THE DAMAGING EFFECT OF SUPER SINGLES ON PAVEMENTS

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ABSTRACT

This paper outlines the analysis of the NZ Transport Agency (NZTA) weigh-in-motion (WiM) 2012 data comparing the calculated values of the Equivalent Standard Axle (ESA), based on the NZTA assumption of all non-steer axles being dual tyred, and for differing assumptions of the proportion being single tyred (0 to 100%).

The paper tabulates the calculated ESAn values (standard n=4, 5, 7 and 12) for some of the most common heavy vehicle types with 6 or more axles (the NZTA annual WiM reports do not provide any ESA statistics).

The paper discusses the circumstances when the current assumption of 0% single tyred could lead to significant under estimation of traffic loadings for pavement design.

It concludes with the recommendation that the NZTA should investigate the proportion of super single tyres, and if this is significant to establish ways of monitoring heavy vehicles to distinguish between super single and dual tyred axles.
INTRODUCTION

Currently design for New Zealand state highways is to the Austroads Pavement Design Guide (2004). The Austroads guide offers two types of design, empirical and mechanistic. For both methods the damaging effect of axle loads on pavements is calculated in terms of a power law.

Empirical design only applies to granular pavements with thin bituminous surfacings. Mechanistic design can be applied to a broad range of pavement types. For empirical design, the 4th power law is used. For mechanistic design the 5th, 7th and 12th power laws are used; the 5th power is for fatigue of asphalt (cracking), the 7th power is for rutting and shape loss, while the 12th power law is for fatigue of cemented materials.

In the calculation of the damaging effect of axle loads, inherent in both empirical and mechanistic is comparison of actual axle loads with reference axle loads. The reference axle loads are dependent on the size of tyres, and the number of tyres per axle and axles in an axle group.

REFERENCES AXLE LOADS

Austroads (2012) includes reference axle loads – axle loads which cause the same damage as a Standard Axle. The reference loads may be summarised as reproduced in Table 1:

Table 1: Axle loads which can cause the same damage as a Standard Axle.

<table>
<thead>
<tr>
<th>Axle and Tyre Type</th>
<th>Reference Load</th>
<th>Reference Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single axle with dual tyres</td>
<td>80 kN</td>
<td>8.2 tonnes</td>
</tr>
<tr>
<td>Single axle with super single tyres*</td>
<td>71 kN</td>
<td>7.2 tonnes</td>
</tr>
<tr>
<td>Tandem axle with dual tyres</td>
<td>135 kN</td>
<td>13.8 tonnes</td>
</tr>
<tr>
<td>Tandem axle with super single tyres*</td>
<td>120 kN</td>
<td>12.2 tonnes</td>
</tr>
<tr>
<td>Triaxle with dual tyres</td>
<td>181 kN</td>
<td>18.5 tonnes</td>
</tr>
<tr>
<td>Triaxle with super single tyres **</td>
<td>132 kN</td>
<td>13.5 tonnes</td>
</tr>
<tr>
<td>Quad axle with dual tyres</td>
<td>221 kN</td>
<td>22.5 tonnes</td>
</tr>
<tr>
<td>Quad axle with super single tyres **</td>
<td>164 kN</td>
<td>16.7 tonnes</td>
</tr>
</tbody>
</table>

Note: *Super single tyres taken as ≥ 450mm wide.  **Super single tyres taken as at least 375mm wide but less than 450mm wide.

From Table 1, it is clear that Austroads assigns a lower reference axle load to axles with super single tyres than to axles with dual tyres. That is, Austroads recognises that super single tyres cause more pavement wear than dual tyres, for the same axle load. This is for single, tandem, tri or quad axle groups.

LEGAL AXLE LOADS

In New Zealand the maximum axle load on an axle group is defined in law (refer NZTA (1995)). Table 2 below summarises the legal maximum axle loads for various axle groups and tyres.

Table 2: Legal Maximum Axle Loads.

<table>
<thead>
<tr>
<th>Type of Axle Group</th>
<th>Tyre Type</th>
<th>Maximum Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single axle</td>
<td>Twin (dual) standard tyres</td>
<td>8,200</td>
</tr>
<tr>
<td></td>
<td>Large (single) tyres</td>
<td>7,200</td>
</tr>
<tr>
<td>Tandem axle</td>
<td>Twin (dual) tyres</td>
<td>14,500 to 15,500</td>
</tr>
<tr>
<td></td>
<td>Large (single) tyres</td>
<td>13,000</td>
</tr>
<tr>
<td>Tri axle</td>
<td>Twin (dual) tyres</td>
<td>15,500 to 18,000</td>
</tr>
<tr>
<td></td>
<td>Large (single) tyres</td>
<td>Same as twin tyres</td>
</tr>
<tr>
<td>Quad axle</td>
<td>Twin (dual) tyres</td>
<td>20,000</td>
</tr>
<tr>
<td></td>
<td>Large (single) tyres</td>
<td>Same as twin tyres</td>
</tr>
</tbody>
</table>
From Table 2 for single axles and tandem axles, super single tyred axles have a lower maximum axle load than dual tyred axles. This accords with the Austroads concept of Table 1 where super singles cause more wear than dual tyres for any given axle or axle group load.

However, from Table 2 for tri-axle and quad axle configurations, super single tyred axles have the same maximum axle loads as dual tyred axles. This is contrary to the Austroads concept.

**ROAD USER CHARGES**

For trailers with tandem axle sets, the Road User Charges (NZTA (2013)) are the same for twin (dual) tyred axles as for large tyred (super singles) axles, for the same axle load.

For trailers with tri-axle sets, the road user charges are the same for dual tyred axles as for super single tyred axles. Similarly for quad axles.

If we accept the Austroads concept of super singles causing more pavement damage than dual tyres for any given axle load, then these Road Users Charges are not equitable. Super singles cause more pavement damage than dual tyred axles, for any given axle load, yet pay no more for Road User Charges.

**WEIGH IN MOTION DATA**

The New Zealand Transport Agency (NZTA) has Weigh in Motion (WiM) data in their Traffic Monitoring System (TMS), and produces annual WiM reports. The authors have analysed the raw WiM data as exported from TMS, for the Drury site on the Auckland southern motorway.

*It is important to note that the WiM sites do not capture tyre configurations. The WiM data does not currently differentiate between dual tyres and super single tyres.*

**HEAVY VEHICLES TYPES AND FREQUENCY**

For this analysis MWH developed an Excel based tool which used the raw Weigh in Motion (WiM) data as exported from TMS.

With all the WiM sites using the PAT DAW equipment, the NZTA heavy vehicles are categorised according to the PAT class type as shown in the example figure below.

![Figure 1: Three of the most common longer truck types](PAT type 891 is an 8 axle T & T)

Analysis of the WiM data reveals that the Drury site accounts for almost half of the total number of heavy vehicles recorded at all the six WiM sites (the Auckland Harbour Bridge site is not in TMS). Approximately 55% of all heavy vehicles (> 3.5 tonnes gross) have 6 or more axles, and just under half have 7 or more axles.

Table 2 of the NZTA (2012) annual WiM report gives the frequency and percentage of each PAT type including the proportion of overweight heavy vehicles (HV), which for interest was as follows: 2½ % of rigid HV; 17½ % of truck & trailers; 6 % of artics and 11 % of A and B trains combined.
OUTPUT RESULTS
Our results for analysis of approximately 17,400 data records during February 2012 for the Drury site are summarised in Figure 2 below (similar tables have been produced by MWH by the number of axles and by the NZTA 2011 vehicle class, as well as load distribution tables).

In Figure 2 below the values in green relate to dual tyred axle sets and the red values relate to super single trailer axle sets. The blue values (second column) apply to their rows and are for an assumed percent of those truck types with super single tyres. As aforementioned, as WiM sites cannot distinguish between single and dual tyred axles, the NZTA raw WiM report assumes that there are 0% super singles, although they acknowledge in their 2012 WiM report that “80-90% of Quad Axles are single tyred”.

The small differences in gross vehicle tonnage (GWT) between dual and super single vehicles in Figure 2 relates to sampling, as based on actual truck data.

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DISCUSSION
As an example from Figure 2 above, for truck type PAT690 (adjusted 690, six axle artic A123), our analysis of the almost 1200 vehicle records reveals:

- Empirical design ESA 4th power

Figure 2: Effect on average ESA by PAT type (most common HVs with 6 or more axles)
− 0% super singles, damage 1.74 ESA per truck.
− 100% super singles, damage 2.73 ESA per truck.

- Mechanistic design ESA 7th (really SAR7) power
  - 0% super singles, damage 1.77 SAR7 per truck.
  - 100% super singles, damage 5.05 SAR7 per truck.

From Figure 2 above, if there are a significant number of super single tyres on trucks with more than 6 axles, then the pavement will be subjected to more damage than currently indicated in the ESA values in RAMM. Again it is noted that the WiM data currently does not differentiate between super single and dual tyred axles, and the TMS raw WiM data only gives the ESA 4th power values (furthermore no ESA values are currently provided in the annual WiM report).

Based on the above values, it would also be possible to derive the factors by which the average ESA 4th power value is multiplied to get the equivalent average ESA 5th, 7th and 12th power values.

CONCLUSIONS
Austroads (2012) assigns greater pavement wear to super single tyres than dual tyres for the same axle configuration and axle load. Yet legal maximum axle loads and Road User Charges do not differentiate, at least for tri axles and quad axles.

Analysis of the WiM data and application of the Austroads power laws show that trucks with 6 or more axles may be causing significantly more pavement wear if they have super single tyres than the current assumption of all dual tyres.

Accordingly, it is recommended that research and data capture is needed to determine what percentage of the New Zealand truck fleet includes super single tyres. If the percentage is significant then, if only for the purposes of pavement design, the Weigh in Motion facilities at least should be modified to include the ability to differentiate between super singles and dual tyres.

It is furthermore recommended that the NZTA could add to their annual WiM reports (which commendingly have been continually improved), various ESA and SARn statistics for the different power exponents (as well as the generalised factor to convert the standard ESA4 values to the higher powers).

REFERENCES


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