Today’s moderator

**Eliz Esteban**
Communications Officer
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E: eesteban@austroads.com.au
Austroads acknowledges the Australian Aboriginal and Torres Strait Islander peoples as the first inhabitants of the nation and the traditional custodians of the lands where we live, learn and work. We pay our respects to Elders past, present and emerging for they hold the memories, traditions, culture and hopes of Aboriginal and Torres Strait Islander peoples of Australia.

Austroads acknowledges and respects the Treaty of Waitangi and Maori as the original people of New Zealand.
About Austroads

The peak organisation of Australasian road transport and traffic agencies

- Transport for NSW
- Roads Corporation Victoria
- Department of Transport and Main Roads Queensland
- Main Roads Western Australia
- Department of Planning, Transport and Infrastructure South Australia
- Department of State Growth Tasmania
- Department of Infrastructure, Planning and Logistics Northern Territory
- Transport Canberra and City Services Directorate, Australian Capital Territory
- Department of Infrastructure, Regional Development and Cities
- Australian Local Government Association
- New Zealand Transport Agency
Our structure

Austroads Board

Austroads National Office

Assets Program
- Assets Task Force
- Bridge Task Force
- Pavements Task Force
- Road Tunnels Task Force
- Project Delivery Task Force

Network Program
- Network Task Force
- Freight Task Force

Safety Program
- Road Safety Task Force
- Road Design Task Force
- Registration and Licensing Task Force
- Austroads Safety Barrier Assessment Panel

Connected and Automated Vehicles
- CAV Steering Committee
- Industry Reference Group

NEVDIS
- Vehicle governance
- Licensing governance
Housekeeping

Presentation = 40 mins
Question time = 15 mins

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Austroads Guide

Free online access and PDF at
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RoadWatch publication and webinar alerts
Today’s presenters

**Geoff Jameson**
Chief Technology Leader
Future Transport Infrastructure
ARRB
E: geoff.jameson@arrb.com.au

**Dr Michael Moffatt**
Group Leader
Infrastructure Management
ARRB
E: michael.moffatt@arrb.com.au
# Agenda

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<td></td>
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<td>Guidance on Design Moduli of Existing Asphalt</td>
<td>Geoff Jameson &amp; Dr Michael Moffatt</td>
</tr>
<tr>
<td>Q&amp;A</td>
<td></td>
</tr>
</tbody>
</table>
Project Background and Introduction
Introduction to the team

Project Team

- **Austroads Project Manager**
  Andrew Papacostas

- **Project Leader, ARRB**
  Geoff Jameson

- **Team Member, ARRB**
  Dr Michael Moffatt

Review Team

- Austroads Pavements Structures Working Group
- Stakeholders - Road and Traffic Authorities
- Industry - AustStab, AAPA Civil Contractors NZ
- Austroads Pavements Task Force
- Austroads Board
The Project Team

Austroads Pavement Structures Working Group

Simon Kenworthy -Groen MRWA
Costa Tsemtsidis DPTI
Andrew Papacostas DoT Vic
Erik Denneman AAPA
Jothi Ramanujam TMR
James Allen RMS
Graham Hennessy AustStab
Greg Arnold Civil Contractors NZ
David Alabaster NZTA
Background – 40 year history
Project objectives

- Align the structural design with the mechanistic-empirical (ME) design method for new pavements (Part 2 of the Guide 2017)
- Improved guidance on thickness design of flexible treatments for flexible pavements
- Review the entire text to incorporate developments since last published in 2011
Mechanistic-empirical thickness design

- Calculate critical strains under truck axle loads using a linear elastic model
- Predict life using performance relationships

Asphalt fatigue relationship

\[ N = \frac{SF}{RF} \left[ \frac{6918(0.856V_b + 1.08)}{E^{0.36} \mu \varepsilon} \right]^5 \]
2017 edition of Part 2

- New approach to calculating fatigue damage
- Strains are calculated due to each axle group load and types
- Fatigue damage is sum of damage due to each axle group load and type

<table>
<thead>
<tr>
<th>Axle group load (kN)</th>
<th>Expected group repetitions</th>
<th>Axles in group</th>
<th>Critical strain (microstrain)</th>
<th>Allowable group repetitions</th>
<th>Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>66,334</td>
<td>1</td>
<td>21.9</td>
<td>2.06E+11</td>
<td>1.14E-09</td>
</tr>
<tr>
<td>20</td>
<td>166,094</td>
<td>1</td>
<td>43.8</td>
<td>6.42E+09</td>
<td>1.45E-07</td>
</tr>
<tr>
<td>30</td>
<td>448,096</td>
<td>1</td>
<td>65.6</td>
<td>8.46E+08</td>
<td>1.19E-06</td>
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<tr>
<td>40</td>
<td>418,863</td>
<td>1</td>
<td>87.5</td>
<td>2.01E+08</td>
<td>1.59E-05</td>
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<tr>
<td>50</td>
<td>320,880</td>
<td>1</td>
<td>109.4</td>
<td>6.58E+07</td>
<td>1.60E-04</td>
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<tr>
<td>60</td>
<td>183,475</td>
<td>1</td>
<td>131.3</td>
<td>2.64E+07</td>
<td>5.82E-04</td>
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<tr>
<td>70</td>
<td>124,150</td>
<td>1</td>
<td>153.1</td>
<td>1.22E+07</td>
<td>1.45E-03</td>
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<tr>
<td>80</td>
<td>88,299</td>
<td>1</td>
<td>175.0</td>
<td>6.27E+06</td>
<td>2.52E-03</td>
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<tr>
<td>90</td>
<td>56,708</td>
<td>1</td>
<td>196.9</td>
<td>3.48E+06</td>
<td>3.54E-03</td>
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<tr>
<td>100</td>
<td>26,606</td>
<td>1</td>
<td>218.8</td>
<td>2.06E+06</td>
<td>5.70E-03</td>
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<tr>
<td>110</td>
<td>7,827</td>
<td>1</td>
<td>240.6</td>
<td>1.28E+06</td>
<td>7.95E-03</td>
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<tr>
<td>120</td>
<td>2,212</td>
<td>1</td>
<td>262.5</td>
<td>8.26E+05</td>
<td>1.17E-02</td>
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<tr>
<td>130</td>
<td>466</td>
<td>1</td>
<td>284.4</td>
<td>5.54E+05</td>
<td>1.72E-02</td>
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<tr>
<td><strong>Total SADT damage</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>0.271</strong></td>
</tr>
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</table>
## Change in Part 5 mechanistic-empirical design process

<table>
<thead>
<tr>
<th>2011 Guide</th>
<th>2019 Guide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design traffic in terms of Cumulative HVAGs and SAR5, SAR7, SAR12</td>
<td>Design traffic in terms of Cumulative HVAGs and ESA</td>
</tr>
<tr>
<td>Calculate strains under 80 kN Standard Axle</td>
<td>Calculate strains under each axle load of each axle type in TLD (including Standard Axle)</td>
</tr>
<tr>
<td>Allowable repetitions of a Standard Axle (SAR5, SAR7, SAR12)</td>
<td>Fatigue: allowable repetitions of each axle load of each axle type</td>
</tr>
<tr>
<td></td>
<td>Rutting: allowable ESA</td>
</tr>
<tr>
<td></td>
<td>Fatigue: sum damage (want ≤ 1)</td>
</tr>
<tr>
<td>Compare allowable SARs to design traffic in SARs</td>
<td>Rutting: compare allowable ESA to design traffic in ESA</td>
</tr>
</tbody>
</table>
Reformatting

1. Introduction
2. Project definition
3. Pavement data and inspection
4. Investigative testing on pavement surface
5. Pavement composition and subgrade characterisation
6. Causes and modes of distress
7. Selection of treatments for flexible pavements
8. Treatments for rigid pavements
Reformatting

9. Empirical design of granular overlays for flexible pavements
10. Mechanistic-empirical method of designing strengthening treatments for flexible pavements
11. Concrete overlays on flexible pavements
12. Thickness design of structural treatments for rigid pavements
13. Economic comparison of alternative treatments

Appendices A to Q
Overview of rehabilitation design process
Overview of rehabilitation design process

See Figure 1.2
Use of TSD Pavement Deflections
Pavement response to load useful to evaluate structural adequacy
Traffic speed deflectometer (TSD)

• 7 laser sensors measure deflection velocities
• Deflections are estimated from the vertical and horizontal velocities
• Use area under the velocity curve as described in test method

AUSTROADS TEST METHOD AG:AM/T017
Pavement Data Collection with a Traffic Speed Deflectometer (TSD) Device
Devices used Part 5 (2011) thickness design methods

Benkelman Beam

Deflectograph

Falling weight deflectometer (FWD)
Can TSD be used to design treatments?
TSD maximum deflections correlated with FWD values

$$D_0 \text{ (FWD 40 kN)} = 1.06 \times D_0 \text{ (TSD 50 kN)}$$
Empirical method of granular overlay design based on Benkelman Beam maximum deflections $D_0$
Estimation of Benkelman Beam $D_0$ from TSD values

$D_0 (BB) = 1.06 \times 1.1 \ D_0 \ (TSD \ 50 \ kN)$

Table 9.2: Deflection standardisation factors

<table>
<thead>
<tr>
<th>Deflection measurement device</th>
<th>Deflection standardisation factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deflectograph, 80 kN single axle with dual tyres</td>
<td>1.2</td>
</tr>
<tr>
<td>TSD, 50 kN dual tyres</td>
<td>1.2</td>
</tr>
<tr>
<td>Falling Weight Deflectometer, 40 kN load</td>
<td>1.1</td>
</tr>
</tbody>
</table>

$D_0 (BB) = 1.2 \ D_0 \ (TSD)$
Use of TSD data in project level design

- To identify homogeneous subsections

See Section 9.2.5
Use of TSD data in project level design

- Select sites for pavement investigations and FWD testing

See Section 9.2.5
Design of granular overlays

See Section 9.5

\[ D_0 \text{ (BB)} = 1.2 \ D_0 \text{ (TSD)} \]
Calculation of Characteristic Deflection
Characteristic deflection (CD)

- Pavement deflections vary within a homogeneous sub-section
- Need to identify a deflection value that best reflects the weakest chainages that limits life

See Section 9.2.6
2011 Guide method for Characteristic Deflection

- CD reflected the weakest 2.5%, 5% and 10% of the project length
- Austroads Working Group considered these values did not reflect the extent of distress when pavements are rehabilitated

\[ CD = \mu + fs \]

<table>
<thead>
<tr>
<th>Road Class</th>
<th>( f^* )</th>
<th>Per cent of all deflection measurements which will be represented by the Characteristic Deflection**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeway and arterials/highways with lane AADT &gt; 2000</td>
<td>2.00</td>
<td>97.5</td>
</tr>
<tr>
<td>Arterials/highways with lane AADT &lt; 2000</td>
<td>1.65</td>
<td>95</td>
</tr>
<tr>
<td>Other roads</td>
<td>1.30</td>
<td>90</td>
</tr>
</tbody>
</table>

* \( f^* \) values applicable for 30 or more deflection measurements.
** After identifying areas to be patched/reconstructed.
2019 Guide method

CD reflects the weakest 10% of the project length

CD = μ + f × SD

where

f is selected by the designer to provide a 10% probability of the characteristic value not being exceeded by an individual value

Table 9.3: Recommended values for ‘f’

<table>
<thead>
<tr>
<th>Number of deflection measurements *</th>
<th>f*</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1.38</td>
</tr>
<tr>
<td>12</td>
<td>1.36</td>
</tr>
<tr>
<td>14</td>
<td>1.35</td>
</tr>
<tr>
<td>16</td>
<td>1.34</td>
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<tr>
<td>19</td>
<td>1.33</td>
</tr>
<tr>
<td>24</td>
<td>1.32</td>
</tr>
<tr>
<td>≥ 30</td>
<td>1.31</td>
</tr>
</tbody>
</table>

* After identifying areas to be patched/reconstructed.
Deletion of Charts for Design of Asphalt Overlays
2011 Guide thickness design methods for asphalt overlays

<table>
<thead>
<tr>
<th>Existing pavement type</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible pavements without cemented materials</td>
<td>6.2</td>
</tr>
<tr>
<td></td>
<td>(using Design Charts)</td>
</tr>
<tr>
<td>All flexible pavements</td>
<td>6.3</td>
</tr>
<tr>
<td></td>
<td>(using General Mechanistic Procedure)</td>
</tr>
</tbody>
</table>
Example of a curvature ($D_0$-$D_{200}$) design charts used to estimate asphalt overlay thickness in the 2011 Guide
Based on predicted strains in overlays and predicted FWD curvature before overlay

- $D_0 - D_{200}$ before overlay can be related with Standard Axle strain at bottom of an asphalt overlay
- Method assumes fixed asphalt moduli for overlay and existing asphalt
- e.g. Adelaide, Sydney & Perth overlays $E = 3000$ MPa
Limitations of the design chart method

• Limited to a maximum design traffic of $10^7$ ESA
• Not applicable to pavements with cemented materials
• Method assumes fixed asphalt modulus for overlay and existing asphalt
• Inability to cater for range of possible mixes
Austroads decision to delete charts

• The charts needed to be revised to reflect recent changes in asphalt fatigue life prediction in Part 2
• Since original development 30 years ago, design traffic values have increased significantly
• Now common for arterials and highways to have design traffic > $10^7$ ESA
• Over the last 10 years the use of general mechanistic procedure (GMP) has increased and use of simplified approach using charts has reduced
• Assumed asphalt moduli in charts do not cater for wide range of possible mixes
Austroads decision to delete charts

Decided:

• Retained empirical design chart method based on $D_0$ for design of granular overlays
• Delete simplified design charts for thickness design asphalt overlays
• General mechanistic procedure (GMP) used to determine the required thickness of all flexible treatments
Overview of Thickness Design of Treatments Using the Mechanistic-Empirical Procedure
Mechanistic-empirical procedure (MEP)

- Previously called the GMP - general mechanistic procedure to delineate it from the design chart method which was a simplified mechanistic method
- GMP now renamed MEP
- Used to design thickness of any treatment to a flexible pavement other than concrete overlays/inlays
  - Asphalt overlays
  - Asphalt inlays/major patchings
  - Stabilisation of pavement layers and subgrade

See Section 10
### Scope of MEP

- Strengthening treatments are designed to limit fatigue cracking in treatment layers and permanent deformation of the treated pavement.

<table>
<thead>
<tr>
<th>Granular subbase</th>
<th>Existing asphalt or cemented material</th>
<th>Asphalt overlay</th>
</tr>
</thead>
</table>

MEP predicts fatigue life of treatment layers.
Scope of MEP

• Procedures yet to be develop to design treatments to limit fatigue cracking of existing bound materials

• Concepts of remaining structural life yet to be developed

• Similarly MEP not applicable to newly-constructed pavements

Asphalt overlay

Existing asphalt or cemented material

Granular subbase

Does NOT predict fatigue life of existing bound materials
Reflective cracking

- The MEP does not predict allowable traffic loading in terms of reflective cracking from any cracked underlying material
- Designer needs to consider cost-effective treatment options
MEP treatment design similar to Part 2

Similar to Part 2 for new pavement design, except there is an initial phase in which the properties of in situ materials are determined.
Part 5 uses the same performance relationships as Part 2.

Asphalt fatigue relationship:

\[ N = \frac{SF}{RF} \left[ \frac{6918(0.856V_b + 1.08)}{E^{0.36} \mu \varepsilon} \right]^5 \]

where:

- \( N \) = allowable number of repetitions of the load-induced tensile strain
- \( \mu \varepsilon \) = load-induced tensile strain at the base of the asphalt (microstrain)
- \( V_b \) = percentage by volume of bitumen in the asphalt (%)
- \( E \) = asphalt modulus (MPa)
- \( SF \) = shift factor between laboratory and service fatigue lives (presumptive value = 6)
- \( RF \) = reliability factor for asphalt fatigue (Table 6.16)

See Section 10.9.
Elastic characterisation of treatment layers

- Part 2 performance relationships are applicable to design moduli determined following the Part 2 methods.
- To use these relationships to design rehab treatments, the design moduli adopted for treatment materials need to be determined using Part 2 methods.

See Section 10.7.
Elastic characterisation of existing pavement materials and subgrade

• Again, as far as possible the design moduli should be consistent with Part 2 methods
• Design moduli for existing pavement materials are not necessarily the same values as used in the design of new pavements
• If existing bound materials are fatigue cracked or increased in modulus with time this needs consideration in selecting their design moduli
• Improved guidance has been provided in relation to determining design moduli of existing materials and subgrade.
Send us your questions

Step 1: Open side panel

Step 2: Type questions here

Let us know the slide number your question relates to
Back-calculation of Moduli from Deflection Bowls Measured on the Pavement Surface
If FWD deflections have been measured, opportunity to back-calculate layer moduli.
Modulus back-calculation concept

- Predict deflection bowl
- Iteration approach is used to search layer moduli where predicted deflection bowl best matches measured deflection bowl
- Compare measured & predicted deflection bowls
Improved back-calculation guidance

- Selection of deflection bowls for estimation of design moduli
- Sublayering of subgrade into 3 layers
  for pavement thicknesses 500 mm or less:
  - top 300 mm
  - 300 mm to 800 mm and
  - semi-infinite thickness
- Use of Composite Modulus to seed the back-calculation subgrade layer moduli

\[
CM_r = \sigma_0 (1 - \mu^2) \left( \frac{a^2}{r \times d_r} \right)
\]
Appendix G example of use of Composite Modulus

Plot CM with distance from centre of FWD loading plate

Does subgrade modulus increase with depth?

Useful in seeding subgrade moduli and acceptance of back-calculated values
Improved back-calculation guidance

• In Part 2 and Part 5, use anisotropic modulus characterisation for granular materials and subgrade

  Vertical modulus \( (E_v) = 2 \times \text{Horizontal modulus} \ (E_h) \)

• Available back-calculation software limited to isotropic characterisation \( (E_v=E_h) \)

• Part 5 has a process to determine anisotropic granular and subgrade moduli from isotropic back-calculated values

  \[ E_v = 2 \times E_h = 1.1 \times E_{iso} \]
Subgrade Design Moduli
Selection of subgrade design modulus

Designer needs to consider:

• Laboratory CBR tests of field samples
• In situ CBR testing adjusted for seasonal moistures
• Back-calculated moduli of top 300 mm of subgrade, adjusted for seasonal moistures

See Section 10.7.2
Selection of subgrade design modulus

- If lab CBR values not available to confirm values from DCP and back-calculation, maximum subgrade design moduli suggested

<table>
<thead>
<tr>
<th>Description of subgrade material</th>
<th>Maximum vertical design modulus (MPa)&lt;sup&gt;(1,2)&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Excellent to good drainage</td>
</tr>
<tr>
<td>Highly plastic clay</td>
<td>100</td>
</tr>
<tr>
<td>Silt</td>
<td>80</td>
</tr>
<tr>
<td>Silty-clay, sandy-clay</td>
<td>100</td>
</tr>
<tr>
<td>Sand</td>
<td>150</td>
</tr>
</tbody>
</table>

<sup>(1,2)</sup> See Section 10.7.2
Existing Granular Materials Design Moduli
Selection of granular design moduli

- Use method closely aligned with Part 2 method
- The total granular thickness divided into 5 sublayers
- Moduli depends on:
  - underlying subgrade design modulus
  - total granular thickness
  - maximum modulus the granular material can develop
  - thickness and modulus of overlying bound materials
Example of granular characterisation under foamed bitumen stabilised layer

Table N 2: Modelled pavement configuration

<table>
<thead>
<tr>
<th>Material type</th>
<th>Thickness (mm)</th>
<th>Elastic modulus (MPa)</th>
<th>Poisson’s ratio</th>
<th>f value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$E_v$</td>
<td>$E_h$</td>
<td>$\nu_v$</td>
</tr>
<tr>
<td>Sprayed seal surface</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>FBS</td>
<td>300</td>
<td>2200</td>
<td>2200</td>
<td>0.40</td>
</tr>
<tr>
<td>Granular</td>
<td>20</td>
<td>87</td>
<td>43.5</td>
<td>0.35</td>
</tr>
<tr>
<td>Granular</td>
<td>20</td>
<td>78</td>
<td>39</td>
<td>0.35</td>
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<tr>
<td>Granular</td>
<td>20</td>
<td>70</td>
<td>35</td>
<td>0.35</td>
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<tr>
<td>Granular</td>
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<td>62</td>
<td>31</td>
<td>0.35</td>
</tr>
<tr>
<td>Granular</td>
<td>20</td>
<td>56</td>
<td>28</td>
<td>0.35</td>
</tr>
<tr>
<td>Subgrade</td>
<td>Semi-infinite</td>
<td>50</td>
<td>25</td>
<td>0.45</td>
</tr>
</tbody>
</table>
Modulus characterisation of granular materials

Designer needs to consider:

• maximum design moduli are those used to design new pavements
• the qualities of the granular materials as assessed from test pits and laboratory testing
• moduli back-calculated from deflections
Use of back-calculated granular moduli

The 5 sublayer design moduli are then limited such that the middle sublayer does not exceed the back-calculated modulus.

Table N2: Modelled pavement configuration

<table>
<thead>
<tr>
<th>Material type</th>
<th>Thickness (mm)</th>
<th>Elastic modulus (MPa)</th>
<th>Poisson’s ratio</th>
<th>f value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$E_v$</td>
<td>$E_h$</td>
<td>$\nu_v$</td>
</tr>
<tr>
<td>Sprayed seal surface</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
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<td>FBS</td>
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<td>2200</td>
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<td>0.40</td>
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<td>Granular</td>
<td>20</td>
<td>87</td>
<td>43.5</td>
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<td>0.35</td>
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<td>Granular</td>
<td>20</td>
<td>56</td>
<td>28</td>
<td>0.35</td>
</tr>
<tr>
<td>Subgrade</td>
<td>Semi-infinite</td>
<td>50</td>
<td>25</td>
<td>0.45</td>
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Existing Asphalt Design Moduli
Existing asphalt moduli

- The thickness and modulus of existing asphalt can markedly affect the calculated treatment thickness

See Section 10.7.5
Existing asphalt moduli

In selecting design moduli consider:

• Maximum design moduli are those used to design new pavements

• Current condition, is it fatigue cracked?

• Lab modulus testing of extracted cores or slabs

• Back-calculated modulus
Allowance for future fatigue damage to existing asphalt

- How will the modulus change during treatment design period?
- Additional load-induced strains during the treatment design period
- If the existing asphalt is fatigue cracked due to past traffic, it is likely that it will continue to be damaged during treatment life

existing asphalt reduces in modulus
In 2011 Guide used a conservative approach

Existing asphalt layers were assumed to be crocodile cracked during the treatment design period, regardless of current condition.
2019 Guide enables use measured modulus values

If core or back-calculated moduli available, a process is provided to determine design modulus of existing asphalt

Field cores  Moduli back-calculated from measured deflections
Modulus reduction factor to allow for future damage

If the existing asphalt is fatigue cracked, the design modulus is calculated by multiplying the core or back-calculated moduli by a Modulus Reduction Factor (MRF)

See Figure 10.2
Guide continues to provide presumptive moduli for fatigue cracked asphalt

Particularly useful when existing asphalt is already fatigue cracked and core or back-calculated moduli not available

See Figure 10.3
Austroads has many requests
Out of print
No longer available from Austroads, but ……. 
Appendix A of Part 5 is an update of the old green guide
Send us your questions

Step 1: Open side panel

Step 2: Type questions here

Let us know the slide number your question relates to
Questions?

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<th>Date</th>
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<td>29 August</td>
</tr>
<tr>
<td>Opportunities in Mobility as a Service (MaaS)</td>
<td>3 September</td>
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<td>Dangerous Goods in Tunnels</td>
<td>12 September</td>
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<tr>
<td>Key Freight Routes – Heavy Vehicle Usage Data Project</td>
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