6	25.0
9000	11.5	3.5	23.9	21.2	581.0	405.2	200.9	136.1	87.6	60.1	43.5	34.4	29.5	24.5
9000	12	4	23.9	21.2	568.0	419.8	209.6	142.7	88.4	63.0	44.5	36.8	31.1	26.7
9000	12.5	4.5	24.0	21.2	596.0	409.9	220.8	143.9	90.2	65.1	45.6	36.0	30.1	25.5
9000	13	5	23.9	21.2	575.0	450.2	229.5	141.2	84.2	65.2	45.5	36.1	30.7	25.2
9000	13.5	5.5	24.0	21.1	580.0	460.1	241.4	146.5	85.3	63.2	46.4	35.2	30.9	26.6
9000	14	6	24.0	21.0	569.0	439.2	230.5	144.8	88.2	63.9	46.4	35.4	30.8	25.5
9000	14.5	6.5	23.8	21.0	576.0	541.7	262.2	166.4	95.7	75.8	49.0	36.2	29.7	23.9
9000	15	7	23.8	20.9	571.0	487.2	247.2	164.7	97.3	69.3	45.0	36.2	32.2	26.6
9000	15.5	7.5	23.7	20.9	583.0	444.9	256.0	167.0	99.5	71.9	47.4	36.3	30.5	25.5
9000	16	8	23.8	20.8	577.0	484.9	232.2	148.3	90.0	66.6	48.1	35.4	29.5	24.8
9000	16.5	8.5	23.7	20.7	589.0	503.4	271.6	156.2	86.5	60.3	45.7	36.8	30.8	25.3
9000	17	9	23.7	20.6	584.0	508.6	266.9	157.3	89.5	60.5	45.5	37.4	31.3	26.2
9000	17.5	9.5	23.7	20.5	590.0	569.4	271.0	160.5	86.9	60.8	45.9	37.1	31.0	26.1
9000	18	10	23.7	20.5	576.0	482.1	260.7	153.7	83.3	59.7	44.7	36.2	31.2	26.1
9000	18.5	10.5	23.7	20.4	585.0	498.2	263.9	150.1	83.7	60.0	45.1	36.6	31.2	25.2
52500	8	0	21.7	20.5	603.0	340.7	194.2	140.5	90.4	65.3	46.6	37.3	34.4	26.5
52500	8.5	0.5	21.7	20.5	592.0	366.4	185.1	127.4	81.4	62.4	46.0	37.1	31.9	25.4
52500	9	1	21.7	20.5	592.0	378.9	193.5	127.8	78.5	58.4	42.9	35.3	34.8	21.9
52500	9.5	1.5	21.7	20.5	588.0	376.5	191.0	123.9	76.5	56.9	44.0	37.2	32.5	25.0
52500	10	2	21.7	20.5	588.0	407.2	193.8	124.8	77.8	55.1	41.4	34.1	29.8	24.6
52500	10.5	2.5	21.7	20.5	584.0	398.1	214.5	131.7	75.4	57.6	42.0	33.8	30.9	22.4
52500	11	3	21.6	20.5	599.0	383.8	235.9	142.8	85.1	59.8	45.5	35.5	31.0	25.3
52500	11.5	3.5	21.6	20.5	593.0	441.9	222.7	139.7	85.8	53.8	39.8	34.2	29.2	24.7
52500	12	4	21.5	20.5	583.0	469.6	233.0	148.1	88.8	62.0	41.8	35.7	31.3	24.3
52500	12.5	4.5	21.5	20.5	598.0	462.5	229.7	148.1	92.2	66.9	46.8	35.7	30.8	23.5
52500	13	5	21.6	20.5	601.0	511.9	246.8	149.2	86.4	65.0	46.5	36.9	31.5	25.5
52500	13.5	5.5	21.7	20.5	599.0	520.4	259.9	156.8	88.5	66.8	48.9	37.4	30.8	23.6
52500	14	6	21.7	20.6	598.0	503.9	249.0	151.1	89.1	63.5	47.0	37.5	32.1	26.2
52500	14.5	6.5	21.6	20.6	595.0	634.2	289.8	177.4	97.7	68.1	46.3	36.8	32.9	27.3
52500	15	7	21.6	20.6	603.0	567.4	272.5	179.8	96.0	68.3	50.5	37.5	34.8	25.4

52500	15.5	7.5	21.6	20.5	592.0	501.6	272.2	168.7	97.4	72.7	47.5	36.7	34.6	27.8
52500	16	8	21.6	20.5	595.0	529.7	244.8	147.4	87.3	66.7	50.8	37.9	31.2	25.6
52500	16.5	8.5	21.6	20.5	593.0	546.0	292.4	165.1	85.3	57.2	45.7	41.9	30.1	21.7
52500	17	9	21.5	20.5	607.0	562.3	281.8	164.6	86.3	59.2	44.0	35.8	32.9	25.9
52500	17.5	9.5	21.5	20.5	600.0	615.0	290.4	162.1	85.7	61.9	45.5	37.9	31.7	25.8
52500	18	10	21.5	20.5	605.0	539.6	277.8	153.8	82.3	58.8	46.0	37.7	32.1	27.7
52500	18.5	10.5	21.5	20.5	600.0	540.3	264.7	154.4	82.5	60.2	45.7	38.1	31.6	25.9

Table A.7: Falling Weight Deflectometer data: test 7 (experiment 4000)

Load	Chainage		Temperature (°C)		Load	Deflection (µm)								
Cycle	Site	Experiment	Surface	Air	(kPa)	0	200	300	450	600	900	1200	1500	1800
0	8	0	22.1	20.7	592.0	507.3	266.4	164.6	106.6	72.6	48.9	37.9	31.5	25.6
0	8.5	0.5	22.0	20.7	586.0	506.3	241.1	157.9	100.7	69.1	46.6	37.5	30.1	24.9
0	9	1	22.0	20.6	581.0	355.8	185.5	134.7	91.9	67.6	45.4	34.6	30.0	25.6
0	9.5	1.5	22.0	20.6	591.0	344.8	167.5	118.8	80.7	61.1	42.6	32.7	32.2	25.3
0	10	2	21.9	20.7	596.0	311.5	160.3	112.6	78.7	60.9	43.2	35.4	29.3	25.2
0	10.5	2.5	21.9	20.7	585.0	309.1	153.8	110.7	77.1	59.5	43.5	34.7	29.6	24.0
0	11	3	21.9	20.7	594.0	320.1	147.2	106.4	75.9	58.4	43.6	34.7	29.8	24.6
0	11.5	3.5	22.1	20.7	585.0	323.1	160.3	113.4	75.4	58.0	43.2	34.1	29.7	23.7
0	12	4	22.0	20.7	593.0	317.7	151.9	111.1	75.1	59.4	40.6	32.0	28.7	24.9
0	12.5	4.5	22.0	20.8	578.0	290.9	141.8	105.5	75.4	59.1	41.5	31.6	27.2	23.6
0	13	5	22.0	20.8	596.0	301.9	142.9	103.7	72.4	57.4	41.6	33.4	30.0	23.0
0	13.5	5.5	22.0	20.8	594.0	338.2	157.2	106.6	72.1	56.1	41.3	33.2	28.3	24.0
0	14	6	22.2	20.9	589.0	322.6	146.4	104.9	72.5	57.6	40.9	33.9	29.2	24.2
0	14.5	6.5	22.1	20.9	596.0	320.4	160.9	107.8	73.5	57.2	42.1	33.6	28.6	24.3
0	15	7	22.1	20.9	598.0	347.7	148.7	102.0	71.7	56.8	42.2	33.2	28.2	24.0
0	15.5	7.5	22.1	20.9	590.0	315.7	162.6	113.7	75.4	57.4	43.8	33.7	28.1	24.9
0	16	8	22.1	20.9	594.0	346.4	164.0	114.4	76.1	57.9	42.5	35.6	26.8	23.4
0	16.5	8.5	22.1	20.9	600.0	334.4	179.9	118.7	79.6	62.1	43.9	35.0	29.9	23.1
0	17	9	22.1	21.0	595.0	341.6	165.3	117.7	79.7	61.6	43.2	34.4	29.7	23.4
0	17.5	9.5	22.1	21.0	602.0	335.8	165.4	115.6	80.2	61.1	44.3	34.5	29.4	24.6
0	18	10	22.1	21.0	597.0	335.2	164.0	113.3	80.2	60.0	43.4	34.5	30.0	25.1
0	18.5	10.5	22.1	21.0	589.0	382.0	171.7	116.9	76.1	59.3	43.8	34.2	29.1	24.0
0	19	11	22.0	21.1	592.0	353.3	170.4	120.4	80.9	60.2	42.9	33.0	28.8	24.6
0	19.5	11.5	22.0	21.1	593.0	354.6	165.2	117.5	81.5	61.8	44.5	34.4	29.3	24.0

0	20	12	22.0	21.1	594.0	365.6	186.9	126.8	82.7	61.5	43.2	34.7	29.7	24.5
9000	8	0	21.4	19.5	594.0	497.3	260.2	165.1	97.7	68.2	47.7	38.9	31.8	27.9
9000	8.5	0.5	21.4	19.6	591.0	524.9	280.6	179.2	99.8	64.0	46.6	38.1	31.2	26.9
9000	9	1	21.4	19.6	591.0	476.5	261.8	171.1	101.5	68.2	45.7	36.8	32.3	27.0
9000	9.5	1.5	21.4	19.6	594.0	447.2	227.5	144.4	88.8	63.1	46.3	37.5	31.3	26.4
9000	10	2	21.4	19.6	604.0	408.9	215.9	139.1	87.0	64.4	46.0	36.7	30.6	25.2
9000	10.5	2.5	21.4	19.6	597.0	406.4	208.1	135.8	81.8	59.4	45.3	36.4	29.7	24.7
9000	11	3	21.4	19.5	602.0	415.5	196.5	128.8	80.2	59.4	43.9	35.8	31.6	25.6
9000	11.5	3.5	21.4	19.6	594.0	414.6	203.7	128.8	79.7	58.9	43.7	35.3	30.5	24.9
9000	12	4	21.4	19.5	603.0	407.3	197.9	126.1	79.0	59.2	45.3	35.4	29.1	26.6
9000	12.5	4.5	21.4	19.5	606.0	393.4	200.2	128.0	82.2	58.9	43.2	35.0	29.6	24.6
9000	13	5	21.4	19.5	602.0	415.3	192.0	123.3	77.3	58.5	43.8	35.4	29.6	25.2
9000	13.5	5.5	21.4	19.5	606.0	460.7	211.5	127.5	77.3	56.0	42.8	34.7	29.1	24.2
9000	14	6	21.4	19.5	590.0	453.1	203.5	126.7	77.5	58.3	42.8	34.1	29.1	24.5
9000	14.5	6.5	21.4	19.5	605.0	445.0	229.6	130.1	75.1	59.0	46.1	32.8	28.9	24.6
9000	15	7	21.4	19.5	599.0	489.3	210.2	123.9	78.5	57.6	45.0	35.1	28.7	25.8
9000	15.5	7.5	21.4	19.4	606.0	460.1	236.3	146.2	81.7	61.3	43.1	33.5	31.5	26.5
9000	16	8	21.4	19.4	597.0	487.0	221.4	138.0	77.9	58.9	45.9	35.6	27.0	25.5
9000	16.5	8.5	21.4	19.4	599.0	468.1	241.9	140.6	84.3	59.8	44.2	36.2	30.5	25.2
9000	17	9	21.4	19.4	600.0	464.6	227.8	140.3	84.6	60.8	44.5	35.6	30.3	24.9
9000	17.5	9.5	21.4	19.4	608.0	473.2	224.6	139.3	83.5	63.8	43.5	36.5	31.5	25.7
9000	18	10	21.4	19.4	593.0	465.8	215.0	137.8	84.6	60.4	44.6	35.3	30.2	24.6
9000	18.5	10.5	21.4	19.4	597.0	524.2	237.5	144.2	85.4	60.2	44.3	35.4	30.4	25.7
60000	8	0	20.7	19.9	589.0	505.2	267.4	163.9	94.2	65.9	47.5	37.8	30.3	26.7
60000	8.5	0.5	20.8	19.9	593.0	543.7	295.1	184.0	107.6	64.8	45.8	37.1	32.2	25.7
60000	9	1	20.8	19.9	595.0	508.0	275.4	176.2	99.9	67.2	48.6	37.5	30.5	27.5
60000	9.5	1.5	20.8	19.9	597.0	482.5	237.3	147.5	86.6	61.4	45.3	36.7	31.1	25.6
60000	10	2	20.7	19.9	600.0	435.7	229.4	142.2	86.6	62.5	44.4	35.9	30.1	26.0
60000	10.5	2.5	20.7	19.9	597.0	433.0	237.9	138.8	81.1	59.6	44.2	36.8	29.1	22.1
60000	11	3	20.7	20.0	603.0	450.2	216.3	136.6	79.1	57.0	40.8	36.5	30.8	25.9
60000	11.5	3.5	20.7	19.9	604.0	446.4	217.9	133.3	77.9	56.8	43.7	35.1	29.7	25.4
60000	12	4	20.6	19.9	603.0	436.0	206.0	129.4	78.0	59.1	43.4	35.3	30.3	25.2
60000	12.5	4.5	20.6	19.9	598.0	426.3	207.3	132.6	79.0	58.6	42.9	34.4	29.7	26.0
60000	13	5	20.6	20.0	588.0	452.0	203.0	122.4	71.7	59.9	42.6	34.2	30.2	25.4
60000	13.5	5.5	20.6	19.9	588.0	505.9	221.9	125.8	72.7	54.1	42.2	34.2	29.1	23.3
60000	14	6	20.6	20.0	589.0	522.4	215.7	133.5	72.9	57.8	40.7	31.8	29.2	22.5

60000	14.5	6.5	20.6	20.0	599.0	484.7	233.7	134.4	77.0	58.0	44.2	33.4	29.3	24.6
60000	15	7	20.5	20.0	596.0	534.8	220.6	127.5	76.8	57.4	42.8	34.8	29.5	24.0
60000	15.5	7.5	20.6	20.0	595.0	498.5	240.7	148.0	81.6	64.0	42.5	33.3	27.9	24.7
60000	16	8	20.5	20.0	602.0	530.3	247.8	152.8	77.8	59.3	44.2	35.4	29.9	24.8
60000	16.5	8.5	20.5	20.0	596.0	515.1	258.8	145.5	81.0	57.7	42.5	35.2	30.7	23.2
60000	17	9	20.4	20.0	598.0	518.7	246.9	146.7	81.5	59.9	43.9	35.2	30.2	25.2
60000	17.5	9.5	20.4	19.9	602.0	513.3	244.4	141.6	80.8	60.4	43.6	35.9	29.8	25.3
60000	18	10	20.4	19.9	601.0	499.1	222.1	140.2	79.1	63.3	50.2	31.9	29.6	25.9
60000	18.5	10.5	20.4	19.9	609.0	569.3	255.8	150.3	83.8	59.4	43.9	35.3	30.6	25.3

Table A.8: Falling Weight Deflectometer data: test 8 (experiment 4001)

Load	Chainage		Temperature (°C)		Load	Deflection (µm)								
Cycle	Site	Experiment	Surface	Air	(kPa)	0	200	300	450	600	900	1200	1500	1800
0	20.5	0	21.6	17.3	727.9	-48.4	110.1	61.2	70.4	57.2	79.3	51.0	44.3	41.6
0	21	0.5	21.4	17.3	722.3	-23.7	115.8	65.3	71.6	57.8	77.9	50.5	43.8	41.0
0	21.5	1	21.2	17.3	716.7	1.1	121.5	69.5	72.8	58.5	76.6	50.0	43.4	40.4
0	22	1.5	21.1	17.3	711.1	25.8	127.2	73.7	74.0	59.2	75.2	49.4	42.9	39.7
0	22.5	2	20.9	17.3	705.6	50.5	132.8	77.8	75.1	59.9	73.8	48.9	42.4	39.1
0	23	2.5	20.7	17.3	700.0	75.2	138.5	82.0	76.3	60.5	72.4	48.4	41.9	38.4
0	23.5	3	20.6	17.3	694.4	99.9	144.2	86.1	77.5	61.2	71.0	47.9	41.5	37.8
0	24	3.5	20.4	17.3	688.9	124.6	149.9	90.3	78.7	61.9	69.6	47.3	41.0	37.1
0	24.5	4	20.3	17.3	683.3	149.3	155.5	94.4	79.9	62.6	68.3	46.8	40.5	36.5
0	25	4.5	20.1	17.3	677.7	174.0	161.2	98.6	81.0	63.2	66.9	46.3	40.1	35.9
0	25.5	5	19.9	17.3	672.1	198.7	166.9	102.8	82.2	63.9	65.5	45.8	39.6	35.2
0	26	5.5	19.8	17.3	666.6	223.4	172.6	106.9	83.4	64.6	64.1	45.2	39.1	34.6
0	26.5	6	19.6	17.3	661.0	248.1	178.3	111.1	84.6	65.3	62.7	44.7	38.6	33.9
0	27	6.5	19.5	17.3	655.4	272.8	183.9	115.2	85.8	65.9	61.4	44.2	38.2	33.3
0	27.5	7	19.3	17.3	649.9	297.5	189.6	119.4	86.9	66.6	60.0	43.7	37.7	32.6
0	28	7.5	19.1	17.3	644.3	322.3	195.3	123.5	88.1	67.3	58.6	43.1	37.2	32.0
0	28.5	8	19.0	17.3	638.7	347.0	201.0	127.7	89.3	68.0	57.2	42.6	36.8	31.4
0	29	8.5	18.8	17.3	633.1	371.7	206.7	131.9	90.5	68.6	55.8	42.1	36.3	30.7
0	29.5	9	18.7	17.3	627.6	396.4	212.3	136.0	91.6	69.3	54.4	41.6	35.8	30.1
0	30	9.5	18.5	17.3	622.0	421.1	218.0	140.2	92.8	70.0	53.1	41.0	35.3	29.4
0	30.5	10	18.3	17.3	611.0	445.2	222.4	144.1	94.1	70.3	50.2	40.7	34.2	28.8
0	31	10.5	18.1	17.3	614.0	471.0	232.8	152.6	96.6	70.2	50.2	39.5	33.9	27.9

9000	20.5	0	17.7	14.6	606.0	485.5	238.5	150.1	87.3	60.4	44.7	35.3	29.7	25.3
9000	21	0.5	17.7	14.6	609.0	529.7	252.8	152.7	89.6	73.2	46.3	36.8	30.4	25.2
9000	21.5	1	17.5	14.5	611.0	513.0	262.3	163.0	93.8	64.7	44.7	36.8	30.8	25.8
9000	22	1.5	17.5	14.5	609.0	508.5	253.1	154.8	90.6	64.0	46.0	36.5	31.2	26.4
9000	22.5	2	17.5	14.4	600.0	502.1	260.8	164.0	90.0	62.0	45.5	36.6	33.5	26.9
9000	23	2.5	17.6	14.3	608.0	493.2	278.5	172.5	94.4	65.1	46.7	37.1	31.1	26.7
9000	23.5	3	17.7	14.2	612.0	485.9	246.3	163.0	96.6	67.0	47.2	37.8	31.5	26.5
9000	24	3.5	17.8	14.2	612.0	468.0	254.9	159.5	95.8	69.0	48.8	37.3	32.3	26.2
9000	24.5	4	17.8	14.1	602.0	488.8	240.6	154.9	92.8	72.3	48.0	38.8	32.3	27.3
9000	25	4.5	17.8	14.1	616.0	527.1	258.3	161.6	96.3	70.8	50.7	40.2	34.8	28.8
9000	25.5	5	17.8	14.1	611.0	505.5	263.9	159.9	97.1	67.9	49.4	39.6	36.6	27.8
9000	26	5.5	17.8	14.0	603.0	543.8	277.0	165.6	94.8	68.0	49.2	40.3	35.4	27.4
9000	26.5	6	17.8	14.0	601.0	556.8	292.5	175.8	100.6	67.8	45.7	41.0	35.9	27.2
9000	27	6.5	17.8	14.0	614.0	577.6	284.7	182.4	104.9	74.4	54.6	40.6	34.8	29.2
9000	27.5	7	17.7	14.0	612.0	584.0	290.5	177.1	103.7	73.2	52.6	42.2	35.9	29.7
9000	28	7.5	17.7	14.0	606.0	554.4	270.8	175.6	105.9	77.0	52.8	40.8	35.6	29.6
9000	28.5	8	17.6	13.9	606.0	546.1	315.7	180.5	101.8	71.4	52.7	42.2	35.5	28.2
9000	29	8.5	17.6	13.8	609.0	646.7	315.4	187.4	101.3	70.9	52.6	42.6	36.4	30.2
9000	29.5	9	17.6	13.8	609.0	594.0	288.6	179.9	102.7	72.5	52.6	41.7	35.3	30.6
9000	30	9.5	17.6	13.7	607.0	651.3	366.9	202.8	103.7	69.7	52.5	42.4	35.0	29.7
9000	30.5	10	17.6	13.7	611.0	671.2	370.0	215.8	108.5	71.0	51.8	42.4	35.5	29.9
9000	31	10.5	17.7	13.6	609.0	708.8	372.0	221.2	110.6	68.8	50.7	41.6	35.9	29.2
60000	20.5	0	19.4	19.1	603.0	534.6	258.3	149.7	82.9	63.1	43.5	35.4	28.6	24.6
60000	21	0.5	19.5	19.1	604.0	557.3	250.5	148.3	85.3	60.1	43.5	34.9	29.8	24.2
60000	21.5	1	19.6	18.9	607.0	561.2	284.4	164.1	90.8	62.6	44.5	36.3	31.0	26.3
60000	22	1.5	19.6	18.9	605.0	577.2	268.2	157.7	85.5	61.3	44.8	34.2	30.7	26.0
60000	22.5	2	19.6	18.9	591.0	557.5	251.6	157.5	102.0	65.1	41.0	34.1	28.7	25.3
60000	23	2.5	19.6	18.9	607.0	541.6	306.3	173.9	91.7	59.4	48.8	36.5	31.5	24.6
60000	23.5	3	19.6	18.9	606.0	532.2	257.7	163.1	92.8	63.7	45.7	37.0	31.1	26.7
60000	24	3.5	19.6	18.8	604.0	508.3	267.6	160.3	91.9	65.8	47.8	36.8	32.2	26.6
60000	24.5	4	19.6	18.8	604.0	526.5	258.0	154.7	90.1	68.8	48.3	35.4	32.7	27.5
60000	25	4.5	19.6	18.8	606.0	547.2	273.0	158.2	89.2	64.7	51.9	39.1	34.2	25.9
60000	25.5	5	19.6	18.8	605.0	568.3	285.1	162.7	90.7	66.8	48.6	39.6	35.5	26.0
60000	26	5.5	19.6	18.7	601.0	606.0	303.0	170.1	92.2	65.6	48.6	39.5	34.1	28.0
60000	26.5	6	19.6	18.7	600.0	620.1	312.2	185.3	98.2	66.5	48.1	43.0	33.4	28.5
60000	27	6.5	19.6	18.7	606.0	646.5	301.9	179.3	102.8	70.4	49.8	39.9	34.6	29.4

60000	27.5	7	19.6	18.7	605.0	661.1	295.3	178.9	98.6	69.2	51.5	42.8	34.9	30.9
60000	28	7.5	19.6	18.7	601.0	616.3	287.0	182.0	109.6	74.7	59.1	45.6	31.8	31.5
60000	28.5	8	19.6	18.6	598.0	613.1	329.1	185.5	95.4	67.9	51.8	41.6	35.1	28.7
60000	29	8.5	19.6	18.6	597.0	705.5	341.2	193.4	99.1	68.0	50.9	41.4	35.9	29.4
60000	29.5	9	19.6	18.5	597.0	645.3	317.5	187.8	100.8	70.4	52.0	41.7	35.7	29.9
60000	30	9.5	19.6	18.5	603.0	711.4	370.5	200.1	100.9	67.9	52.0	40.8	34.9	30.2
60000	30.5	10	19.6	18.5	591.0	766.3	388.3	217.7	104.9	67.9	51.3	41.0	34.8	29.1
60000	31	10.5	19.6	18.5	598.0	751.3	402.0	218.5	104.1	71.8	50.8	41.1	36.1	28.7

Table A.9: Falling Weight Deflectometer data: test 9 (experiment 4002)

Load	Chainage		Temperature (°C)		Load	Deflection (µm)								
Cycle	Site	Experiment	Surface	Air	(kPa)	0	200	300	450	600	900	1200	1500	1800
0	33	0	16.5	15.1	603.0	495.8	290.9	174.7	102.1	73.2	53.3	40.9	34.7	28.5
0	33.5	0.5	16.5	15.1	606.0	538.2	270.8	162.9	102.8	76.8	53.3	41.8	35.5	29.4
0	34	1	16.4	15.1	604.0	476.7	257.6	163.0	97.9	72.2	52.7	41.9	34.9	29.2
0	34.5	1.5	16.4	15.1	605.0	528.5	257.8	159.7	99.4	73.5	55.5	39.7	34.7	28.5
0	35	2	16.3	15.2	598.0	519.7	262.1	153.7	92.8	71.6	54.2	41.3	36.7	29.0
0	35.5	2.5	16.4	15.1	610.0	555.3	284.2	169.6	102.0	77.2	53.2	42.0	35.5	29.5
0	36	3	16.4	15.2	603.0	589.5	241.0	160.1	103.7	73.5	52.3	43.1	36.6	27.6
0	36.5	3.5	16.7	15.2	607.0	489.3	205.7	168.3	102.8	76.6	55.8	42.7	34.8	29.5
0	37	4	16.5	15.3	614.0	461.3	227.2	144.9	96.4	74.2	54.5	41.6	35.4	29.6
0	37.5	4.5	16.7	15.4	601.0	508.7	224.6	135.9	89.1	70.3	52.9	41.6	35.1	29.4
0	38	5	16.7	15.4	603.0	466.9	239.3	147.0	90.5	69.0	54.9	42.8	36.1	30.8
0	38.5	5.5	16.6	15.4	597.0	454.8	232.0	140.0	92.1	70.3	52.9	42.4	34.9	29.4
0	39	6	16.5	15.5	611.0	468.0	240.6	145.1	92.1	70.8	53.1	42.3	36.3	29.5
0	39.5	6.5	16.6	15.5	602.0	469.6	244.0	146.6	87.4	69.3	53.0	41.7	36.4	29.2
0	40	7	16.5	15.4	618.0	451.1	218.1	134.3	88.2	69.6	52.8	42.8	35.8	29.5
0	40.5	7.5	16.4	15.4	615.0	432.3	219.0	130.4	84.5	66.3	52.5	41.7	35.5	29.6
0	41	8	16.3	15.4	606.0	429.6	204.7	129.7	81.9	64.7	50.0	41.3	35.2	29.1
0	41.5	8.5	16.2	15.4	614.0	435.8	227.5	145.3	83.7	65.6	51.5	42.5	34.3	29.5
0	42	9	16.2	15.3	607.0	511.0	209.3	133.0	84.0	65.5	50.7	41.1	35.2	29.2
0	42.5	9.5	16.2	15.2	617.0	503.9	220.6	134.4	85.8	66.8	51.1	41.5	35.3	29.2
0	43	10	16.2	15.2	622.0	487.4	247.4	144.9	87.4	66.5	50.2	40.7	35.6	27.7
0	43.5	10.5	16.3	15.2	620.0	508.2	231.8	145.2	86.3	65.3	50.2	40.1	34.2	28.5
9000	33	0	15.2	14.7	555.0	572.4	308.8	183.0	92.5	67.9	50.6	39.2	31.7	26.1
9000	33.5	0.5	15.2	14.7	572.0	621.3	329.1	188.6	98.3	69.3	48.8	38.8	33.7	27.4

9000	34	1	15.2	14.7	579.0	552.9	304.1	186.2	96.5	66.4	50.1	40.2	33.6	27.7
9000	34.5	1.5	15.2	14.6	581.0	591.4	301.2	168.1	89.9	69.3	52.4	38.8	33.6	28.2
9000	35	2	15.1	14.6	563.0	612.2	314.2	178.5	88.8	62.7	48.8	38.7	32.4	27.0
9000	35.5	2.5	15.2	14.6	574.0	652.0	338.6	186.1	102.2	67.6	46.3	41.9	34.0	27.5
9000	36	3	15.2	14.6	569.0	694.1	200.2	202.2	100.0	68.0	50.3	41.3	33.1	27.9
9000	36.5	3.5	15.3	14.6	586.0	606.3	322.0	188.8	97.8	67.1	49.4	40.6	33.5	26.6
9000	37	4	15.2	14.6	590.0	576.9	299.0	177.7	97.7	68.8	51.2	40.5	33.5	28.9
9000	37.5	4.5	15.2	14.6	587.0	612.9	288.9	163.6	89.8	68.5	56.8	40.5	34.8	27.8
9000	38	5	15.2	14.6	576.0	599.3	324.9	187.4	94.6	66.7	52.5	41.9	33.6	29.7
9000	38.5	5.5	15.1	14.7	584.0	536.2	303.2	170.0	94.1	66.8	50.3	40.4	34.9	28.0
9000	39	6	15.1	14.6	571.0	526.5	282.9	162.2	92.6	68.1	51.3	40.9	35.4	28.8
9000	39.5	6.5	15.1	14.7	571.0	536.4	285.5	163.8	87.0	66.4	52.2	40.6	34.1	28.5
9000	40	7	14.9	14.7	582.0	521.9	262.7	149.0	86.1	64.2	49.2	40.6	34.4	27.6
9000	40.5	7.5	14.9	14.8	588.0	528.7	283.3	154.2	82.7	59.9	49.1	40.5	34.4	28.1
9000	41	8	14.9	14.8	573.0	571.3	274.4	156.6	80.4	61.2	48.8	39.9	33.5	28.2
9000	41.5	8.5	15.1	14.8	592.0	525.8	270.1	158.4	86.7	62.0	48.9	40.1	33.6	27.8
9000	42	9	15.2	14.9	588.0	587.6	265.4	160.8	89.2	64.9	50.7	40.4	34.9	28.8
9000	42.5	9.5	15.3	15.1	579.0	588.9	277.2	164.0	85.9	60.8	46.6	39.7	33.9	28.1
9000	43	10	15.3	15.2	585.0	560.2	293.3	164.2	90.1	65.0	49.2	39.9	33.7	28.0
9000	43.5	10.5	15.3	15.8	628.0	623.1	312.9	187.0	98.2	66.0	51.1	41.2	35.1	30.1
67500	33	0	14.3	13.1	564.0	679.7	349.7	182.9	95.6	66.1	50.1	37.6	32.5	26.9
67500	33.5	0.5	14.4	13.1	581.0	696.3	354.2	204.4	100.0	68.0	49.1	38.4	33.1	27.7
67500	34	1	14.5	13.1	584.0	640.0	336.3	196.7	95.0	67.4	53.4	41.4	33.9	28.8
67500	34.5	1.5	14.5	13.1	568.0	658.2	335.2	182.7	90.2	72.0	57.0	37.3	31.7	31.0
67500	34.5	1.5	14.5	13.1	568.0	658.2	335.2	182.7	90.2	72.0	57.0	37.3	31.7	31.0
67500	35	2	14.5	13.1	578.0	700.6	362.3	196.5	93.9	64.5	51.7	38.9	33.8	26.9
67500	35.5	2.5	14.5	13.1	571.0	727.7	378.1	199.0	101.7	70.3	83.4	41.6	33.5	28.0
67500	36	3	14.5	13.1	573.0	766.6	188.6	210.7	101.7	67.2	47.9	41.0	35.7	26.9
67500	36.5	3.5	14.5	13.1	582.0	718.3	283.2	201.8	101.9	69.4	52.3	41.3	34.1	27.2
67500	37	4	14.5	13.1	580.0	678.2	341.9	193.0	99.2	69.3	51.2	41.1	33.9	28.7
67500	37.5	4.5	14.5	13.0	571.0	716.2	331.8	178.7	94.3	66.9	52.1	41.5	34.7	30.4
67500	38	5	14.5	13.1	576.0	686.9	359.2	203.5	99.4	66.5	51.5	42.1	35.0	28.9
67500	38.5	5.5	14.5	13.0	579.0	607.9	337.0	182.3	99.3	67.2	51.1	41.1	35.1	30.1
67500	39	6	14.4	13.0	588.0	604.3	319.8	180.3	99.3	67.8	53.1	41.9	33.3	30.1
67500	39.5	6.5	14.4	13.0	581.0	637.7	322.3	178.9	90.3	67.9	52.6	41.3	35.4	29.6
67500	40	7	14.4	13.0	592.0	591.3	282.7	158.4	87.2	69.9	54.1	41.3	34.6	29.4

67500	40.5	7.5	14.4	13.0	583.0	604.4	320.7	167.3	83.5	61.8	50.2	41.1	33.8	28.7
67500	41	8	14.4	13.0	584.0	671.3	327.3	166.0	87.9	61.1	48.1	40.3	36.2	29.7
67500	41.5	8.5	14.4	13.0	580.0	624.9	310.9	182.6	88.0	62.3	49.9	41.3	34.2	28.6
67500	42	9	14.4	13.0	588.0	666.8	300.0	170.7	89.4	65.9	53.4	39.9	35.3	31.5
67500	42.5	9.5	14.4	13.0	598.0	666.9	309.1	172.6	88.8	64.7	50.7	40.7	34.7	28.9
67500	43	10	14.4	12.9	590.0	629.9	325.3	175.7	91.7	64.2	48.8	39.9	34.0	28.4

Table A.10: Falling Weight Deflectometer data: test 10 (experiment 4012)

Load	Chainage		Temperature (°C)		Load	Deflection (µm)								
Cycle	Site	Experiment	Surface	Air	(kPa)	0	200	300	450	600	900	1200	1500	1800
0	27	0	17.8	17.7	586.0	456.4	195.0	134.0	93.8	72.7	50.8	39.3	35.0	29.2
0	27.5	0.5	17.8	17.7	585.0	435.1	229.1	156.5	102.4	76.7	52.7	41.0	32.2	29.3
0	28	1	18.0	17.6	591.0	453.0	230.7	161.3	110.2	80.6	52.5	39.8	35.4	27.8
0	28.5	1.5	18.0	17.7	565.0	483.7	242.9	163.7	107.8	77.6	52.3	40.2	33.8	28.8
0	29	2	18.0	17.7	578.0	503.0	274.5	171.6	109.9	80.8	53.6	41.7	35.4	29.5
0	29.5	2.5	18.0	17.8	583.0	500.9	271.1	178.5	108.4	78.7	52.5	41.5	34.8	29.4
0	30	3	18.0	17.8	551.0	429.8	245.0	152.6	93.0	69.7	49.0	38.5	33.3	27.7
0	30.5	3.5	18.0	17.8	555.0	431.2	223.0	141.5	93.1	69.4	48.6	38.4	33.0	27.9
0	31	4	18.0	17.8	555.0	399.6	228.4	141.3	86.0	63.4	47.3	38.3	32.5	27.8
0	31.5	4.5	18.0	17.8	553.0	427.0	217.2	136.6	85.7	64.4	46.3	37.6	32.4	28.0
0	32	5	18.1	17.7	552.0	389.6	246.6	145.9	88.6	65.2	46.2	37.5	31.6	26.1
0	32.5	5.5	18.1	17.6	558.0	445.7	244.3	135.3	81.3	62.5	46.1	37.9	30.8	28.0
0	33	6	18.1	17.6	550.0	452.6	256.3	144.2	82.3	59.9	44.3	36.3	31.1	26.4
0	33.5	6.5	18.1	17.6	538.0	467.9	257.9	150.0	82.2	58.3	43.6	34.6	31.2	27.8
0	34	7	18.1	17.6	552.0	486.0	254.6	145.4	86.6	61.1	45.0	36.1	30.9	26.1
0	34.5	7.5	18.1	17.6	546.0	478.5	295.2	151.8	84.3	62.9	46.4	37.9	32.6	25.5
0	35	8	18.1	17.6	554.0	507.3	267.1	149.8	81.9	63.9	47.1	37.9	32.6	27.3
0	35.5	8.5	18.1	17.6	575.0	496.4	278.9	160.2	94.0	70.1	49.6	40.6	33.5	28.6
0	36	9	18.0	17.6	579.0	474.2	272.9	152.8	90.4	69.3	50.5	38.7	31.8	29.8
0	36.5	9.5	18.0	17.6	552.0	453.0	191.6	144.3	90.8	69.0	49.9	42.4	32.9	27.4
0	37	10	18.0	17.6	544.0	543.1	300.1	165.0	84.8	66.2	49.7	39.2	34.0	27.7
0	37.5	10.5	18.1	17.6	539.0	592.4	309.9	159.1	86.4	66.9	47.4	39.3	32.8	27.4
9000	27	0	20.1	18.4	604.0	540.2	265.0	163.4	103.1	74.6	54.0	42.7	37.0	31.9
9000	27.5	0.5	20.2	18.5	592.0	617.2	364.7	214.3	120.0	80.1	54.6	45.0	36.6	30.8
9000	28	1	20.3	18.5	590.0	692.8	376.6	242.2	133.4	87.4	56.2	43.6	36.3	30.9
9000	28.5	1.5	20.4	18.5	599.0	743.4	431.6	264.3	143.9	89.2	58.8	45.5	38.2	32.3

9000	29	2	20.4	18.6	603.0	788.3	479.1	283.7	151.8	93.8	58.1	44.9	37.9	31.9
9000	29.5	2.5	20.4	18.6	610.0	786.1	473.7	284.4	143.1	85.3	57.4	44.3	37.7	31.5
9000	30	3	20.4	18.8	562.0	661.5	377.3	223.5	121.1	76.9	54.1	41.0	35.4	29.6
9000	30.5	3.5	20.4	18.8	592.0	691.3	386.9	227.4	122.4	79.9	54.1	44.6	37.4	32.7
9000	31	4	20.2	18.9	565.0	637.6	357.4	205.1	103.3	69.0	49.6	39.7	34.8	29.6
9000	31.5	4.5	20.2	18.9	566.0	679.5	389.0	230.5	112.1	68.2	48.4	40.0	34.9	29.7
9000	32	5	20.3	18.9	559.0	640.8	385.9	226.9	114.0	73.0	48.9	39.5	33.1	28.4
9000	32.5	5.5	20.2	19.0	586.0	662.6	387.5	201.5	100.9	67.9	49.8	41.0	34.6	30.6
9000	33	6	20.1	19.0	566.0	712.0	405.8	217.2	103.0	63.1	47.6	39.3	33.5	29.2
9000	33.5	6.5	20.4	19.1	553.0	749.4	422.0	243.6	106.2	63.8	51.6	40.1	33.8	25.2
9000	34	7	20.4	19.1	563.0	754.0	427.3	224.9	106.2	68.1	48.2	38.6	32.3	28.4
9000	34.5	7.5	20.4	19.2	581.0	743.6	407.7	231.1	101.3	68.6	51.8	41.0	36.0	30.0
9000	35	8	20.3	19.2	567.0	771.9	395.6	220.1	92.4	69.4	50.4	40.4	34.7	27.6
9000	35.5	8.5	20.4	19.2	566.0	751.6	428.5	230.1	108.2	69.6	50.8	40.3	34.1	28.9
9000	36	9	20.5	19.3	592.0	786.4	422.8	215.9	107.3	75.4	55.4	44.3	36.1	30.2
9000	36.5	9.5	20.5	19.3	586.0	734.9	347.8	197.6	103.8	78.7	56.7	41.8	38.2	31.5
9000	37	10	20.5	19.4	573.0	858.3	480.2	258.0	116.8	73.8	53.5	42.3	37.6	30.4
9000	37.5	10.5	20.5	19.4	594.0	855.9	493.6	247.5	114.0	76.0	52.9	43.6	36.9	31.3
60000	27	0	16.0	15.1	562.0	589.0	287.9	173.5	102.0	73.4	54.1	42.8	35.3	31.3
60000	27.5	0.5	16.1	15.1	575.0	685.8	384.4	226.4	122.1	80.0	52.9	41.3	34.9	29.4
60000	28	1	16.2	15.1	580.0	762.0	433.5	263.1	132.5	86.5	55.5	41.2	39.3	29.2
60000	28.5	1.5	16.1	15.1	574.0	846.6	451.4	272.7	140.2	81.1	52.9	42.8	37.4	31.6
60000	29	2	16.2	15.1	569.0	838.2	489.9	288.2	144.1	85.4	53.4	42.3	35.0	29.7
60000	29.5	2.5	16.2	15.0	574.0	810.2	483.6	269.8	127.6	76.7	51.0	39.8	33.8	30.8
60000	30	3	16.2	15.1	563.0	749.0	418.8	242.8	121.7	75.0	51.0	40.7	34.9	29.2
60000	30.5	3.5	16.2	15.1	569.0	731.5	408.9	216.8	118.4	76.5	52.3	41.6	36.5	29.3
60000	31	4	16.3	15.1	575.0	698.3	408.4	230.8	111.1	67.7	50.2	41.1	35.5	30.2
60000	31.5	4.5	16.2	15.1	580.0	764.5	424.8	240.6	112.6	68.4	49.3	40.6	35.0	30.9
60000	32	5	16.2	15.1	568.0	695.0	419.8	244.1	117.8	73.2	47.8	38.9	34.0	28.8
60000	32.5	5.5	16.2	15.1	577.0	739.6	415.1	219.8	101.3	67.2	49.4	41.0	34.5	29.6
60000	33	6	16.2	15.1	566.0	761.6	456.7	242.1	101.8	61.5	46.6	37.7	33.7	28.3
60000	33.5	6.5	16.3	15.1	557.0	788.7	477.1	259.6	117.7	65.9	46.3	38.8	33.2	29.1
60000	34	7	16.3	15.1	583.0	804.6	449.9	245.6	108.9	69.9	48.9	40.4	33.5	28.6
60000	34.5	7.5	16.2	15.1	572.0	825.2	296.1	288.0	99.6	65.4	48.3	40.6	32.0	30.8
60000	35	8	16.2	15.2	546.0	752.7	413.9	218.9	82.3	62.0	51.1	38.7	33.0	26.5
60000	35.5	8.5	16.2	15.1	537.0	739.1	442.5	233.8	105.8	68.2	49.6	40.3	33.4	29.5

60000	36	9	16.2	15.1	550.0	752.0	408.6	206.4	107.5	67.3	48.5	44.6	33.3	26.4
60000	36.5	9.5	16.2	15.2	578.0	769.2	340.1	174.0	85.4	75.2	56.6	44.4	36.4	30.7
60000	37	10	16.1	15.1	584.0	863.9	538.2	282.8	126.4	77.8	53.0	44.5	37.8	30.0
60000	37.5	10.5	16.1	15.1	568.0	890.9	514.7	274.0	114.6	74.3	51.5	42.9	35.6	30.3

A.3 Deflection Analysis

A.3.1 Maximum Deflection

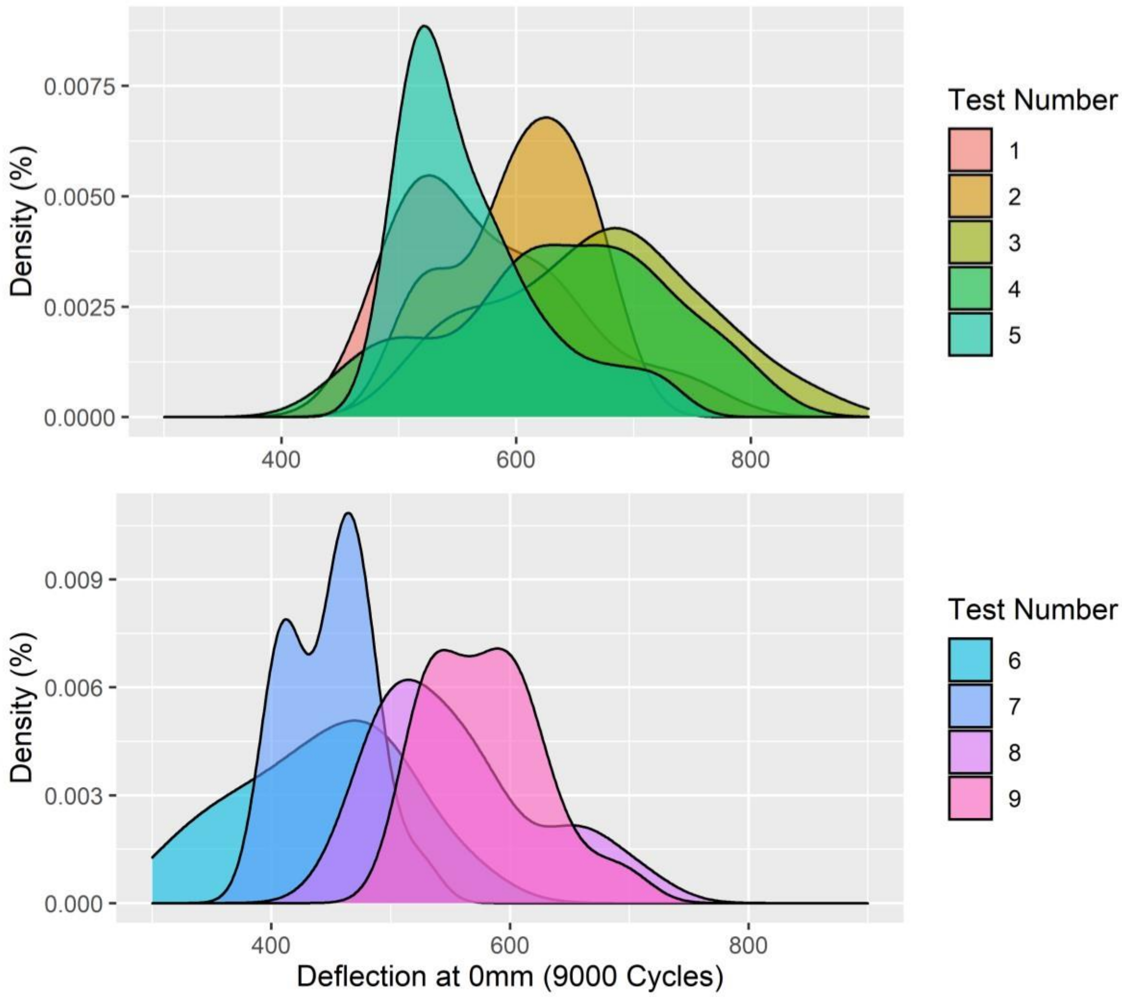
The maximum deflection, measured under the load plate of the FWD, is provided in Figure A.3. When comparing the effects of the tyre pressure, the under-inflated 445/50R22.5 tyres (test number 6) had the least mean deflection. When comparing this with the other 445/50R22.5 tyres, the tyre with the recommended pressure has a relatively tight distribution for the majority, but a portion which is larger. The deflection at the site loaded with the over-inflated 445/50R22.5 is also relatively spread out, with the peak occurring at a similar location.

The differences in pressure for the 11R22.5 tyres show that the tyre tested at its recommended pressure has a tighter distribution, with the peak near the maximum deflection. The uneven and over-inflated tyres have a spread-out distribution, with a similar shape and density of deflection.

Similar to the other tyres, the 385/55R22.5 tyres show more of a spread-out distribution of the deflection.

Generally, it is apparent that the tyres tested at their recommended pressures generated a tighter distribution of deflection than the over-inflated tyres. The distribution of the dual tyres with unevenly distributed inflation pressures, and the under-inflated tyres, was more spread-out, not dissimilar to the over-inflated tyres.

Figure A.3 Deflection density – maximum deflection for tests 1 to 5 and 6 to 9



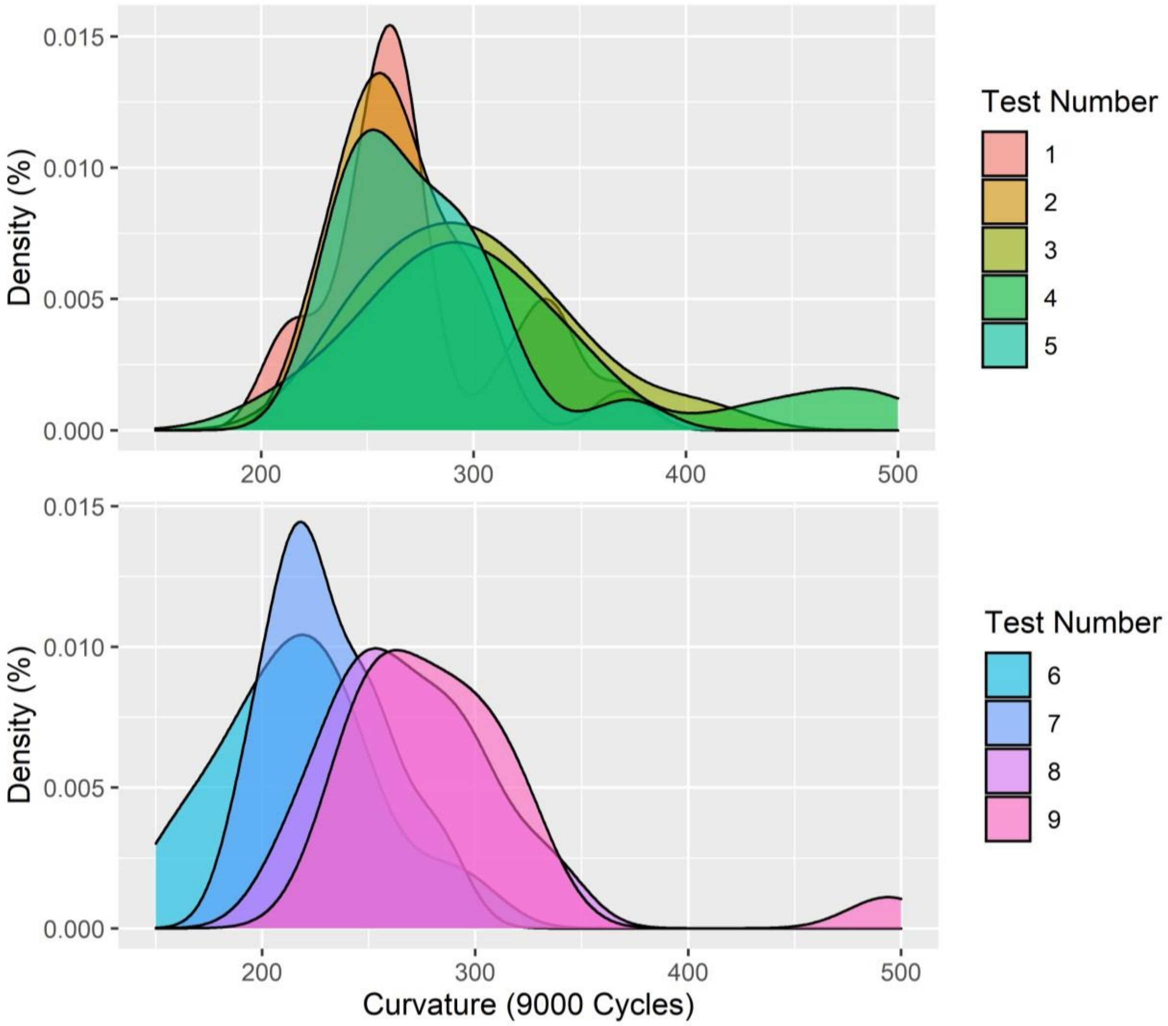
Deflection density –

A.3.2 Curvature: Base Layer

There was less variation in the curvature, with the tyres inflated to the recommended pressure generally having a tighter distribution and lower curvature. The uneven, under-inflated and over-inflated tyres are more spread out in their distribution.

Figure A.4 curvature of deflection for tests 1 to 5 and 6 to 9

Deflection density –

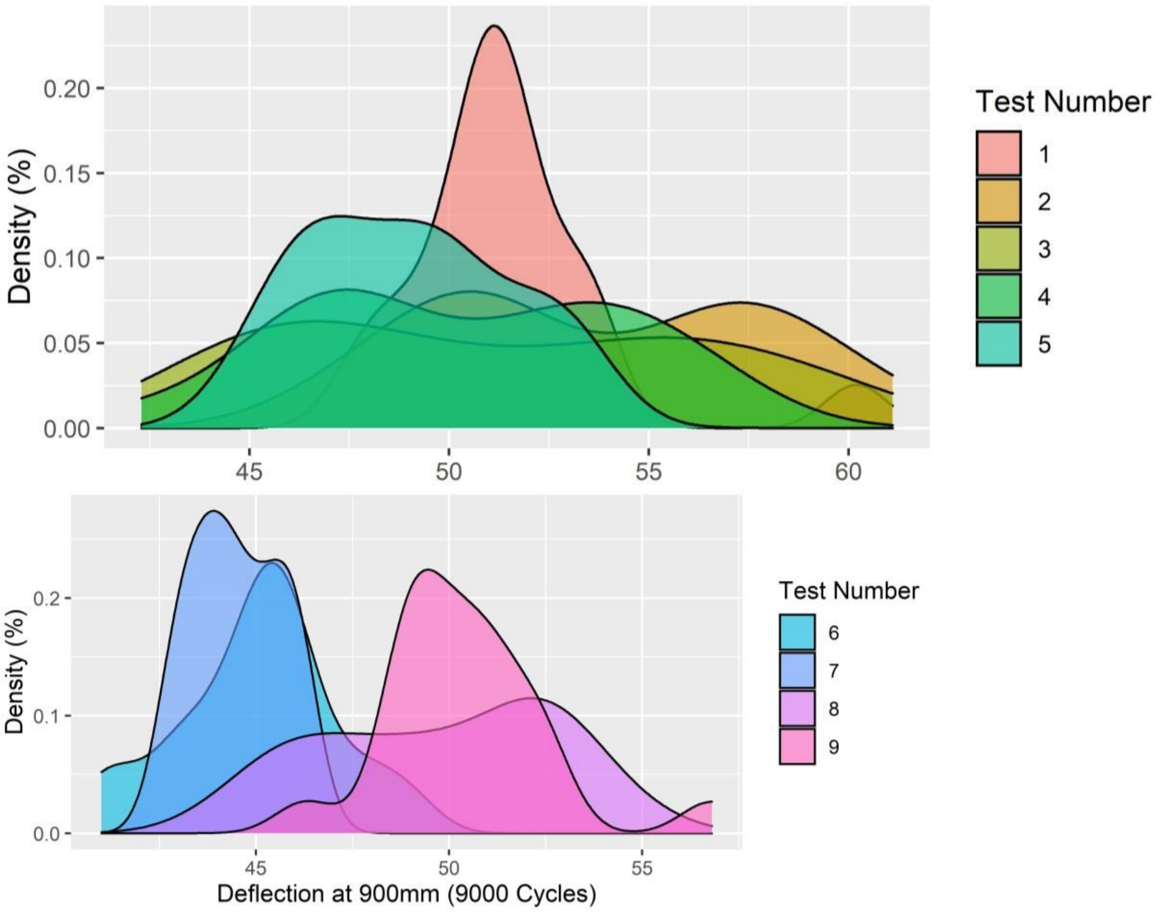


Deflection density –

A.3.3 Deflection: Subgrade

There is no distinct difference or pattern between the different tyre pressures at the subgrade, with the deflection occurring at the test sites being minimal, as shown in Figure A.5.

Figure A.5 **subgrade for tests 1 to 5 and 6 to 9**



Deflection density –

Appendix B Deformation

The average surface deformation of the pavement, measured using the transverse profilometer, is summarised in Table B.1, while the average surface deformation measured during testing is shown in Table B.1 to Table B.1.

The average deformation in all sites, based on number of cycles is plotted in Figure B.1.

Table B.1: Average deformation based on number of cycles

Test no.	Site	Def.	300	1000	9000	10000	15000	22500	30000	37500	45000	52500	60000	67500	75000	100000	130000
1	4006	Average	1.61	2.43	3.24	3.16	3.34	3.53	3.68	3.86	3.90	4.13	–	–	4.11	4.17	4.09
		SD	0.38	0.41	0.54	0.54	0.65	0.64	0.66	0.63	0.69	0.78	–	–	0.72	0.72	0.72
2	4007	Average	1.57	2.09	3.02	3.00	3.12	3.28	3.31	3.45	3.42	3.43	–	–	–	–	–
		SD	0.27	0.21	0.37	0.36	0.36	0.33	0.38	0.39	0.47	0.41	–	–	–	–	–
3	4008	Average	1.29	1.55	2.45	2.61	2.68	2.84	3.01	3.00	3.06	3.04	–	–	–	–	–
		SD	0.27	0.23	0.36	0.39	0.34	0.42	0.41	0.36	0.33	0.31	–	–	–	–	–
4	4005	Average	1.40	1.64	2.53	2.50	2.73	2.87	3.02	3.06	3.15	3.27	–	–	3.35	3.27	3.29
		SD	0.36	0.26	0.27	0.30	0.37	0.22	0.46	0.35	0.37	0.39	–	–	0.41	0.38	0.37
5	4004	Average	1.09	1.50	2.27	2.24	2.43	2.46	2.66	2.78	2.90	2.95	–	–	2.94	–	–
		SD	0.13	0.30	0.37	0.27	0.33	0.33	0.35	0.40	0.40	0.34	–	–	0.38	–	–
6	4003	Average	1.18	1.52	2.26	2.34	2.47	2.60	2.80	3.01	3.17	3.20	–	–	3.32	–	–
		SD	0.25	0.23	0.28	0.23	0.32	0.23	0.31	0.29	0.19	0.41	–	–	0.35	–	–
7	4000	Average	0.91	1.20	1.77	1.86	1.93	1.93	2.10	2.21	2.23	2.37	–	–	-	–	–
		SD	0.21	0.22	0.15	0.31	0.31	0.23	0.27	0.35	0.32	0.37	–	–	-	–	–
8	4001	Average	0.00	0.62	1.34	1.41	1.49	1.61	1.67	1.74	1.75	1.86	–	–	1.92	–	–
		SD	0.00	0.15	0.26	0.28	0.30	0.23	0.25	0.27	0.27	0.37	–	–	0.40	–	–
9	4002	Average	1.06	1.48	2.25	2.23	2.39	2.53	2.59	2.66	2.83	2.82	–	–	2.93	2.90	–

Table

		SD	0.10	0.23	0.27	0.23	0.31	0.26	0.28	0.21	0.35	0.28	–	–	0.44	0.39	–
10	4012	Average	1.10	1.56	2.45	2.59	2.75	2.87	3.07	3.17	3.31	3.34	3.45	–	–	–	–
		SD	0.22	0.32	0.41	0.49	0.46	0.52	0.40	0.40	0.45	0.50	0.44	–	–	–	–

B.2: Surface deformation (mm) for Test 4006 with dual 225/70R22.5 (98 psi) tyres at 40 kN

Chainage (m)	ALF load cycles												
	300	1000	9000	10000	15000	22500	30000	37500	45000	52500	75000	100000	130000
0	**0.91**	2.09	2.83	2.40	2.53	2.88	3.04	3.83	4.22	4.10	4.51	4.60	4.47
0.5	1.39	2.95	3.04	2.78	3.03	3.17	3.32	3.67	3.37	3.46	3.44	3.48	3.56
1	1.60	2.41	2.87	3.15	2.90	3.05	3.07	3.33	3.59	3.42	3.76	3.61	3.72
1.5	1.25	2.05	2.81	2.62	2.72	2.90	2.95	3.05	3.15	3.38	3.29	3.40	3.33
2	1.45	2.15	2.89	2.65	3.10	2.98	3.25	3.61	3.19	3.18	3.17	3.49	3.44
2.5	1.15	2.08	2.63	2.74	2.57	2.91	2.97	3.60	3.32	3.44	3.35	3.18	3.07
3	1.35	2.10	2.66	2.53	2.76	2.98	2.94	2.94	2.81	3.11	3.17	2.95	3.12
3.5	1.55	1.92	3.06	2.76	2.70	3.03	3.48	3.32	3.55	5.73	3.94	3.78	3.55
4	1.24	1.87	2.59	2.44	2.62	2.79	2.87	2.98	3.11	3.29	3.18	3.74	3.34
4.5	1.69	2.52	2.89	2.76	3.06	3.24	3.39	4.16	3.33	3.76	3.81	4.07	3.57
5	1.28	1.84	2.75	2.77	2.66	2.93	3.09	3.08	3.49	3.22	3.44	3.46	3.50
5.5	2.14	2.49	3.67	3.37	3.74	3.88	3.99	4.17	4.07	4.50	4.40	4.51	4.60
6	1.95	2.81	3.65	3.47	3.68	4.06	4.17	4.02	4.21	4.58	4.42	4.63	4.55
6.5	1.85	2.73	3.30	3.37	3.60	3.79	3.84	4.05	4.34	4.22	4.42	4.66	4.49
7	1.43	1.94	2.93	2.79	3.26	3.11	3.25	3.28	3.29	3.63	3.79	3.73	3.55
7.5	**2.31**	3.29	4.12	4.02	4.16	4.41	4.45	4.65	4.85	4.91	4.96	5.10	5.11

Table

8	1.73	2.91	3.73	3.90	4.47	4.34	4.59	4.66	4.43	4.92	5.02	5.09	4.93
8.5	**2.34**	2.90	4.34	**4.40**	4.58	4.76	4.96	5.01	5.18	5.36	5.41	5.34	5.16
9	2.02	2.74	4.15	4.05	3.92	4.47	4.59	4.74	5.03	5.01	5.14	5.16	5.26
9.5	1.60	2.44	3.27	3.44	3.69	4.09	4.44	4.27	4.64	4.55	4.55	4.43	4.35
10	1.42	2.64	3.18	3.36	3.54	3.74	3.99	3.94	4.05	4.37	4.46	4.54	4.49
10.5	1.71	2.54	3.88	3.85	4.12	4.04	4.25	4.60	4.52	4.67	4.87	4.85	4.75
Mean (mm)	1.57	2.43	3.24	3.11	3.34	3.53	3.68	3.86	3.90	4.13	4.11	4.17	4.09

Note: Values in bold were identified as outliers and not included in the mean.

B.3: Surface deformation (mm) for Test 4007 with dual 11R22.5 (76 psi) tyres at 40 kN

Chainage (m)	ALF load cycles									
	300	1000	9000	10000	15000	22500	30000	37500	45000	52500
0	**0.58**	**1.28**	**1.49**	**1.22**	**1.12**	**1.01**	**1.10**	**0.95**	**0.78**	**0.80**
0.5	2.05	1.93	2.55	2.59	2.81	3.00	2.79	3.08	2.98	3.07
1	**2.36**	2.35	3.33	3.03	2.98	3.14	3.20	3.33	2.77	2.99
1.5	**2.35**	**2.73**	2.89	3.05	3.30	3.43	3.57	3.58	3.43	3.37
2	1.50	2.17	2.57	2.66	2.62	2.67	2.70	2.77	2.95	2.74
2.5	1.80	2.21	3.13	2.79	3.18	3.48	3.57	3.42	3.41	3.36
3	1.83	2.36	3.09	3.35	3.53	3.54	3.47	3.96	3.65	3.68
3.5	1.37	**3.08**	3.00	3.25	3.19	3.35	3.59	3.59	3.29	3.64
4	1.45	2.22	2.70	2.60	2.88	3.34	3.24	3.71	3.38	3.66
4.5	1.53	2.13	3.33	3.46	3.65	3.62	3.67	3.52	3.44	3.87
5	1.75	2.29	3.60	3.75	3.66	**3.99**	**4.26**	**4.49**	4.25	**4.61**

Table

5.5	1.57	1.98	3.43	3.04	3.50	3.79	3.99	4.08	3.85	3.85
6	1.99	2.29	3.50	3.63	3.70	**4.07**	**4.43**	4.13	4.16	4.12
6.5	1.62	2.24	3.26	3.23	3.48	3.69	3.76	3.95	3.97	4.21
7	1.30	2.04	2.90	2.92	2.95	**2.30**	3.48	3.36	3.35	3.34
7.5	1.16	1.70	2.57	2.49	2.76	3.04	3.06	3.00	3.09	3.11
8	1.76	2.24	3.53	3.26	3.18	3.43	3.54	3.66	3.78	**4.59**
8.5	1.34	2.10	2.93	2.93	2.84	3.41	3.33	3.19	3.08	3.52
9	1.15	1.76	2.76	2.75	2.80	3.14	3.00	3.25	2.72	2.93
9.5	1.29	**1.56**	2.53	2.75	2.81	2.85	2.84	3.21	3.10	3.25
10	1.59	1.75	3.38	2.99	3.20	3.42	3.47	3.42	4.20	3.60
10.5	1.81	1.91	2.45	2.57	2.58	2.66	2.63	2.81	2.94	2.96
Mean (mm)	1.57	2.09	3.02	3.00	3.12	3.28	3.31	3.45	3.42	3.43

Note: Values in bold were identified as outliers and not included in the mean.

B.4: Surface deformation (mm) for Test 4008 with dual 11R22.5 (76 psi inner and 99 psi outer) tyres at 40 kN

Chainage (m)	ALF load cycles									
	300	1000	9000	10000	15000	22500	30000	37500	45000	52500
0	**0.34**	**0.43**	**0.56**	**0.77**	**0.92**	**0.76**	**1.01**	**0.88**	**0.91**	**0.73**
0.5	1.57	**2.20**	2.98	3.02	3.34	3.09	3.34	3.43	3.35	3.50
1	1.72	**2.21**	**3.74**	**3.88**	**4.21**	**4.31**	**4.34**	**4.38**	**4.40**	**4.67**
1.5	0.85	1.86	2.95	3.20	3.38	3.47	3.50	3.71	3.77	**3.85**
2	1.73	1.97	3.24	3.42	**3.45**	3.65	3.88	**4.09**	**4.10**	**4.04**
2.5	1.29	1.98	2.57	2.57	2.71	3.14	3.19	3.27	3.41	3.28

Table

3	1.31	1.85	2.77	3.08	2.84	3.17	3.39	3.35	3.43	3.58
3.5	1.34	1.61	2.01	2.56	2.41	2.49	2.66	2.62	2.66	2.73
4	1.12	1.39	2.38	2.33	2.65	2.83	2.80	3.04	3.26	2.87
4.5	1.36	1.52	2.62	2.88	3.05	3.54	3.27	3.37	3.18	3.32
5	1.00	1.28	2.09	2.34	2.69	2.71	3.19	3.21	2.98	2.97
5.5	0.79	1.49	1.95	2.37	2.46	2.60	3.03	2.94	2.99	2.92
6	1.32	1.65	2.49	2.64	2.82	3.02	3.43	3.05	2.76	3.27
6.5	1.62	1.44	2.23	2.91	2.92	2.90	2.92	2.96	3.05	3.07
7	1.52	1.61	2.37	2.42	2.36	2.48	2.72	2.53	2.92	2.94
7.5	1.15	1.43	2.35	2.48	2.38	2.60	2.88	2.93	3.00	2.82
8	1.21	1.61	2.59	2.59	2.72	2.89	2.84	2.87	3.18	3.22
8.5	1.48	1.58	2.44	2.88	2.80	2.91	3.35	3.30	3.45	3.21
9	0.93	1.16	2.70	2.08	2.48	2.21	2.31	2.71	2.62	2.64
9.5	1.11	1.32	2.03	1.97	2.09	2.14	2.50	2.32	2.65	**2.04**
10	1.19	1.31	2.21	2.26	2.55	2.62	2.59	2.52	2.71	2.50
10.5	1.49	1.43	1.98	2.22	2.32	2.36	2.45	2.87	2.69	2.77
Mean (mm)	1.29	1.55	2.45	2.61	2.68	2.84	3.01	3.00	3.06	3.04

Note: Values in bold were identified as outliers and not included in the mean.

B.5: Surface deformation (mm) for Test 4005 with dual 11R22.5 (99 psi) tyres at 40 kN

Chainage (m)	ALF load cycles											
	300	1000	9000	10000	15000	22500	30000	37500	45000	52500	75000	100000	130000
0	1.08	1.57	2.41	2.33	2.66	2.71	2.55	2.54	2.64	2.82	2.67	2.61	2.67

Table

0.5	1.33	1.72	2.46	2.53	2.62	2.93	2.88	2.93	3.05	3.27	3.14	3.49	3.35
1	1.33	1.55	2.44	2.48	2.72	2.77	2.82	2.98	3.07	3.11	3.17	3.22	3.26
1.5	2.05	1.93	2.73	2.67	2.75	2.89	3.25	3.30	3.35	3.65	3.71	3.60	3.66
2	1.10	1.54	2.39	2.54	2.61	2.99	3.13	3.27	3.29	3.35	3.34	3.38	3.33
2.5	1.93	1.95	**3.33**	3.22	3.48	**3.43**	3.79	3.68	3.90	3.88	3.96	3.87	4.07
3	1.14	1.81	3.07	**3.37**	3.31	3.19	3.23	3.52	3.44	3.75	3.64	3.71	3.67
3.5	1.43	1.96	3.04	2.80	3.12	2.82	3.72	3.21	3.10	3.53	3.59	3.65	3.57
4	1.99	1.50	2.55	2.44	2.64	3.07	2.68	3.13	3.32	3.28	3.35	3.71	3.54
4.5	1.51	1.59	2.50	2.47	2.57	2.62	3.07	3.15	3.13	3.35	3.53	3.43	3.58
5	1.30	1.45	2.55	2.39	2.42	2.73	2.79	2.83	2.97	3.58	4.00	3.15	3.14
5.5	1.66	2.06	2.45	2.65	2.75	2.88	3.03	2.97	2.93	2.94	3.12	3.05	3.28
6	1.16	1.39	2.50	2.51	2.66	2.87	3.06	3.14	3.20	3.22	3.34	3.30	3.26
6.5	1.95	2.12	**3.19**	**3.31**	3.19	**3.60**	3.71	**3.84**	3.85	3.89	4.02	**4.16**	**4.30**
7	1.35	1.59	2.16	2.16	2.26	2.43	2.39	2.60	3.47	2.72	3.64	2.83	3.06
7.5	1.38	1.84	2.72	2.78	3.23	3.24	3.92	3.77	3.45	3.81	**4.30**	3.58	3.67
8	0.99	1.33	2.08	2.21	2.22	**2.18**	2.52	2.69	2.76	3.25	2.75	2.85	2.86
8.5	0.69	1.25	2.27	2.31	2.40	2.67	2.56	2.66	2.75	2.82	3.11	2.89	2.81
9	1.24	1.47	2.32	2.17	2.48	**2.25**	2.49	2.75	2.83	2.94	3.15	3.05	3.05
9.5	1.75	**2.33**	2.93	2.99	3.17	3.21	3.27	3.19	3.47	3.29	3.50	3.69	3.60
10	1.21	1.57	2.52	2.30	2.60	2.80	3.00	2.82	2.87	2.87	2.94	2.90	2.91
10.5	1.14	1.26	**1.92**	1.99	2.18	**1.93**	2.48	**2.26**	2.48	2.59	2.71	2.74	2.79
Mean (mm)	1.40	1.64	2.53	2.50	2.73	2.87	3.02	3.06	3.15	3.27	3.35	3.27	3.29

Note: Values in bold were identified as outliers and not included in the mean.

Table B.6: Surface deformation (mm) for Test 4004 with single 445/50R22.5 (102 psi) tyres at 40 kN

Chainage (m)	ALF load cycles										
	300	1000	9000	10000	15000	22500	30000	37500	45000	52500	75000
0	1.11	1.78	2.33	2.18	2.17	2.32	2.47	2.54	3.30	2.79	2.76
0.5	0.81	0.96	1.73	1.81	1.95	2.18	2.67	2.30	2.33	2.47	2.26
1	1.08	1.56	2.69	2.51	2.57	2.71	2.65	3.10	2.97	2.92	3.28
1.5	1.24	1.73	2.44	2.47	2.65	2.84	3.03	3.29	3.25	3.45	3.47
2	1.27	1.63	2.46	2.34	2.79	2.01	2.56	2.87	3.04	3.25	3.04
2.5	**1.71**	2.07	2.94	2.75	3.06	3.15	3.17	3.38	3.31	3.51	3.13
3	1.13	1.50	2.39	2.14	2.84	2.74	2.86	3.11	3.05	3.19	3.37
3.5	1.03	1.30	2.40	2.09	2.26	2.61	2.53	2.78	2.76	3.08	3.06
4	**0.76**	1.26	1.93	2.19	2.30	2.34	2.65	2.80	2.85	2.88	3.05
4.5	1.11	1.53	2.17	2.10	2.26	2.50	2.41	2.50	3.07	2.58	2.79
5	1.15	1.72	2.54	2.44	2.47	**3.59**	2.61	2.58	2.87	3.06	2.97
5.5	0.88	1.43	2.01	2.15	2.30	2.42	2.68	2.72	2.70	2.76	2.98
6	1.23	1.58	2.27	2.20	2.34	2.45	2.68	2.77	2.77	2.92	3.10
6.5	**0.58**	1.06	1.70	**1.71**	1.81	2.22	2.27	2.46	2.46	2.69	2.66
7	0.87	1.30	2.13	2.44	2.23	2.31	2.37	2.36	2.58	2.47	2.65
7.5	1.02	1.17	1.76	1.81	2.31	1.87	2.09	2.17	2.14	**2.13**	2.18
8	1.15	1.23	1.74	1.89	2.20	2.20	2.25	2.47	2.44	2.75	2.64
8.5	1.04	1.24	2.04	2.13	2.39	2.31	2.30	2.42	2.58	2.53	2.60
9	1.09	1.35	2.11	1.95	2.25	2.57	3.02	2.91	3.39	3.21	3.31
9.5	1.22	1.78	2.54	2.44	2.80	3.04	3.24	3.27	3.27	3.50	3.61

Table

10	1.24	1.89	2.90	**3.01**	3.03	**3.52**	**3.72**	3.68	3.72	**3.81**	**4.00**
10.5	1.06	1.90	2.66	2.69	**3.25**	**3.60**	3.43	**3.82**	**3.99**	**3.97**	**4.23**
Mean (mm)	1.09	1.50	2.27	2.24	2.43	2.46	2.66	2.78	2.90	2.95	2.94

Note: Values in bold were identified as outliers and not included in the mean.

B.7: Surface deformation (mm) for Test 4003 with single 445/50R22.5 (81 psi) tyres at 40 kN

Chainage (m)	ALF load cycles										
	300	1000	9000	10000	15000	22500	30000	37500	45000	52500	75000
0	0.87	1.07	**1.20**	**1.46**	**1.52**	**1.42**	**1.65**	**2.19**	**2.62**	2.44	**2.36**
0.5	0.72	1.23	1.65	**1.68**	1.99	**1.86**	2.22	2.72	**2.70**	2.59	2.97
1	1.19	1.64	1.91	1.96	1.82	2.21	2.29	**2.39**	**2.56**	2.90	2.70
1.5	1.35	1.79	2.07	2.17	2.57	2.56	2.66	2.90	3.18	3.19	3.45
2	1.09	1.51	2.08	1.96	2.18	2.21	2.54	2.78	3.07	2.89	3.20
2.5	1.20	1.30	1.92	2.23	2.19	2.55	2.78	2.70	2.96	2.76	3.05
3	0.95	1.14	2.05	2.08	2.19	2.49	2.52	2.60	2.85	2.77	3.04
3.5	1.01	1.45	2.23	2.32	2.44	2.63	2.81	2.89	2.94	2.96	2.90
4	1.10	1.39	2.14	2.22	2.25	2.35	2.79	2.86	2.95	2.86	3.14
4.5	1.27	1.85	2.67	2.63	2.73	2.88	2.91	3.11	3.21	3.36	3.37
5	1.62	1.83	2.51	2.76	3.07	**3.41**	3.35	3.53	3.50	3.73	3.74
5.5	1.50	1.78	2.55	2.48	2.43	2.80	3.00	3.13	3.20	3.24	3.32
6	1.10	1.67	2.33	2.20	2.46	2.76	2.57	3.01	3.11	3.48	3.67
6.5	1.52	1.71	2.42	2.30	2.32	2.69	2.77	2.91	3.25	3.15	3.27
7	0.86	1.41	2.25	2.25	2.65	2.52	2.93	2.83	3.06	3.10	2.99

Table

7.5	0.77	1.29	2.10	2.49	2.51	2.64	2.75	3.19	3.24	3.34	3.30
8	1.23	1.53	2.51	2.29	2.62	2.62	3.04	2.98	3.26	3.27	3.50
8.5	1.26	1.49	2.67	2.65	2.82	**3.22**	3.33	**3.77**	3.43	3.66	3.75
9	1.21	1.49	2.38	2.42	2.70	**3.25**	3.22	3.55	3.53	3.94	3.95
9.5	1.43	1.46	2.29	2.39	2.43	2.62	2.80	2.97	3.24	3.25	3.15
10	1.39	1.78	**3.05**	**3.16**	**3.23**	**3.33**	**3.56**	**3.75**	**3.96**	3.82	3.90
10.5	1.32	1.66	2.56	2.70	3.05	3.11	**3.48**	3.56	**3.80**	3.67	**4.45**
Mean (mm)	1.18	1.52	2.26	2.34	2.47	2.60	2.80	3.01	3.17	3.20	3.32

Note: Values in bold were identified as outliers and not included in the mean.

B.8: Surface deformation (mm) for Test 4000 with single 445/50R22.5 (122 psi) tyres at 40 kN

Chainage (m)	ALF load cycles									
	300	1000	9000	10000	15000	22500	30000	37500	45000	52500
0	1.30	1.43	1.83	1.92	1.98	2.00	2.23	1.93	2.07	2.27
0.5	0.82	1.16	**1.38**	1.56	1.62	1.65	1.85	1.88	1.73	1.84
1	0.80	1.16	1.65	1.76	1.86	1.94	2.01	2.75	2.85	2.31
1.5	1.08	1.29	1.91	2.04	2.02	2.16	2.27	2.36	2.40	2.53
2	1.16	1.43	2.08	2.07	2.24	2.17	2.45	2.66	2.69	2.76
2.5	0.71	1.08	1.50	1.43	1.53	1.61	1.65	1.64	1.70	1.83
3	1.11	1.27	1.93	1.83	1.98	1.99	2.16	2.15	2.30	2.31
3.5	0.78	1.05	**1.43**	1.47	1.60	1.72	1.71	1.83	1.95	2.00
4	0.74	0.96	1.71	1.93	1.72	1.85	1.98	1.77	2.04	**3.52**
4.5	0.55	1.01	1.61	1.51	1.59	1.72	1.85	1.95	2.00	2.04

Table

5	0.81	1.11	1.55	1.51	1.58	1.62	2.00	2.00	1.92	2.21
5.5	1.06	1.13	1.77	1.84	1.74	1.83	2.06	2.29	2.30	2.39
6	1.06	1.37	**2.28**	2.29	2.30	2.34	2.41	2.53	2.43	2.57
6.5	1.18	**1.77**	**2.50**	2.20	2.35	**2.79**	2.44	2.66	**2.95**	2.95
7	0.80	1.69	**2.30**	2.43	2.50	2.40	2.70	2.92	**2.89**	3.01
7.5	0.62	1.31	**2.47**	2.50	2.60	**2.58**	**2.87**	**3.33**	**1.39**	3.11
8	0.68	0.77	1.72	1.74	1.68	1.89	2.09	2.41	2.43	2.35
8.5	1.21	1.40	1.73	2.03	1.93	2.07	2.38	2.34	2.70	2.57
9	0.74	1.06	1.81	1.55	1.84	1.91	2.03	2.09	2.33	2.45
9.5	0.89	1.22	1.82	1.71	1.88	1.99	1.99	1.95	2.03	2.02
10	1.08	1.42	1.87	1.63	1.67	1.66	1.91	1.91	2.02	1.92
10.5	0.87	0.84	1.84	2.03	2.16	1.96	1.85	2.29	2.42	2.32
Mean (mm)	0.91	1.20	1.77	1.86	1.93	1.93	2.10	2.21	2.23	2.37

Note: Values in bold were identified as outliers and not included in the mean.

B.9: Surface deformation (mm) for Test 4001 with single 385/55R22.5 (131 psi) tyres at 40 kN

Chainage (m)	ALF load cycles										
	300	1000	9000	10000	15000	22500	30000	37500	45000	52500	75000
0	0.00	0.40	1.02	1.04	1.18	1.14	1.18	**1.07**	1.30	1.15	1.22
0.5	0.00	0.43	1.03	1.26	1.20	1.22	1.39	1.36	1.52	1.37	1.37
1	0.00	0.37	0.85	0.96	0.90	**1.03**	1.30	1.32	1.35	1.40	1.59
1.5	0.00	0.65	1.15	0.97	1.37	1.56	1.49	1.62	1.73	1.91	2.03
2	0.00	0.83	1.38	1.23	1.53	1.48	1.74	1.68	1.88	1.78	1.78

Table

2.5	0.00	0.72	1.17	1.30	1.79	1.66	1.79	1.76	1.62	1.87	1.71
3	0.00	0.48	1.21	1.09	1.40	1.53	1.42	1.39	1.39	1.49	1.67
3.5	0.00	0.42	1.43	1.43	1.28	1.57	1.52	1.53	1.62	1.67	1.64
4	0.00	0.54	1.11	1.37	1.22	1.42	1.62	1.38	1.72	1.54	1.63
4.5	0.00	0.65	1.17	1.38	1.49	1.45	1.54	1.97	1.50	1.57	1.59
5	0.00	0.68	1.32	1.38	0.98	1.45	1.51	1.61	1.74	1.87	1.67
5.5	0.00	0.56	1.52	1.66	1.64	1.77	1.95	1.95	1.96	2.03	2.22
6	0.00	0.77	1.64	1.45	1.62	1.91	1.84	1.94	2.06	2.25	2.23
6.5	0.00	0.87	1.52	1.45	1.50	1.57	1.83	1.92	1.80	2.04	2.07
7	0.00	0.81	1.25	1.16	1.36	1.63	1.54	1.51	1.60	1.67	1.77
7.5	0.00	0.58	1.35	1.62	1.88	1.90	1.93	1.92	1.87	1.93	1.97
8	0.00	0.60	**2.03**	1.69	1.88	1.98	2.12	2.17	2.15	2.26	2.55
8.5	0.00	0.60	1.53	1.76	1.70	1.79	1.86	2.03	2.08	2.27	2.43
9	0.00	0.87	1.69	1.60	1.84	1.88	2.04	2.08	2.19	2.19	2.25
9.5	0.00	0.60	1.58	1.51	1.61	1.61	1.75	1.90	1.96	2.14	2.12
10	0.00	**0.96**	**2.21**	1.97	**2.42**	**2.56**	**2.85**	**2.82**	**2.82**	**2.95**	**3.05**
10.5	0.00	0.63	1.84	1.83	1.97	**2.25**	**2.40**	**2.55**	**2.75**	2.63	2.83
Mean (mm)	0.00	0.62	1.34	1.41	1.49	1.61	1.67	1.74	1.75	1.86	1.92

Note: Values in bold were identified as outliers and not included in the mean.

B.10: Surface deformation (mm) for Test 4002 with single 385/55R22.5 (102 psi) tyres at 40 kN

Chainage (m)	ALF load cycles										
	300	1000	9000	10000	15000	22500	30000	37500	45000	52500	75000	100000

Table

0	**0.69**	**0.67**	**1.38**	**1.34**	**1.37**	**1.45**	**1.52**	**2.01**	**1.83**	**1.98**	**1.96**	2.21
0.5	0.97	1.11	2.02	2.13	2.46	2.59	2.75	2.77	2.79	3.00	2.96	2.96
1	0.88	1.09	2.21	2.35	2.10	2.37	2.25	2.58	2.75	2.59	2.88	2.71
1.5	1.02	1.30	2.37	2.22	2.50	2.67	2.77	2.94	3.09	2.98	3.21	3.02
2	1.07	1.28	2.31	2.34	2.68	2.69	2.72	2.66	3.19	2.95	3.01	2.96
2.5	1.01	1.36	2.21	2.28	2.30	2.49	2.36	2.58	2.85	2.88	2.92	2.94
3	1.09	1.83	2.80	**2.99**	2.96	**3.17**	**3.53**	**3.60**	3.56	**3.64**	3.72	3.67
3.5	1.00	1.58	2.24	2.27	2.31	2.45	2.48	2.53	2.91	3.06	3.03	3.03
4	1.16	1.44	2.32	2.32	2.27	2.42	2.84	2.63	2.69	2.86	2.96	3.04
4.5	**1.44**	1.89	**2.88**	**2.84**	2.83	2.91	3.04	**3.36**	3.34	**3.55**	3.65	3.53
5	0.99	1.24	1.84	1.80	2.01	2.09	2.25	2.41	2.54	2.54	2.67	2.64
5.5	**0.79**	1.32	1.93	2.12	2.12	2.23	2.36	2.64	2.53	2.62	2.48	2.35
6	0.97	1.40	1.98	1.89	2.22	2.58	2.51	2.46	2.72	2.63	2.79	2.93
6.5	1.23	1.81	2.54	2.51	2.83	2.97	**3.29**	2.88	3.13	3.08	3.40	3.14
7	1.27	1.71	2.55	2.49	2.50	2.71	2.74	2.75	2.72	2.97	2.83	2.84
7.5	**1.41**	1.73	2.50	2.48	2.73	2.86	3.08	3.09	3.09	3.35	3.35	3.45
8	1.00	1.69	2.30	2.39	2.48	2.65	2.71	2.53	2.88	2.91	3.03	3.17
8.5	1.15	1.53	2.54	2.49	2.66	2.78	2.81	2.99	3.10	3.18	3.37	3.25
9	0.95	1.49	2.12	2.22	2.02	2.33	2.70	2.66	2.47	2.55	2.51	2.55
9.5	1.12	1.43	2.15	2.00	2.15	2.37	2.46	2.45	2.48	2.51	2.04	2.59
10	1.08	1.36	1.72	1.79	1.84	2.03	2.00	**2.11**	2.00	2.18	2.13	2.26
10.5	1.17	1.45	2.30	2.21	2.31	2.46	2.40	2.36	2.52	2.71	2.52	2.55

Table

Mean (mm)	1.06	1.48	2.25	2.23	2.39	2.53	2.59	2.66	2.83	2.82	2.93	2.90

Note: Values in bold were identified as outliers and not included in the mean.

B.11: Surface deformation (mm) for Test 4012 with single 445/50R22.5 (102 psi) tyres at 40 kN

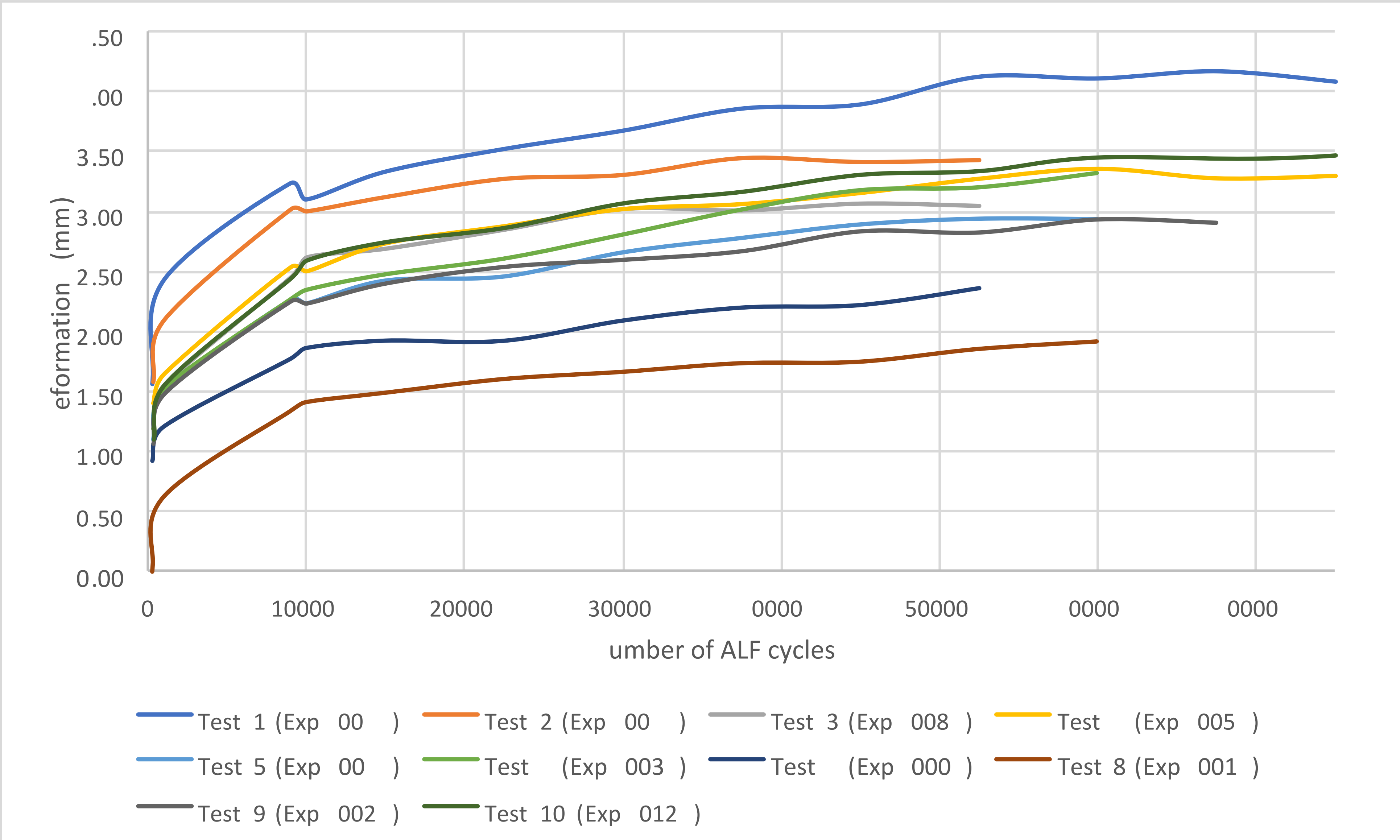
Chainage (m)	ALF load cycles										
	300	1000	9000	10000	15000	22500	30000	37500	45000	52500	60000
0	**0.49**	1.00	**1.56**	1.52	1.75	1.65	**1.80**	**1.76**	1.84	**1.72**	**2.03**
0.5	0.91	1.28	1.69	1.72	2.09	2.25	2.31	2.42	2.64	2.57	2.71
1	0.66	1.15	2.23	2.23	2.43	2.49	**0.76**	2.79	**-4.39**	2.89	3.23
1.5	1.08	1.75	2.78	2.85	3.06	3.07	4.01	3.45	3.49	3.60	3.71
2	1.36	1.77	2.95	3.19	3.30	3.42	3.40	3.72	3.77	3.83	3.86
2.5	1.47	1.57	2.77	2.77	2.84	3.38	3.54	3.53	3.60	3.83	3.86
3	1.08	1.39	2.22	2.24	2.32	2.46	2.95	2.93	2.68	2.49	2.78
3.5	0.95	1.68	2.13	2.19	2.29	2.09	2.47	2.61	2.42	2.68	2.72
4	0.81	0.93	2.12	2.14	2.36	2.59	2.84	2.92	3.02	3.12	3.17
4.5	1.02	2.12	**3.49**	3.10	3.24	3.49	3.55	3.74	3.78	3.83	3.93
5	0.79	1.22	2.09	2.05	2.30	2.42	2.48	2.57	2.56	2.75	2.77
5.5	1.18	1.54	2.16	2.45	2.40	2.43	2.62	2.80	2.95	3.05	3.16
6	1.14	1.62	2.80	2.75	3.05	3.07	3.28	3.42	3.49	3.67	3.69
6.5	1.33	1.99	3.00	3.13	3.35	3.59	3.40	3.61	3.67	3.69	3.80
7	1.38	1.80	2.85	3.15	3.22	3.48	3.37	3.50	3.42	3.73	3.62
7.5	1.21	1.84	2.49	3.03	2.81	2.98	3.07	3.41	3.79	3.90	3.85
8	1.00	1.28	2.27	2.59	2.58	2.84	2.99	3.03	3.24	3.33	3.41

Table

8.5	1.32	1.86	3.03	3.31	3.32	3.43	3.64	**4.77**	3.81	4.11	4.11
9	0.91	1.34	2.57	2.57	2.65	2.84	2.75	2.97	3.24	2.74	3.25
9.5	1.33	1.76	2.72	2.74	3.14	3.02	3.01	3.16	3.30	3.21	3.30
10	1.08	1.63	2.59	2.57	2.77	2.97	3.27	3.27	3.75	3.43	3.76
10.5	1.11	1.77	2.37	2.78	3.16	3.08	3.37	3.47	3.54	3.65	3.79
Mean (mm)	1.10	1.56	2.45	2.59	2.75	2.87	3.07	3.17	3.31	3.34	3.45

Note: Values in bold were identified as outliers and not included in the mean.

Figure B.1: Average deformation based on number of cycles



Appendix C Adjusted Deformation Rate

C.1 Deformation Rate Adjustment Method

In order to correct the measured deformation rate to take account of variability in the test pavement conditions a method derived from previous research was used.

Using the relationship developed for a similar high-quality 20 mm base material (20 mm Montrose crushed rock) (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 identified in equation E5, the relationship between the rutting and SNP is shown in equation E6.

$$Rut = SNP^a \times Cycles^b \times f(load, Tyre, Pressure) \quad \text{E1}$$

$$\frac{\Delta Rut(SNP_i)}{\Delta Rut(SNP_0)} = \left(\frac{SNP_i}{SNP_o}\right)^a \quad \text{E2}$$

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

$$\Delta Rut(SNP_0) = \left(\frac{SNP_0}{SNP_i}\right)^a \times \Delta Rut(SNP_i) \quad \text{E3}$$

C.2 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:

$$SNP = SN + SN_{sg} \quad \text{E4}$$

The method used to estimate the structural number was developed by Roberts (1995) based on FWD deflection data collected in Australia and Philippines (refer to equation E2).

$$SN = 12.992 - 4.167 \times log_{10}(D_0) + 0.936 \times log_{10}(D_{900}) \quad \text{E5}$$

The structural contribution of the subgrade (equation E3) was calculated using an estimation for the California Bearing Ration of the subgrade developed by Jameson (1993) (equation E4).

$$SN_{sg} = 3.51 \times log_{10}(CBR) - 0.85 \times (log_{10}(CBR))^2 - 1.43 \quad \text{E6}$$

$$CBR = 10^{3.264-1.018 \times log10(D900)} \quad \text{E7}$$

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 at 9000 cycles.

Appendix D Statistical Significance of Test Results

A review of the deformation rates was undertaken in an attempt to understand the effect of the tyre pressure on the deformation rate. This was undertaken using the Student *t*-test, with a null hypothesis being that the deformation rates for all tyres are the same. Any values where the probability (p) is less than or equal to 0.05 signals that the tyre pressures had an impact on performance. Comparing the results of the 11R22.5 tyres, it was found that the sites trafficked at the recommended pressure and the uneven pressure had a deformation rate which was statistically the same for the adjusted rate of deformation, as shown in Table D.1. The tyres with the increased tyre pressure had a statistically significant different rate of deformation to the tyres with the recommended tyre pressure, meaning that the higher deformation rate of deformation of the tyres with increased pressure is statistically higher.

Table D.1: Statistical comparison of 11R22.5 tyre pressures with recommended pressure

	Tests 2 & 3	Tests 2 & 4
Rate of deformation	Statistically different to 2	Statistically different to 2
Adjusted rate of deformation	Statistically the same as 2	Statistically different to 2

Similarly, the rate of deformation results for the 445/50R22.5 tyres at low pressure were compared with the results at the recommended pressure. As shown in Table D.2 and Table D.3, the rate at the low tyre pressure was found to be statistically different from that at the recommended pressure. This is not surprising as there were issues identified at the test site associated with moisture content.

Table D.2: Statistical comparison of 445R tyre pressures with recommended pressure

	5 & 6	5 & 7
Rate of deformation	Statistically different to 5	Statistically different to 5
Adjusted rate of deformation	Statistically different to 5	Statistically the same as 5

Note: Test 6 compared for completeness, this should not be considered due to issues with moisture content identified.

Table D.3: Statistical comparison of 385R tyre pressures with recommended pressure

	9 & 8
Rate of deformation	Statistically different to 9
Adjusted rate of deformation	Statistically the same as 9

The tyre sizes were also compared to identify statistically significant differences in results (Table D.4). It was found that, based on the rate of deformation, the results for all the tyres were statistically different.

Table D.4: Statistical comparison of tyre sizes with recommended pressure

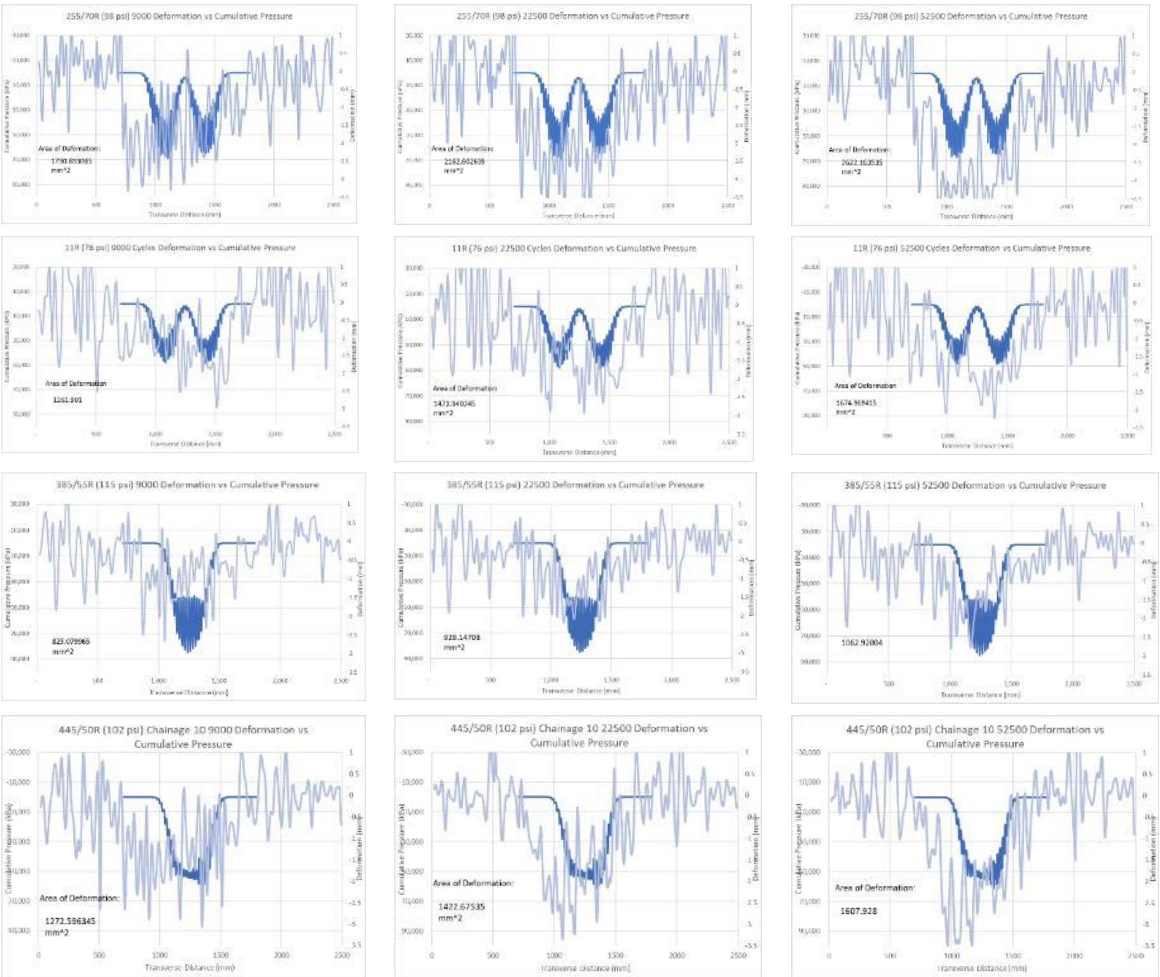
	2 & 1	2 & 5	2 & 9
Rate of deformation	Statistically different to 2	Statistically different to 2	Statistically different to 2

Adjusted rate of deformation	Statistically different to 2	Statistically different to 2	Statistically different to 2

Appendix E Deformation Based on Number of Cycles and Tyre Size

Figure E.1 Average deformation based on cycle number

9,000 22,500 52,500



255/70R

11R

385/55R

445/50R

E.1 255/70R22.5

Figure E.2 Deformation and cumulative pressure profile for 255/70R22.5 (98 psi) at 9,000 cycles

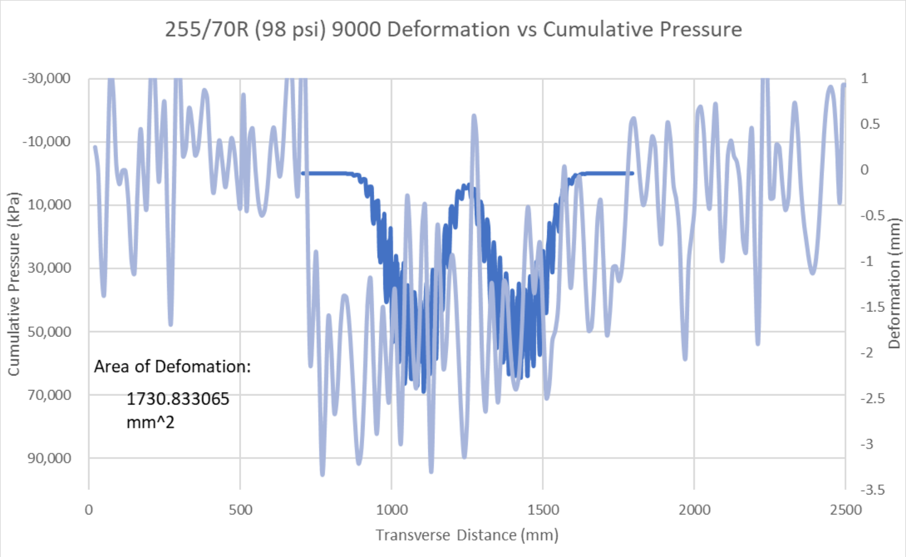
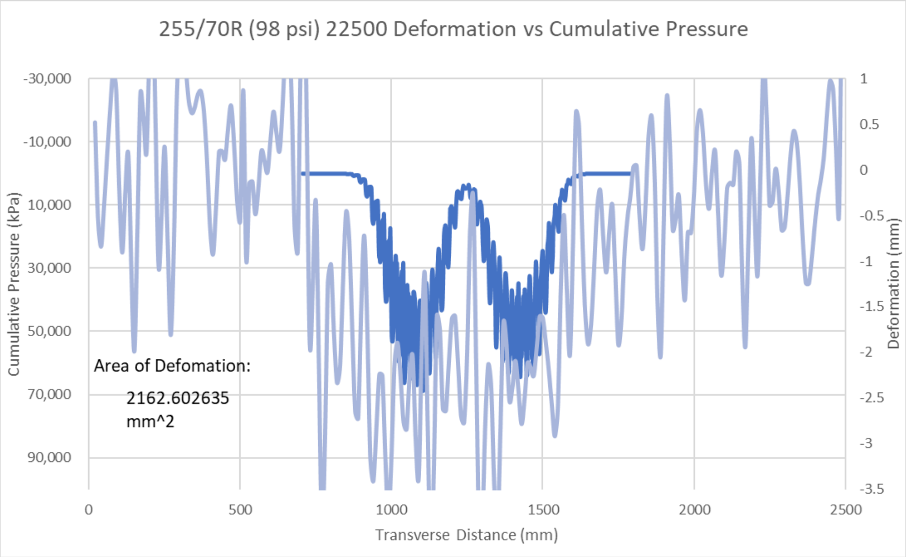
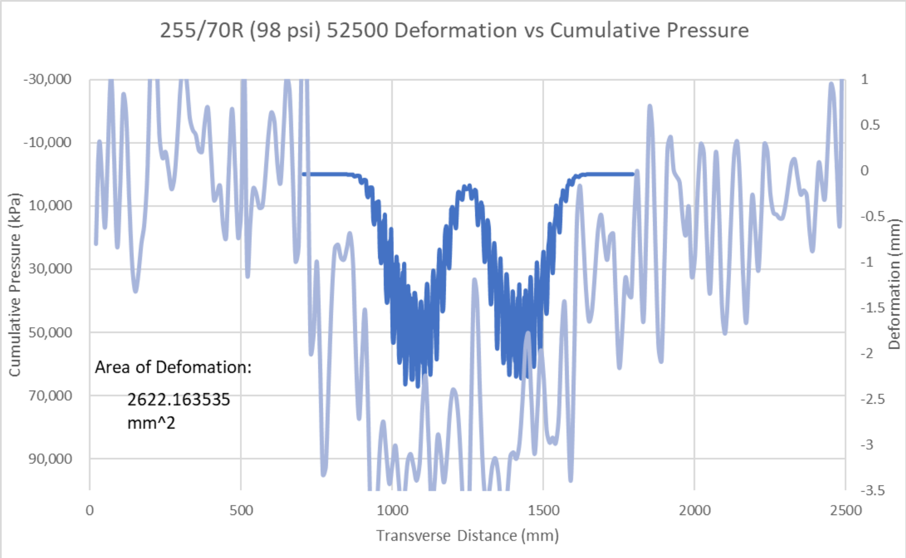


Figure E.3 Deformation and cumulative pressure profile for 255/70R22.5 (98 psi) at 22,500 cycles



255/70R (98 psi) 22500 Deformation vs Cumulative Pressure
Cumulative Pressure (kPa)
-30,000
-10,000
10,000
30,000
50,000
70,000
90,000
Deformation (mm)
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
0
500
1000
1500
2000
2500
Transverse Distance (mm)
Area of Defomation:
2162.602635
mm^2

Figure E.4 Deformation and cumulative pressure profile for 255/70R22.5 (98 psi) at 52,500 cycles



E.2 11R22.5

Figure E.5 Deformation and cumulative pressure profile for 11R22.5 (76 psi) at 9,000 cycles

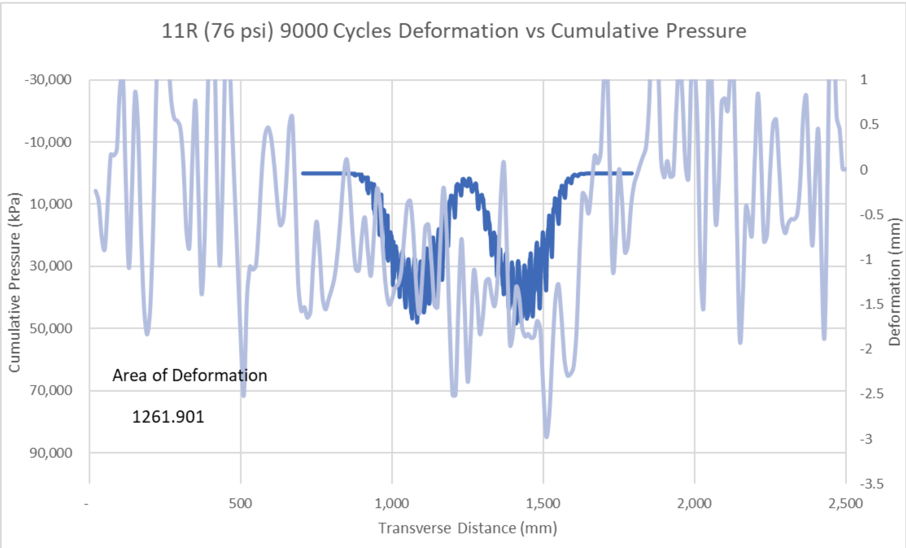


Figure E.6 Deformation and cumulative pressure profile for 11R22.5 (76 psi) at 22,500 cycles

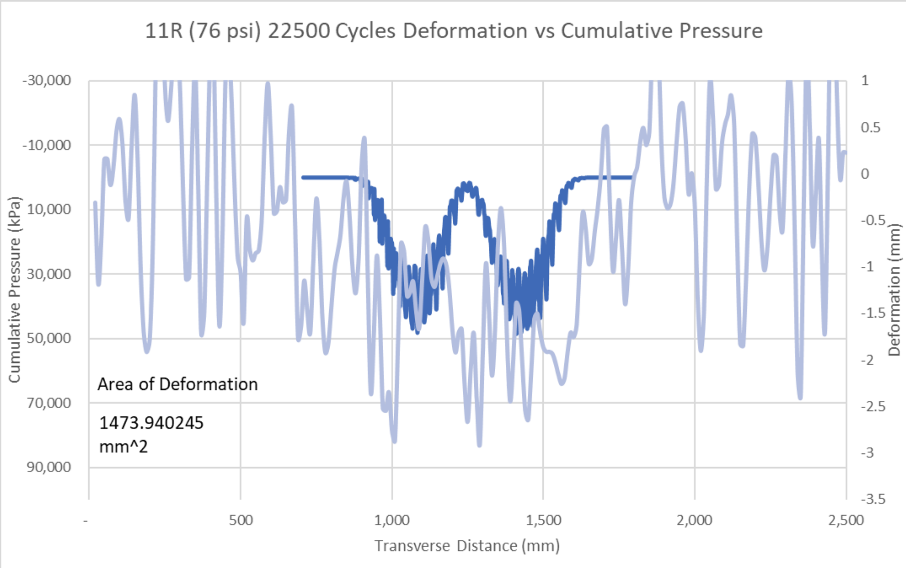
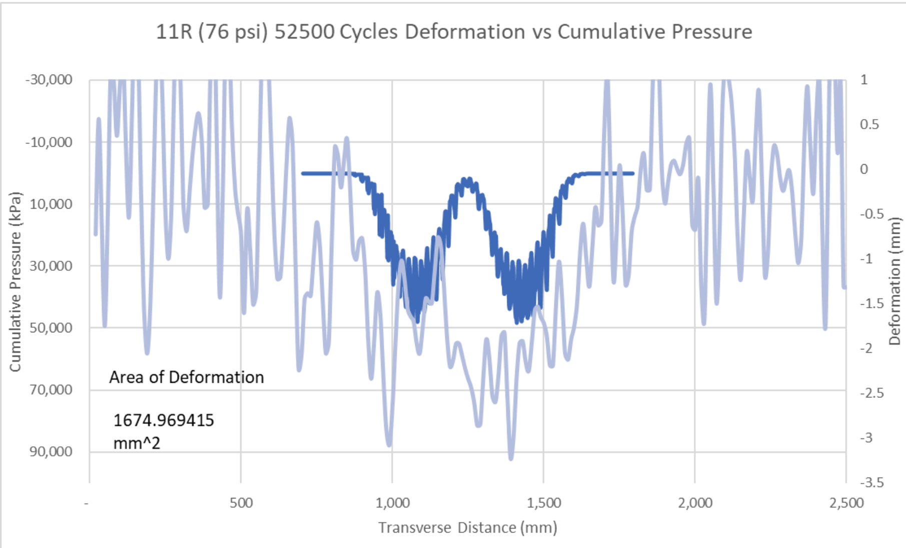


Figure E.7 Deformation and cumulative pressure profile for 11R22.5 (76 psi) at 52,500 cycles



E.3 445/50R22.5

Figure E.8 Deformation and cumulative pressure profile for 445/50R22.5 (102 psi) at 9,000 cycles

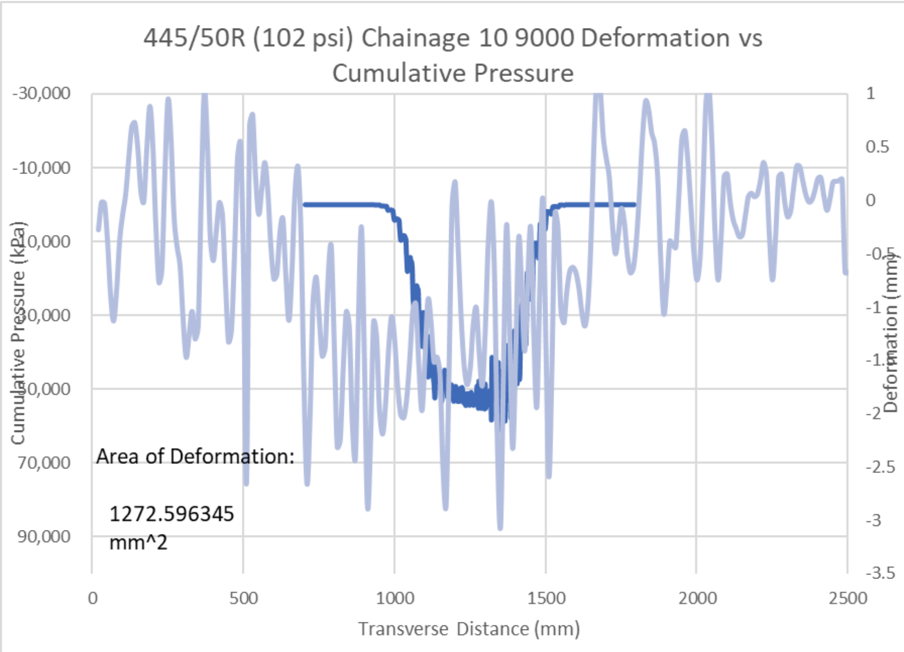


Figure E.9 Deformation and cumulative pressure profile for 445/50R22.5 (102 psi) at 22,500 cycles

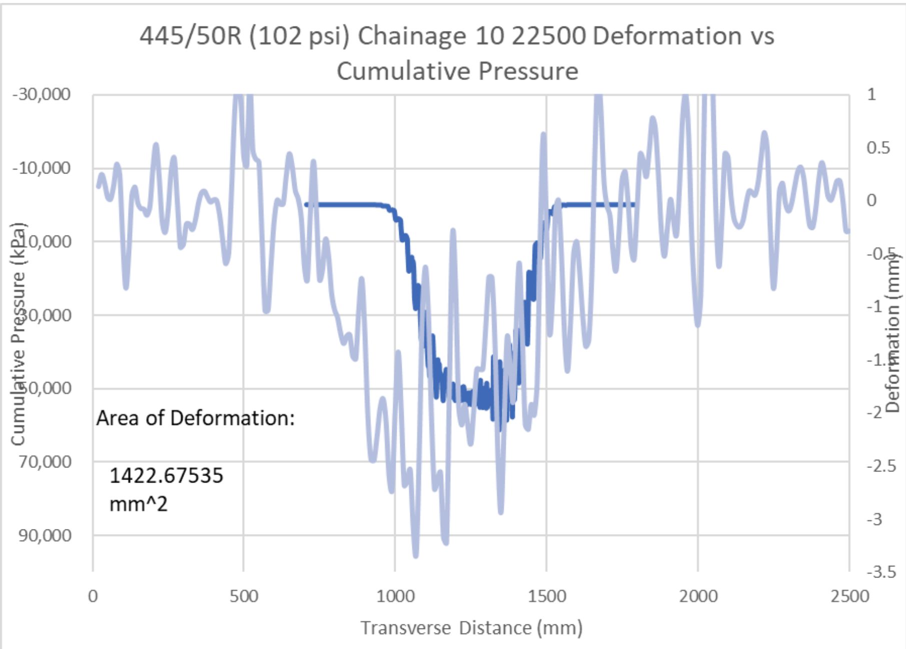
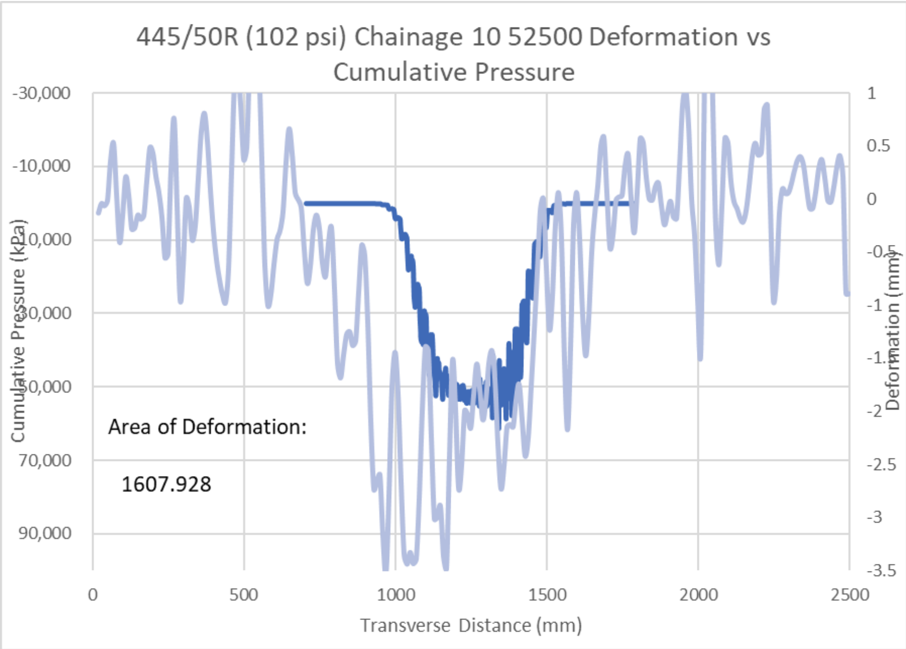


Figure E.10 Deformation and cumulative pressure profile for 445/50R22.5 (102 psi) at 55,500 cycles



E.4 385/55R22.5

Figure E.11 Deformation and cumulative pressure profile for 385/55R22.5 (115 psi) at 9,000 cycles

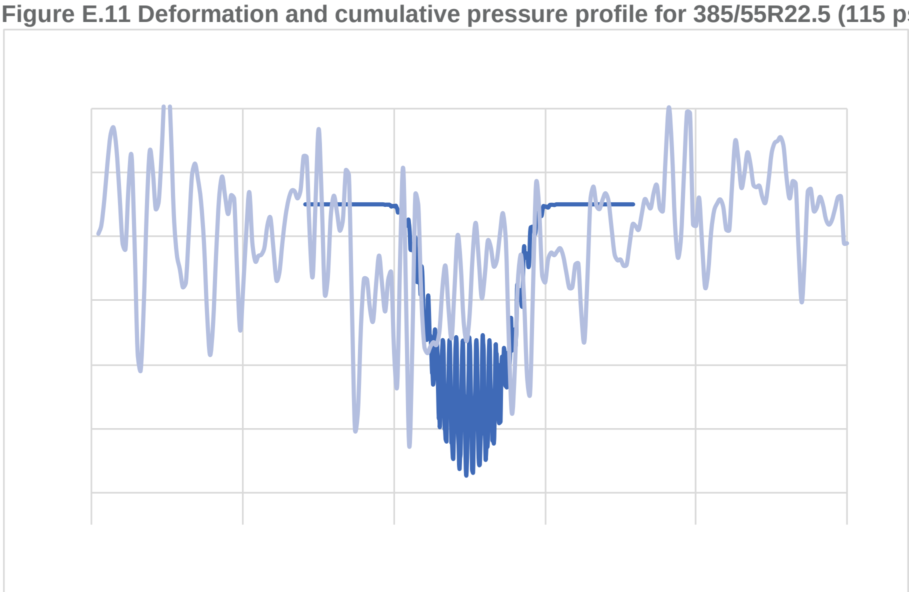


Figure E.12 Deformation and cumulative pressure profile for 385/55R22.5 (115 psi) at 22,500 cycles

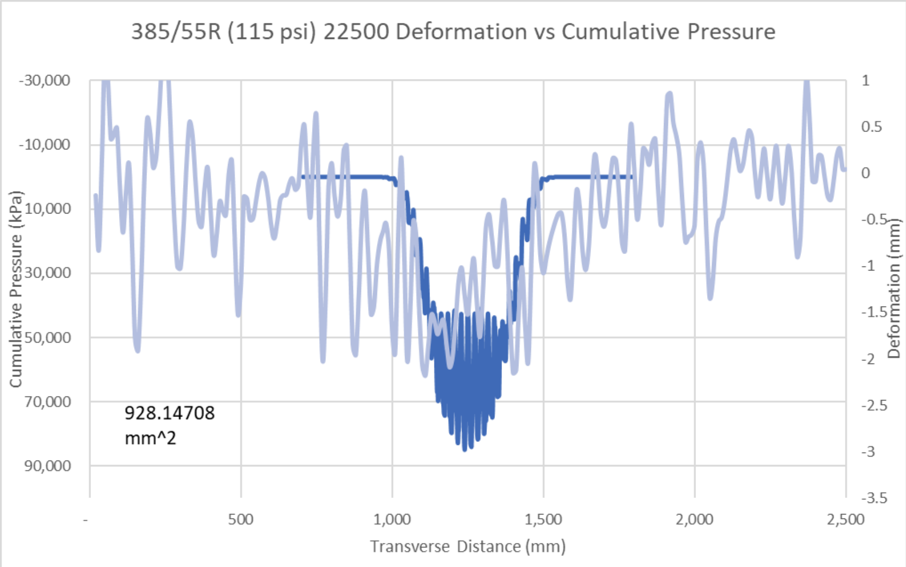
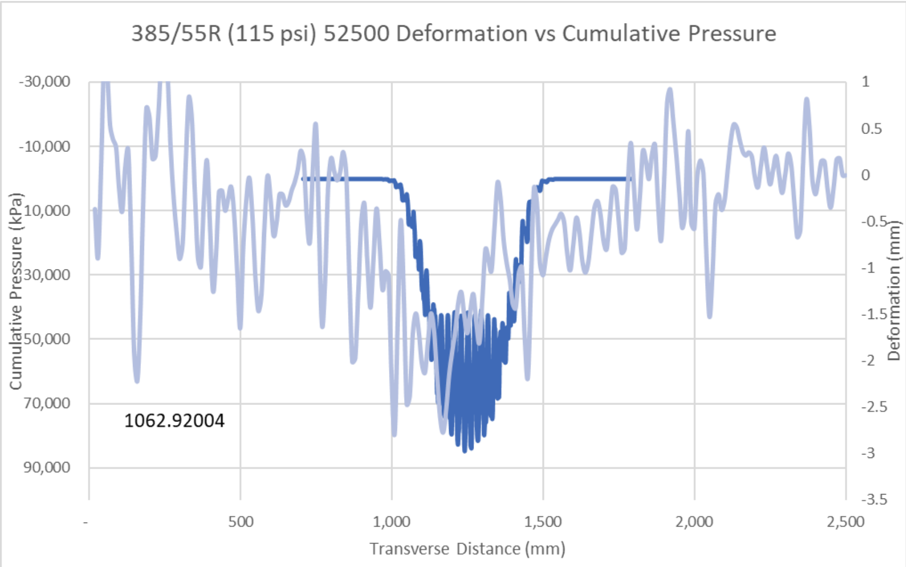


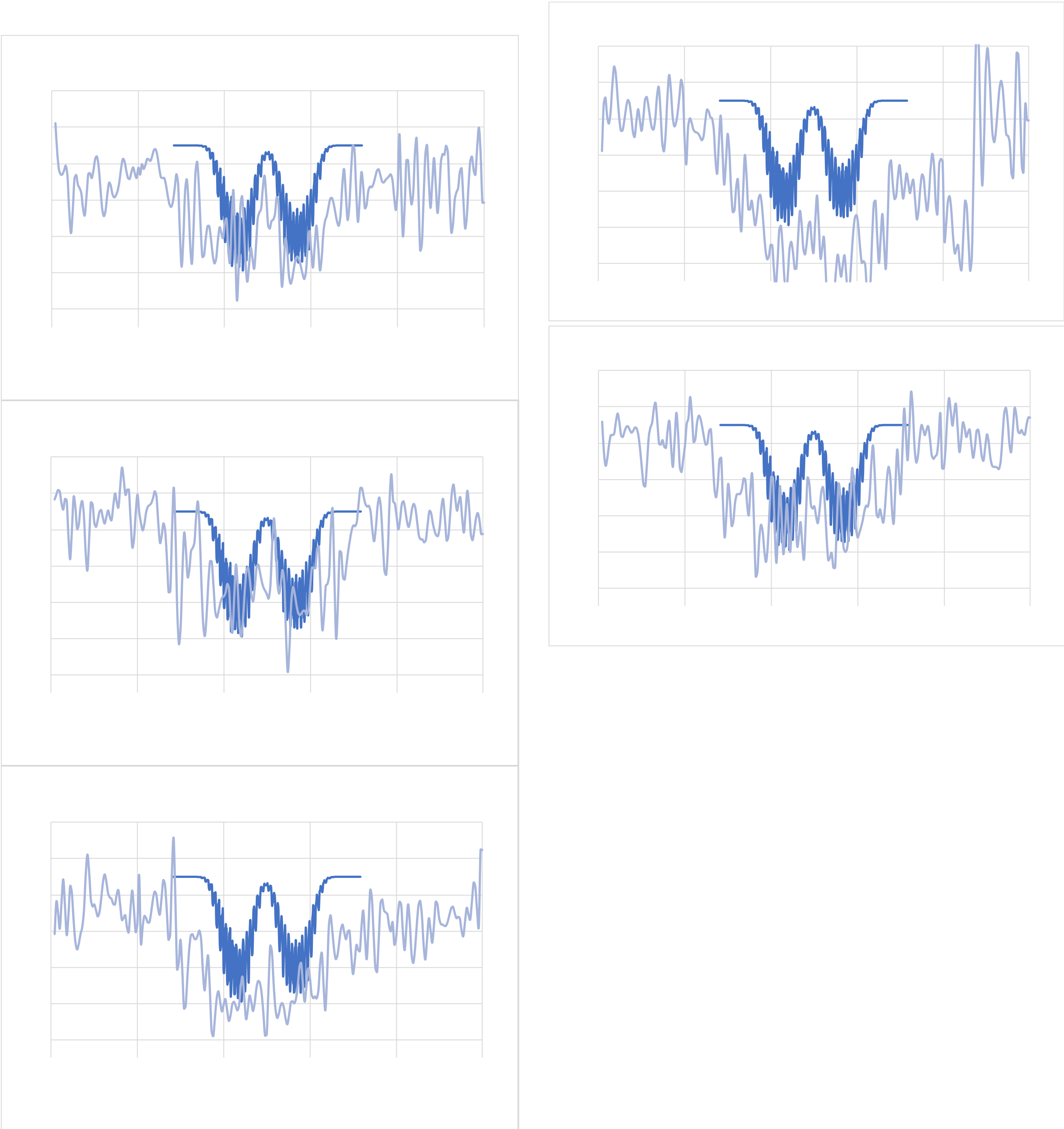
Figure E.13 Deformation and cumulative pressure profile for 385/55R22.5 (115 psi) at 52,500 cycles



Appendix F Deformation Based on Tyre Size and Location

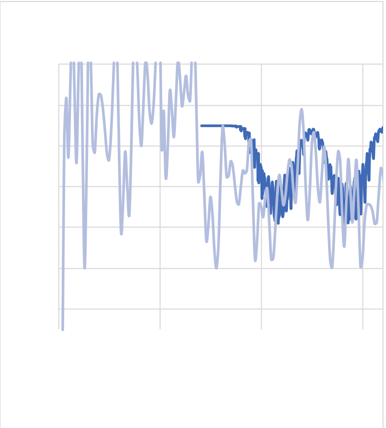
F.1 255/70R22.5 Deformation Profiles

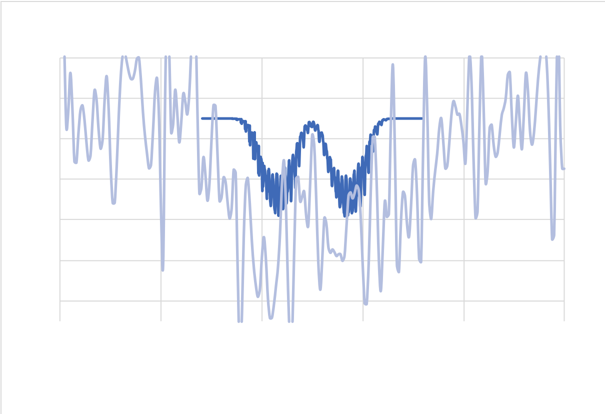
Figure F.1 Deformation by location - 255/70R22.5

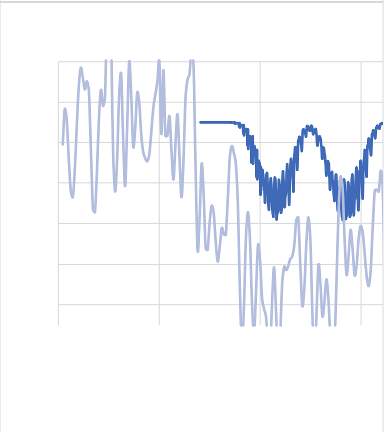


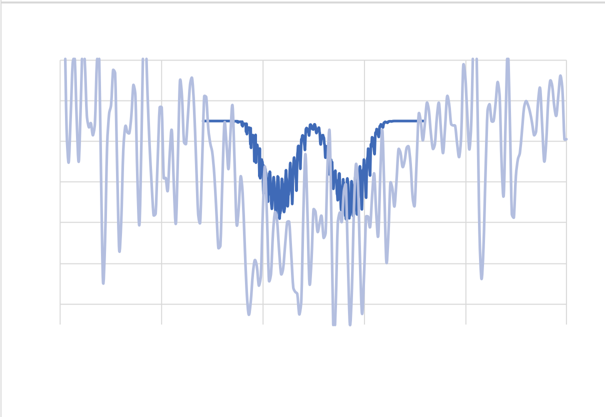
F.2 11R22.5 Deformation Profiles

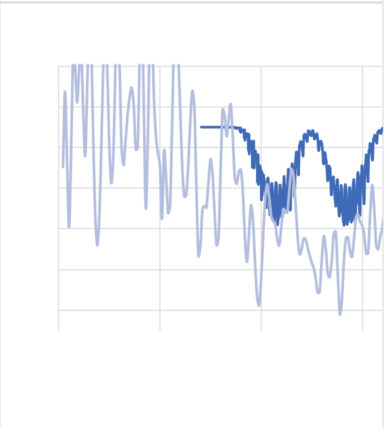
Figure F.2 Deformation by location - 11R22.5





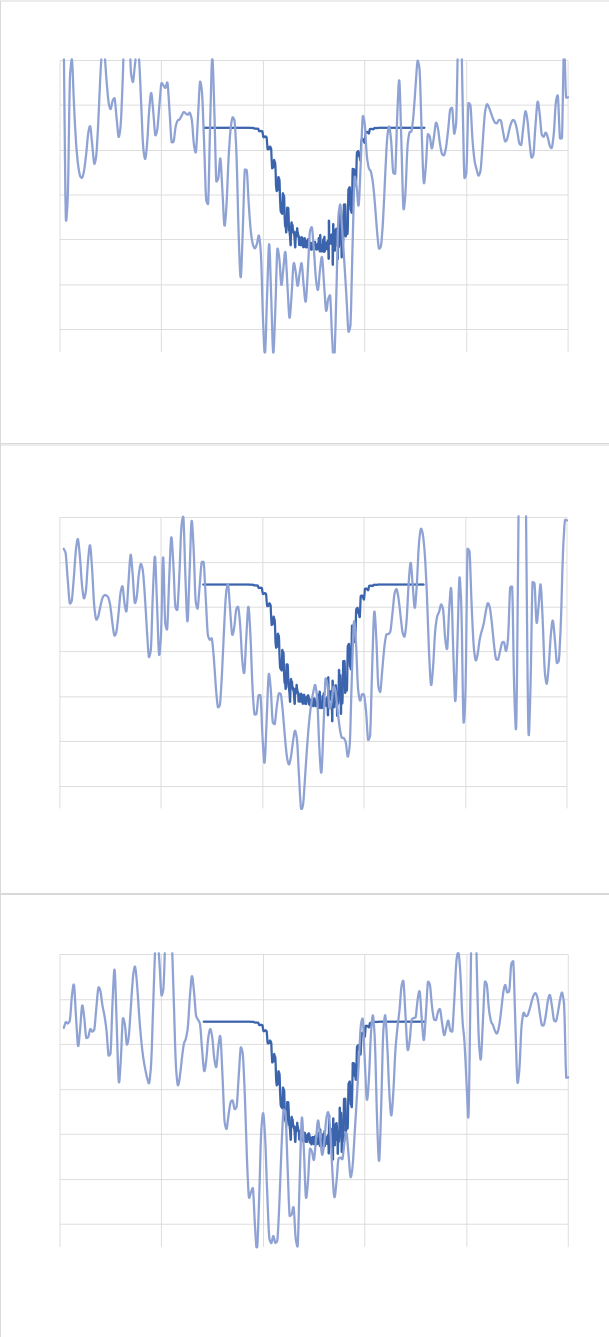


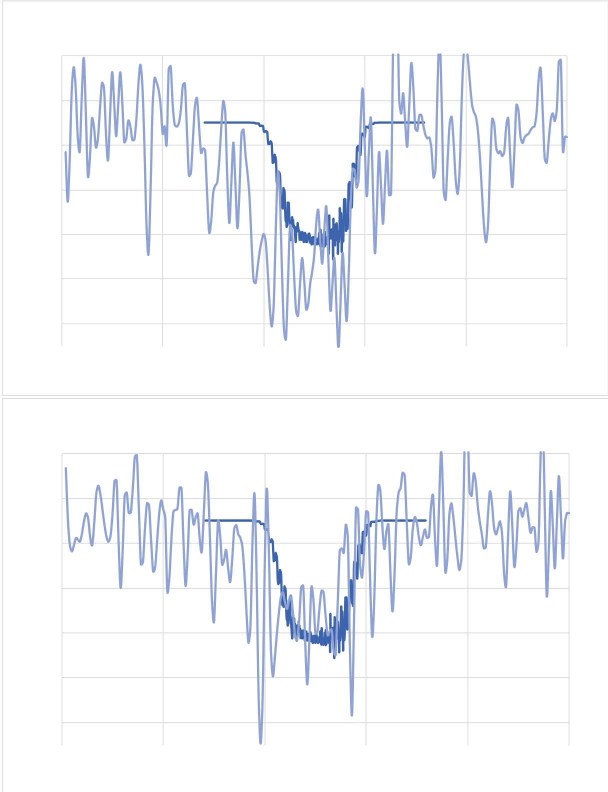




F.3 455/50R22.5 Deformation Profiles

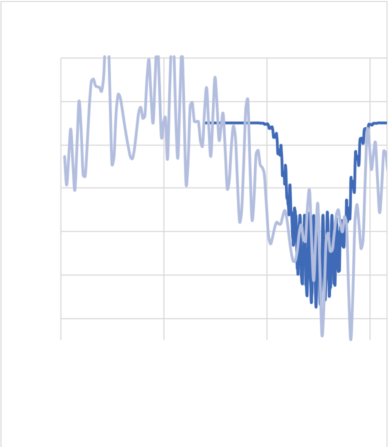
Figure F.3 Deformation by location - 455/50R22.5

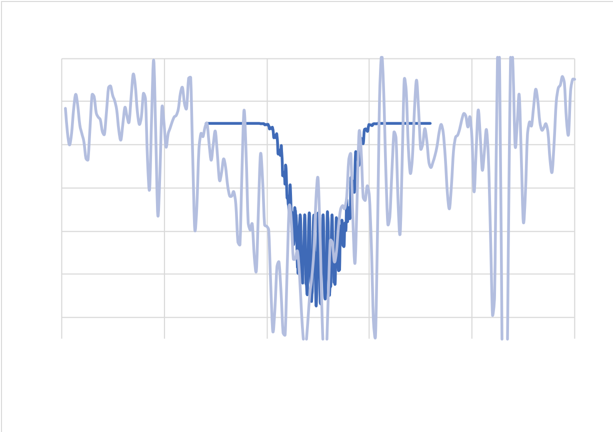


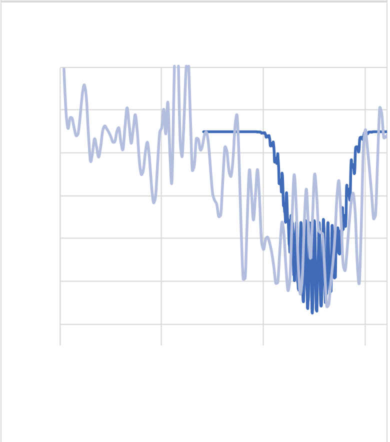


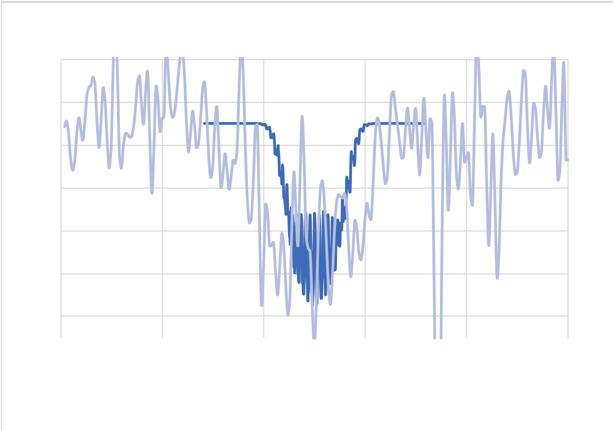
F.4 385/55R22.5 Deformation Profiles

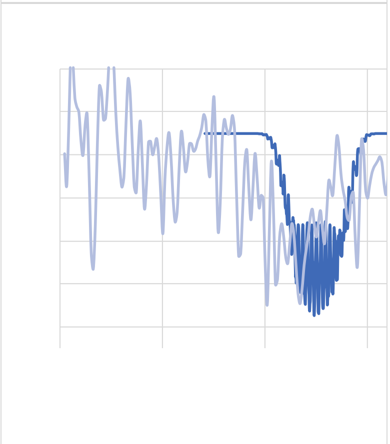
Figure F.4 Deformation by location - 455/50R22.5











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