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FINAL REPORT

Project Title: P39: Implementing Long-life Pavement Concept for Queensland

(Year 2 – 2015/16)

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P39: Implementing Long-life Pavement Concept for Queensland

SUMMARY

This report presents the work that has been completed in Year 2 of the National Asset Centre of Excellence (NACOE) P39 project (NACOE 2015). In recent years, there has been much research on long-life asphalt pavement and the concept of fatigue endurance limit (FEL) or endurance limit strain (ELS). The first part of the report presents the latest discussion on this topic that is relevant in Queensland. At this stage, a consensus has not yet been reached.

To implement the long-life pavement concept for Queensland, the project team has determined that the limiting design traffic approach is the simplest and most compatible with the current Austroads Guide to Pavement Technology, Part 2, AGPT02 (Austroads 2012) method. Based on the outcomes of this study, limiting the design traffic at 200 million ESA has been proposed as an interim approach for use on TMR projects. The design traffic limit is expected to be used in conjunction with the latest strain-based multiple-axle group design method (Austroads 2015, Moffatt 2015) recommended by Austroads. This limit has been defined for the climatic conditions and traffic loadings in South East Queensland, where this type of full-depth asphalt pavement will most likely be used.

Research in this area is ongoing, and it is envisaged that Austroads will develop a nationally-endorsed methodology in coming years. When an Austroads method becomes available in the future, it is likely that TMR will adopt this method.

A key deliverable of this year is a technical note to present changes that can be made to the current flexible pavement design method in Queensland. A copy of the proposed text in included in Appendix A of this report.

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1 INTRODUCTION

1.1 Background

Over the years, asphalt pavement thicknesses have continued to increase with increasing traffic volumes and higher legal axle loads. However, there is growing recognition of the existence of an asphalt fatigue endurance limit (FEL), where the asphalt thickness can be capped without the need for further increases in thickness with increasing traffic. The central principle of the concept is that as long as the strain of the critical asphalt layer stays below its FEL, the only pavement interventions that will be required should be limited to resurfacing treatments. FEL is often referred to as endurance limit strain (ELS), and both terms have the same meaning in this report.

In 2008, the Department of Transport and Main Roads (TMR) engaged ARRB Group to commence investigations into the possible application of the FEL concept to its pavement designs. This review was reported by de Carteret and Jameson (Austroads 2009). It was concluded that the concept had not been sufficiently developed for adoption in a standard design process.

Since the 2008 review, further efforts, both within Australia and worldwide, have advanced the understanding of the FEL concept, and more generally, long-life asphalt pavements. While there is still no universal consensus on how best to define the endurance limit, recent research has created the possibility of now including a design traffic limit as part of the TMR pavement design system.

This report presents a review of the latest research findings in Australia and overseas studies, and the proposed design traffic limit for use in Queensland. Effectively, placing a design traffic limit will limit the total asphalt pavement thickness in Queensland.

1.2 Outcomes from Year 1

Year 1 (2014/15) of this project conducted a thorough literature review of long-life pavements (NACOE 2015). Year 1 of the project was not limited to full-depth asphalt, but also covered other pavement types such as flexible composite and concrete pavements. Definitions and typical thicknesses of long-life pavements were reported.

Subsequent meetings focused this project on full-depth asphalt pavement, which is the most common heavy-duty pavement type used in Queensland. The work included a review of data from the TMR pavement management system in an attempt to identify potential long-life pavement sites that could be used for calibration of the long-life pavement design procedure for Queensland. However, only very limited suitable data was identified.

1.3 Tasks Undertaken in Year 2

The key focus in Year 2 (2015/16) of this project was to develop a methodology for limiting the design traffic or capping the asphalt thickness for full-depth asphalt pavements in Queensland. The work brought together various current and recent research projects relevant to long-life asphalt pavements.

The key tasks completed in Year 2 of this project are listed as follows:

- Task 1 – refine project scope
- Task 2 – review Austroads recommendation on the FEL
- Task 3 – identify issues and changes for Queensland
- Task 4 – draft long-life asphalt pavements technical note
- Task 5 – preparation of final report.

1.4 Report Structure

Different research projects have studied this topic, and their mutual aim is to optimise the current design methods for improved asphalt pavement performance. With the improvements proposed by these projects, Section 2 of this report highlights the key features of each method. At the time of this report, there was ongoing discussion and refinements to the different methods. The status on aligning the different methods is presented in Section 3.

When considering the use of long-life asphalt pavements in Queensland, there are factors which are unique to Queensland. For example, the hotter Queensland climate has a healing effect on the asphalt. These factors are presented in Section 4 of the report.

Finally, Section 5 provides a summary and conclusions from this study. Proposed text to be used as an interim measure to limit the design traffic in Queensland is presented in Appendix A.

2 ADVANCEMENT OF CURRENT PAVEMENT DESIGN METHOD

In recent years, various Australian research projects have aimed to improve the current design method for flexible pavements. Some studies lead by TMR, Austroads and the Australian Asphalt Pavement Association (AAPA) have been focused on reducing costs by reducing the asphalt thickness in full-depth asphalt pavements. As a result, some improved design methods have been developed. This chapter provides a brief summary of these methods and directs readers to relevant literature for the design basis and technical details of each method.

2.1 TMR/Austroads Review of Fatigue Endurance Limit

In 2008, TMR engaged ARRB Group to commence investigations into the possible application of FEL concepts to its pavement designs. As the research was of broader interest nationally, the review was published as Austroads Report AP-T131/09 (Austroads 2009). Some of the key findings at that time included: limited use of FEL in published design methods internationally; inadequate long-term performance data in Australia to derive an empirical FEL relationship for local mixes; and other relevant ongoing research, particularly in the USA.

Based on the review at the time, it was concluded that the FEL concept had not been sufficiently developed for adoption in a standard design process. However, it did lead to recognition of the concept in the 2012 update of the Austroads Guide to Pavement Technology, Part 2: Pavement Structural Design, AGPT02 (Austroads 2012).

2.2 Austroads Project TT 1826

Austroads Project TT 1826 (Austroads 2016a) was completed in September 2015. The project is complementary to the work undertaken in Queensland under NACOE research project P10 (NACOE 2016). The project updated the AGPT-T274-16 test method (Austroads 2016), and proposed the use of master curves to characterise the variation of asphalt stiffness at different temperatures and loading frequencies. The modified Shell equation remained as the asphalt fatigue model to be used in AGPT02 (Austroads 2012).

2.3 NACOE Research Project P10

The NACOE P10 project (NACOE 2016) has investigated improvements to characterisation of the fatigue life of asphalt for the climatic conditions in Queensland (i.e. pavement temperatures are generally hotter in Queensland than southern parts of Australia). Asphalt mixes were tested using the AGPT-T274-16 test method (Austroads 2016). Models for mix-specific asphalt fatigue relationships were presented. The outcomes include a method for the development of fatigue models for the Queensland climatic environment.

2.4 Austroads Project TT 1614

The current pavement design approach used by AGPT02 (Austroads 2012) to assess the relative damaging effects of different axle groups is undertaken by converting axle group loads to standard axles using standard loads for each axle group type. The standard loads were derived based on an analysis of pavement surface deflections under each axle group type. This is inconsistent with the strain-based approach used in the asphalt fatigue performance relationship in AGPT02 (Austroads 2012). The final report of Austroads Project TT 1614 (Austroads 2015) proposed a revised method where the pavement strains are calculated for each axle load and each axle group within a traffic load distribution, negating the use of standard loads to convert to standard axles. This approach results in a reduction in pavement design thickness for full-depth asphalt pavements.

A recommendation has been provided to members of the Austroads Pavement Structures Working Group (PSWG) and Pavements Task Force (PTF) for adoption in the next revision of the AGPT02. A working paper (Moffatt 2015) that documents the proposed changes to the text of the AGPT02 has been prepared.

At the time of this report, the strain-based method had not yet been endorsed by all Austroads members; however, the method was considered acceptable by TMR.

2.5 AAPA Asphalt Pavement Solutions for Life (APSfL)

In 2011, Australian Asphalt Pavement Association (AAPA) commenced the APSfL project. This project was initiated to address the concerns from industry that the current pavement design procedures were producing overly conservative asphalt thickness requirements (Sullivan et al. 2015). In particular, it was noted that one of the principal drivers for the development of a long-life asphalt pavement was to address the overdesign of asphalt pavements in warmer northern climates in Australia (e.g. Queensland).

The project develops a new method to determine the FEL for the Australian environment. As long as asphalt strains are maintained below the FEL, no accumulation of fatigue damage will occur, which results in a pavement with an indefinite design life.

In March 2015, a draft version of the proposed supplement to the AGPT02 (Austroads 2012) became available to the project team. The FEL equation presented was:

$$FEL = 3800\,Smix^{-0.34} - 100 \quad (1)$$

where

$Smix$ = stiffness of the mix (MPa)

In October 2015, a revised design supplement and a draft technical report (Sullivan et al. 2015) were submitted to the Austroads PTF for their consideration in the forthcoming revision of the AGPT02 (Austroads 2012). In response to the initial feedback from Austroads, a revised equation was proposed by AAPA as follows:

$$FEL = \frac{8.2}{U_l}\left[k_1 21625\,Smix^{-0.65} + k_2\right] \quad (2)$$

where

U_l = upper 97.5th percentile load, usually 9 tonnes (ton)

$k1$ = adjustment constant for differences in rest periods, or confidence levels

$k2$ = mix adjustment factor (0 for conventional mixes)

$Smix$ = stiffness of the mix (MPa)

The remainder of this study uses the above equation when evaluating the AAPA APSfL method.

2.6 Austroads Project TT 2044

Austroads Project TT 2044 is a multi-year project to encourage pavement design innovations. The aim of the project is to facilitate the introduction of appropriate innovative and lower cost pavement technology practices into Australian/New Zealand practice. One of the four key focus areas of the project is relevant to the current discussion: namely, the establishment of a method that incorporates asphalt FEL into pavement design.

A progress report was prepared (Jameson 2016a), and a discussion paper titled *Asphalt Fatigue Endurance Limits: Guide Implementation Options* (Jameson 2016b) was circulated to members of the Austroads PSWG in June 2016 for comment and discussion. The discussion paper presented five different options for implementing the FEL concept in the next revision of the AGPT02. At the June 2016 Austroads PSWG meeting, TMR recommended the use of a limiting design traffic approach, which was consistent with the approach being developed under the current NACOE P39 project presented in this report.

3 DEVELOPMENT AND DISCUSSION UNDERTAKEN TO ALIGN DIFFERENT DESIGN METHODS

3.1 Alignment of Different Design Methods

Section 2 provided a summary of completed and ongoing projects conducted at both the Queensland and Austroads level. The objectives of these projects can collectively be summarised as introducing innovation to improve the current asphalt pavement design methodology, material characterisation, and prediction of asphalt fatigue behaviour in the field. The challenge that has been addressed as part of the NACOE P10 and P39 projects is to bring all the various research projects together into a single method that is suitable for practical use.

About the FEL, the consensus is that long-life pavements do exist. However, the approach to implement the various research outcomes requires further discussion and research. At the time of this report, a consensus had not yet been reached on the methodology for incorporating long-life asphalt pavement design into existing procedures. Further research was considered necessary to develop first principle methods reported in the literature. In Queensland, TMR has elected for a more rapid implementation based on the best available knowledge at the time of this report. It is intended that any further research outcomes will be considered in future developments.

An outline of the main design features of different design methods is summarised in Table 3.1. Using the design features of AGPT02 as the base case, new features proposed by each method are presented and compared with each other. For example, the FEL concept introduced by the AAPA APSfL design method is a unique design consideration when compared to the current AGPT02 and other similar Austroads and NACOE projects to date.

Table 3.1: Summary of the main design features for different design methods

	Austroads AGPT02-12	Austroads TT 1826	Austroads TT 1614	NACOE P10	AAPA APSfL
Design reliability	as per AGPT02				✓
Flexural modulus as design modulus					×
Modified Shell asphalt fatigue model					×
Sub-layering of granular material					×
Anisotropic material property for unbound granular and subgrade materials					×
Equivalent standard axle loading (ESA)					×
Modulus relationship based on master curve	×	✓	×	✓	✓
Mix-specific fatigue model	×	×	×	✓	×
Fatigue endurance limit (FEL)	×	×	×	×	✓
Cumulative damage for each load level & load group	×	×	✓	×	×

Reference Documents:

1. AGPT02 (Austroads 2012)
2. Austroads TT 1826 (Austroads 2016a)
3. Austroads TT 1614 (Austroads 2015)
4. NACOE P10 (NACOE 2016)
5. AAPA APSfL (Sullivan et al. 2015).

The recently released discussion paper (Jameson 2016b) a thorough review of the AAPA APSfL design method. Furthermore, five different implementation options for the next revision of AGPT02 were presented. The document is most relevant to the objectives of this NACOE P39 project, so is discussed in further detail in Section 3.1.1 of this report.

3.1.1 Austroads Project TT 2044 Discussion Paper (June 2016)

Following the progress report (Jameson 2016a) published in February 2016, a discussion paper became available in June 2016 (Jameson 2016b) to present a comprehensive literature review of the different research on this topic. The five options presented in the discussion paper are listed below:

- OPTION A – APSfL method to estimate ELS from asphalt modulus
- OPTION B – NCHRP 9-44A method to calculate ELS from modulus
- OPTION C – NCHRP 9-44A estimating ELS from temperature and mix volumetrics
- OPTION D – limiting design traffic loading
- OPTION E – modify fatigue relationship to allow for healing at elevated temperatures.

The discussion paper critically reviewed each of the five presented options. A brief summary is presented herein:

OPTION A is the APSfL method, where the ELS criteria are currently applied at three pavement temperatures: summer, weighted mean annual pavement temperature (WMAPT), and winter. Based on the assumption of a small variation in air voids and binder contents of Australian mixes, the method used the modulus as a surrogate and presented a relationship between ELS and asphalt modulus. The ELS is very different to the findings from NCHRP 9-44A. It was demonstrated again that the method presented similar maximum asphalt thicknesses across a range of asphalt design modulus and pavement temperatures. For a given total asphalt thickness and supporting condition, there is a more significant increase in allowable design traffic for Brisbane and warmer climates. The paper pointed out that the use of ELS is simple and versatile. However, changes in asphalt mix volumetrics have not been adequately addressed. If Option A is to be adopted in the AGPT02, only the ELS corresponding to the WMAPT was suggested to be used. Furthermore, it was proposed that the method could be modified to include consideration for mix volumetrics.

OPTION B is similar to OPTION A in that the method estimates ELS from asphalt design modulus. The NCHRP 9-44A method proposed a different ELS relationship against asphalt modulus based on the laboratory ELS obtained by Witczak et al. (2013) and adjusted it to an in-service ELS by taking into account the performance data of UK long-life asphalt pavements. It is noted that the impact on design thickness is the greatest at a lower temperature, and is less relevant for a high temperature climate such as in Queensland.

OPTION C is different to OPTIONS A and B in that the ELS was developed based on the beam fatigue testing undertaken in NCHRP Project 9-44A (Witczak et al. 2013). The study only considered one mix, but the impact of bitumen content, air voids, as well as the mix performance at three temperatures, have been studied. The impact of this option on design thickness is greatest at a lower temperature and has less effect for high temperature climates.

OPTION D is the simplest among all five options because it does not explicitly require the determination of ELS, but simply includes a limiting design traffic loading. The option is similar to the approach undertaken in the UK. By limiting the design traffic, this, in turn, limits the total asphalt thickness. This option has an impact on design thicknesses across a range of pavement temperatures.

OPTION E is the last option presented which suggests modification of the current Austroads asphalt fatigue relationship to reduce the rate at which asphalt thickness increases with temperature. In particular, this method has the effect of reducing asphalt thickness for WMAPT more than 27 °C. This would have a direct impact on the perceived overdesign of asphalt thickness at high temperatures. New shift factors (WMAPT-dependent, with increasing weighting at high temperature) and reliability factors can be introduced to the current asphalt fatigue relationship.

In addition to the above five options, the discussion paper highlighted the thickness reduction potential when using the above options together with the proposed method of assessing the damage due to axle loads (Austroads 2015, Moffatt 2015). The proposed method is based on a strain-based approach of evaluating the damage due to axle group loads, and the report suggested that this would result in a 60% increase in predicted asphalt fatigue lives.

Of most interest to TMR is Option D (limiting design traffic loading), which is similar to the preferred method that was concurrently being developed as part of this project. However, Options A to C are also of interest as they can be used to assist with setting the traffic limit value used in Option D.

4 ISSUES AND CHANGES FOR QUEENSLAND

Section 3 presented the Austroads review of the long-life pavement concept. Currently, there are ongoing discussions between stakeholders at the national level on how to implement the concept into published national design procedures. This chapter presents the issues around implementation of the long-life pavements concept in Queensland. As TMR is committed to maintaining a nationally-consistent approach as far as practical, some slight refining of the method that was being developed in Queensland has occurred to remain consistent with the likely national direction.

4.1 Advantages of Option D

As has been previously mentioned, Option D detailed in Section 3 is favoured by TMR and is very similar to the approach that was being concurrently developed as part of this NACOE P39 project. The principal reasons for this are:

- The alternative methods require further development before they can be implemented, with an unknown timeframe for this to be completed.
- There are some limitations and potentially contentious issues that would need to be overcome with the alternative methods.
- Option D is simple to implement and is compatible with both the current AGPT02 (Austroads 2012) design method and changes proposed under other related research projects such as the NACOE P10 project (NACOE 2016).
- Option D can be implemented in the short-term.

Further discussion is provided below for development of the traffic limit.

4.2 Latest Austroads TT 2044 Recommendation to Limit Design Traffic

The WMAPTs differed widely across Australia, and it has been acknowledged that the greatest asphalt design thickness reduction using the APSfL method will be in warmer climate zones, i.e. Queensland and the northern part of Australia. Major towns across Queensland have WMAPTs between 27 °C and 37 °C. Furthermore, heavy-duty traffic scenarios (i.e. > 1 x 10^8 ESA) are historically only limited to the south-east Queensland region, where the WMAPT is typically 31 to 32 °C.

Austroads project TT 2044 has made suggestions of the upper design traffic limits for different climatic zones across Australia. The current proposed limiting values are presented in Table 4.1.

Table 4.1: Suggested upper limits on design traffic

WMAPT	≤ 25 °C	26 – 34 °C	≥ 35 °C
Design traffic loading limit (ESA)	4 x 10^8	2 x 10^8	1 x 10^8

4.3 Comparison of Results from Different Design Methods

The effects of different design traffic limits on the different design methods available can be illustrated using a number of design examples, as presented in Table 4.2. The subgrade condition ranges from CBR 5 to 12%.

Table 4.2: Summary of pavement structures

Pavement case 1	Pavement case 2	Pavement case 3	Pavement case 4
50 mm AC14M(C320)	50 mm AC14M(C320)	50 mm AC14M(C320)	50 mm AC14M(C320)
X mm AC20M(C600)	X mm AC20M(C600)	X mm AC20M(C600)	X mm AC20M(C600)
150 mm improved layer	150 mm improved layer	150 mm improved layer	150 mm improved layer
Subgrade CBR 5%	Subgrade CBR 7%	Subgrade CBR 10%	Subgrade CBR 12%

Notes:

1. The improved layer is a lightly stabilised cement treated material with a 7-day UCS between 1–2 MPa.

The design thicknesses determined using different methods are summarised in Table 4.3.

Table 4.3: Comparison of asphalt thicknesses computed based on different design methods

	Design Traffic = 1 x 10^8 ESA		Design Traffic = 2 x 10^8 ESA		AAPA Long-life Pavements	
	Current TMR Method	Strain-based Multi-axle Group Method	Current TMR Method	Strain-based Multi-axle Group Method	APSfL Method (Anisotropic Model)	APSfL Method (Isotropic Model)
Case 1 (CBR 5%)	340 mm	315 mm	370 mm	345 mm	370 mm	355 mm
Case 2 (CBR 7%)	320 mm	297 mm	350 mm	325 mm	350 mm	335 mm
Case 3 (CBR 10%)	295 mm	277 mm	325 mm	305 mm	330 mm	315 mm
Case 4 (CBR 12%)	285 mm	269 mm	315 mm	296 mm	315 mm	305 mm

Note 1. Weather station data from Brisbane (Bureau of Meteorology weather station 040214) was used for APSfL method computation.

Note 2. The current TMR method was based on a SAR5/ESA of 1.1.

Note 3. The strain-based multi-axle group method uses a weigh-in-motion load distribution in a major project in South East Queensland, a value of 1.08 ESA per heavy vehicle axle group has been assumed.

Note 4. A design reliability of 95% has been adopted for the current TMR method and the strain-based multi-axle group method.

The total asphalt thicknesses reported in Table 4.3 are also plotted in Figure 4.1, Figure 4.2 and Figure 4.3.

Figure 4.1: Total asphalt thicknesses using the AAPA APSfL method using anisotropic and isotropic models

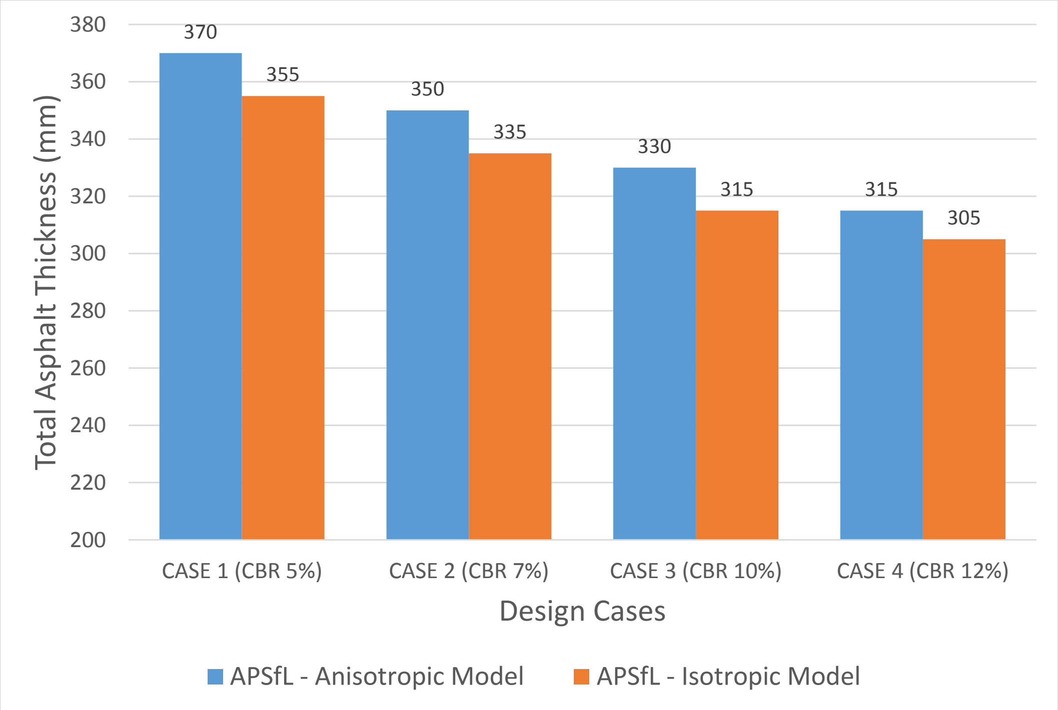


Figure 4.2: Total asphalt thicknesses using the current TMR design method (2e8 ESA) and the AAPA APSfL method

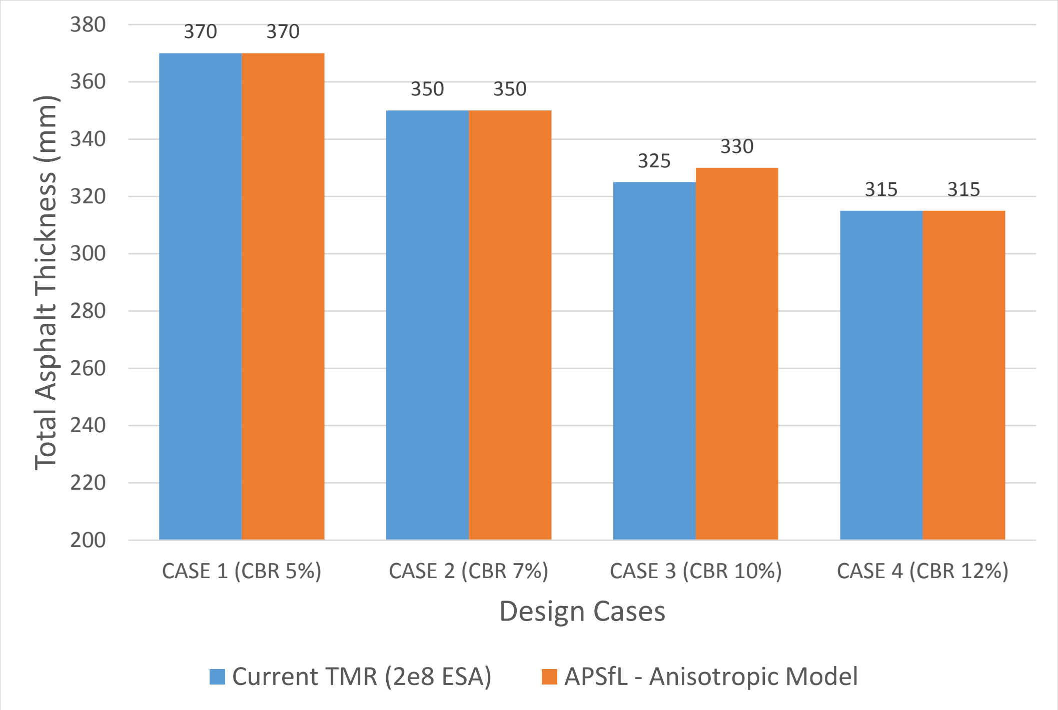
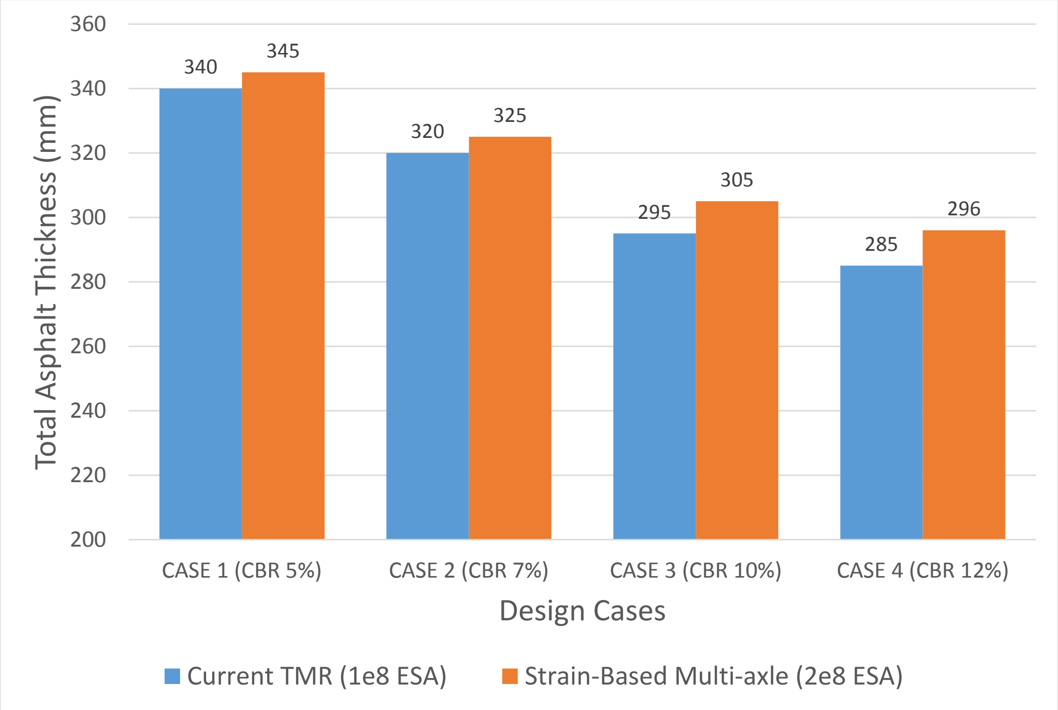


Figure 4.3: Total asphalt thicknesses using the current TMR design method (1e8 ESA) and the strain-based multi-axle approach (2e8 ESA)



The following observations were made based on the above design thickness calculations:

- During the project, it has been identified that the original AAPA method uses an isotropic model for computation of the critical strain. As illustrated in Figure 4.1, the total asphalt thicknesses will increase if an anisotropic model (similar to the one used in the current AGPT02) was used for the granular and subgrade material. The increase in total asphalt thicknesses is between 10–15 mm.
- By applying a design traffic limit of 2 x 10^8 ESA to the current TMR pavement design method, Figure 4.2 shows that the reported asphalt thicknesses are similar to the asphalt thicknesses reported by the AAPA APSfL method (using an anisotropic model). The differences in total asphalt thickness are within 5 mm.
- Figure 4.3 shows that the total asphalt thickness is similar to the design computed using the current TMR design method (design traffic of 1 x 10^8 ESA) and the design computed using the new strain-based multiple-axle approach (design traffic of 1 x 10^8 ESA). The differences in total asphalt thickness are within 5–11 mm.

Based on the above, it has been determined that a limiting design traffic value of 2 x 10^8 ESA using the current TMR pavement design method is an appropriate interim limit. The resulting total asphalt thicknesses is comparable to the AAPA APSfL method and the latest design limit recommended by Austroads TT 2044.

4.4 Proposed Design Traffic Limit

Given that the majority of the heavy-duty full-depth asphalt pavement is expected to be located in South East Queensland, a design traffic limit of 2.0 x 10^8 ESA is proposed. This design limit is anticipated to be used in conjunction with the new strain-based multi-axle method (Austroads 2015, Moffatt 2015) in the next revision of the AGPT02.

While it has been recognised that a lower design traffic limit should be adopted for the hotter climatic zone in Northern Queensland, the actual design traffic in these hotter areas is not likely to reach the design traffic limit nominated (1 x 10^8 ESA for WMAPT exceeding 35 °C). Therefore, for simplicity, a single design traffic limit of 2 x 10^8 ESA has been recommended across Queensland.

There is some risk that this limit was set below the actual value for long-life pavements. However, the limit is set such that a very-long-life pavement will still result, with predicted design life around 25 years or more using the existing design methods for typical heavy traffic roads. It is intended that TMR will consider any further research outcomes in future developments.

The recommended text for the TMR technical note is presented in Appendix A.

5 SUMMARY AND CONCLUSIONS

While some research projects have attempted to identify and define the in-field asphalt fatigue endurance limit, none have been able to prove or demonstrate conclusively its existence. As has been summarised in this report, various design method options for incorporating the FEL concept have their limitations. Research in this area is ongoing, and it is envisaged that Austroads will develop a nationally-endorsed methodology in the coming years. When an Austroads method becomes available in the future, it is likely that TMR will adopt the Austroads method to maintain national consistency.

As part of this project, the discussion paper by Jameson (2016b) was reviewed and the five different options presented were analysed in the context of Queensland. The project team has determined that OPTION D – limiting design traffic is the simplest and most compatible with the current AGPT02 method. This approach is also consistent with the direction that this project has independently been heading, and therefore is the recommended outcome for TMR in the short-term.

As has been detailed in this report, although the traffic limit relevant to Queensland has been based on currently available research findings, there is an element of judgement in the selection of the traffic limit due to inherent limitations of each method, including limited local field validation data. Additionally, a significant amount of such data is unlikely to be available for many years to come. This judgement takes account not only of the technical research, but also the investment strategy of the department. It is also noted that the limiting values proposed is such that even if it was set below the actual thickness/traffic limit for long-life performance, it is still at a level that will provide very long pavement lives (i.e. more than 25 years) using the existing pavement design procedure which may already be conservative.

Limiting the design traffic to 200 million ESA has been proposed as an interim approach for TMR projects. The limit is in line with the direction of the Austroads TT 2044 project and gives comparable asphalt thickness results obtained using the AAPA APSfL method. This design traffic limit is to be used in conjunction with the strain-based approach (Austroads 2015) to model the cumulative damages of axle loads rather than the current deflection-based method that requires conversion to standard axles.

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APPENDIX A PROPOSED TEXT FOR TECHNICAL NOTE TO LIMIT MAXIMUM DESIGN TRAFFIC IN FULL-DEPTH ASPHALT PAVEMENTS

The following proposed text is provided for Section 5 of the Technical Note for limiting maximum design traffic in full-depth asphalt pavements. At the time of this report, the Technical Note was being consulted with stakeholders. Pavement designers should refer to the published Technical Note for the final agreed wording prior to undertaking any designs.

A.1 Upper Limit on Design Traffic for Asphalt Fatigue in Full-depth Asphalt Pavements

AGPT02 notes that there is increasing recognition of the notion that asphalt mixes have endurance strain limits for asphalt fatigue. This suggests that below a given applied strain, repeated cycles of loading no longer result in fatigue damage. Development of an Austroads-endorsed procedure to incorporate the fatigue endurance limit concept into AGPT02 is ongoing, with an assessment of the latest relevant international research underway. This includes consideration of the draft outcomes from the Australian Asphalt Pavement Association's *Asphalt Pavement Solutions for Life* project (Sullivan et al. 2015).

Until such time that an Austroads-endorsed procedure is published, an interim approach for full-depth asphalt pavements, a maximum (capped) asphalt thickness corresponding to a design traffic loading of 200 million ESA has been adopted by TMR, where the locations have a weighted mean annual pavement temperature (WMAPT) of 30 °C or greater.

Adoption of the upper limit on design traffic for asphalt fatigue in full-depth asphalt pavements requires inclusion of the following minimum support conditions:

- an improved layer below the asphalt base course comprising a minimum 150 mm thick layer of Type 2.3 unbound granular material that is treated with a cementitious stabilising agent to achieve an unconfined compressive strength of 1.0 to 2.0 MPa at seven days
- an additional thickness of select fill or unbound granular material (if required), based on the bearing capacity of the underlying subgrade material, to increase the pavement support to an adequate level for long-term pavement performance. Adequate support can be determined by using Equations 19 and 21 in AGPT02, ensuring that the modulus achieved at the top of the improved layer is not less than 150 MPa.

For example, where the design CBR of the existing in-situ subgrade material is 3%, application of Equations 19 and 21 in AGPT02 indicates a select fill layer with minimum CBR 7% and thickness of 170 mm below a 150 mm thick lightly stabilised improved layer is necessary to achieve a modulus of 150 MPa at the top of the improved layer. Equation 19 results in a vertical modulus of 66 MPa for the top sublayer of select fill. Equation 21 then results in a vertical modulus for the top sublayer of the lightly stabilised improved layer of 151 MPa.

Where the design CBR of the existing in-situ subgrade material is 7% or more, a 150 mm thick lightly stabilised improved layer is typically adequate without the need for any additional underlying selected material, unless required to address other issues such as expansive subgrade materials or excess moisture.

While this approach provides for a minimum amount of pavement support, more substantial treatments are likely to have benefits regarding overall asphalt thickness reduction. Therefore, more substantial treatments should also be considered by the pavement designer in assessing project-specific alternatives.

To achieve adequate compaction of the asphalt layers, additional support may be necessary depending on the bearing capacity of lower layers at the time of construction. As a minimum, proof rolling of the lightly stabilised improved layer and all other earthworks layers should be undertaken to confirm acceptable support has been achieved prior to the construction of overlying layers.