Guide to Pavement Technology Part 5: Pavement Evaluation and Treatment Design

22 August 2019

Austroads

Today's moderator

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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.

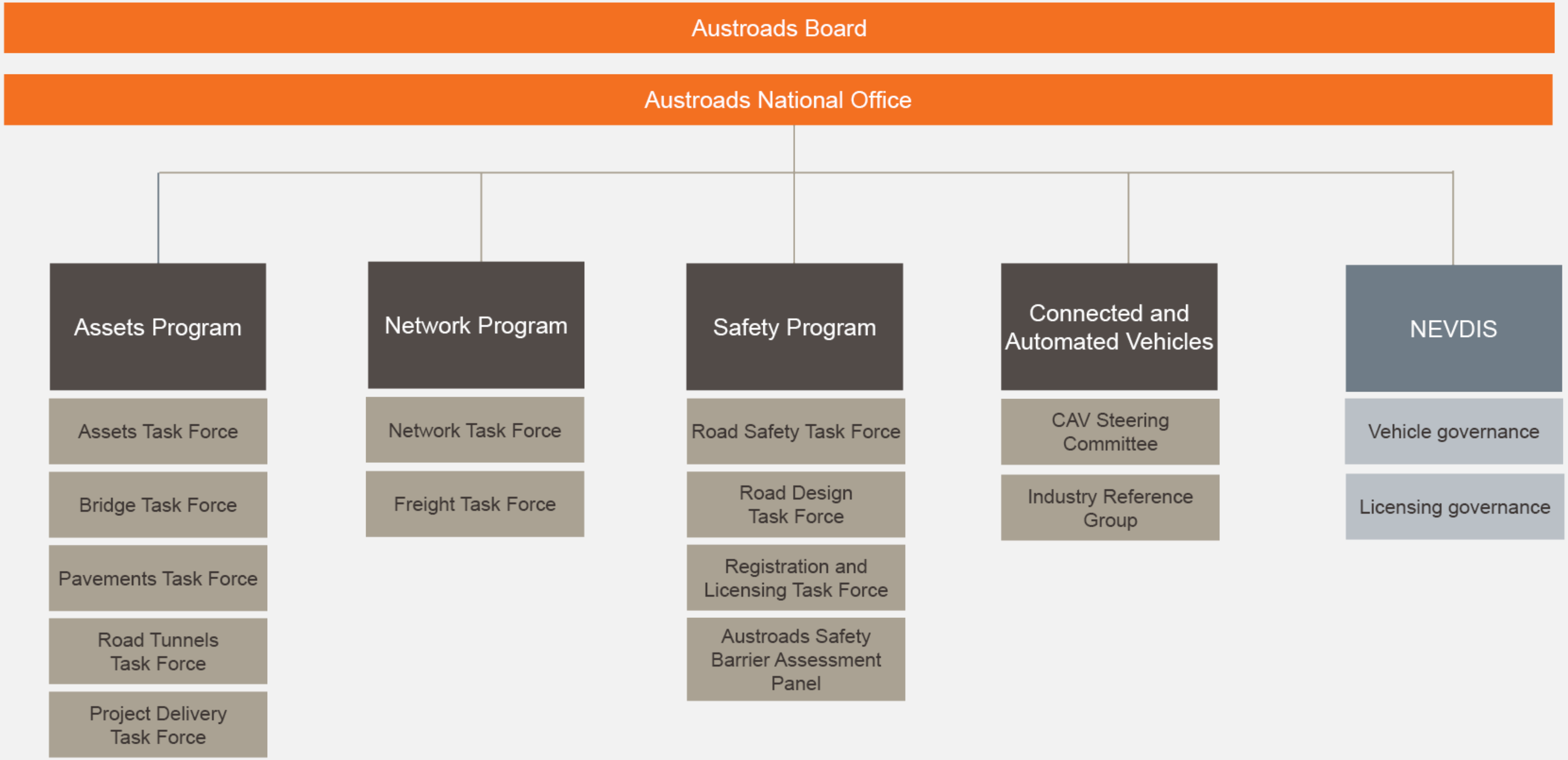
About Austroads

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

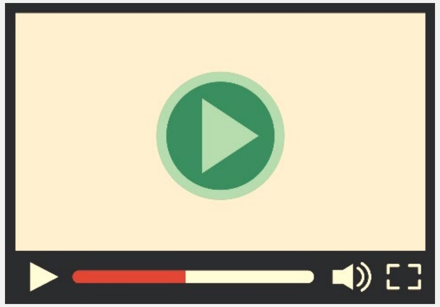
Our structure

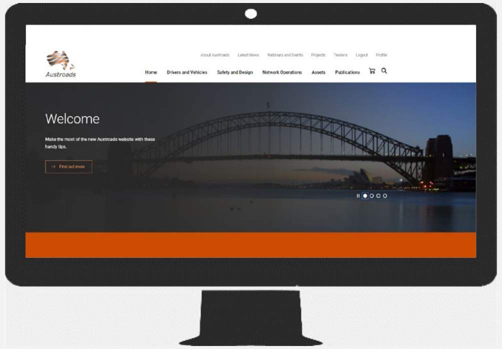


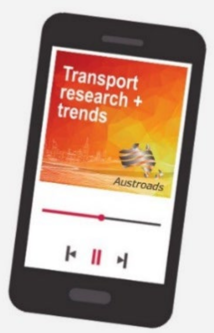
Housekeeping

Presentation = 40 mins

Question time = 15 mins







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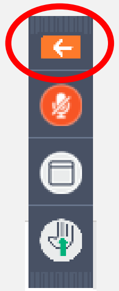

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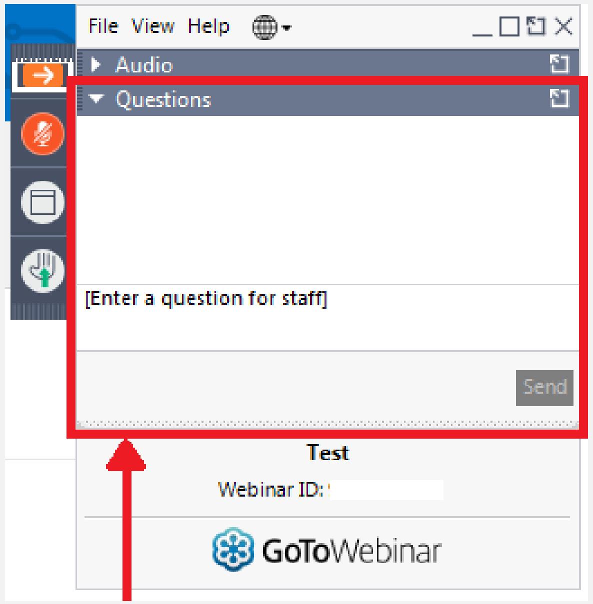

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Let us know the slide number your question relates to

Austroads Guide

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Today’s presenters

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Group Leader

Infrastructure Management

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Agenda

Topic	Presenter
Project Background and Introduction	Geoff Jameson
Revised Format	
Use of Traffic Speed Deflectometer (TSD) Data	
Calculation of Characteristic Deflection	
Deletion of Charts for Thickness Design of Asphalt Overlays	
Overview of Structural Design of Flexible Pavement Treatments	
Back-calculation of Layer Moduli	
Guidance on Subgrade and Granular Design Moduli	
Guidance on Design Moduli of Existing Asphalt	
Q&A	Geoff Jameson & Dr Michael Moffatt

Project Background and Introduction

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Introduction to the team

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Project Team

Austroads Project Manager
Andrew Papacostas

Project Leader, ARRB
Geoff Jameson

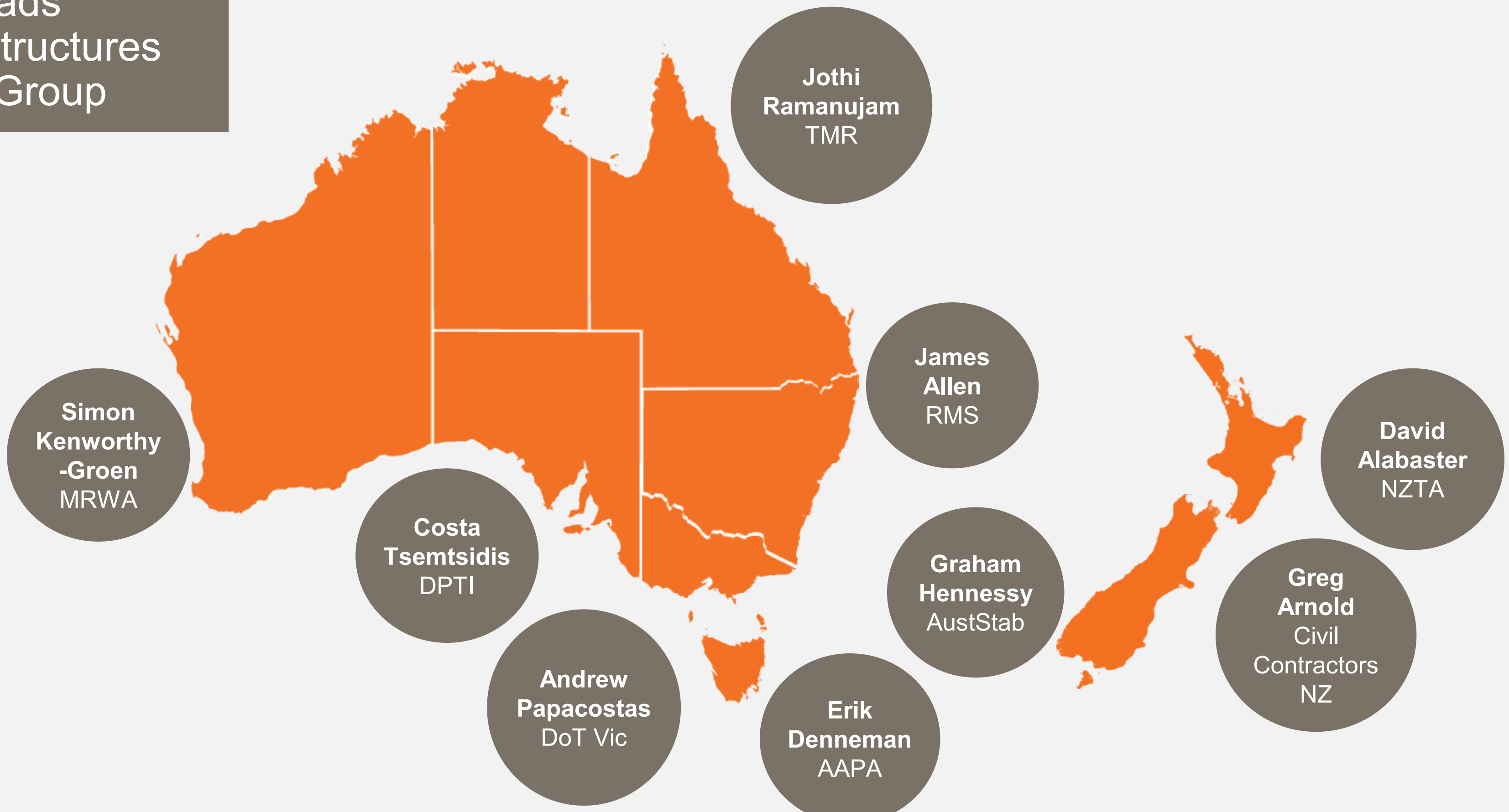
Team Member, ARRB
Dr Michael Moffatt

Review Team

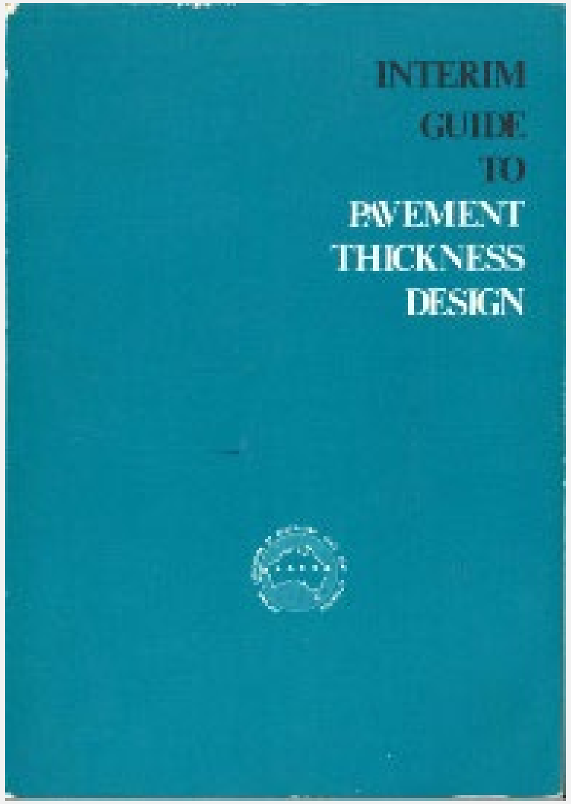
- Austroads Pavements Structures Working Group
- Stakeholders -Road and Traffic Authorities
- Industry - AustStab, AAPA Civil Contractors NZ
- Austroads Pavements Task Force
- Austroads Board

The Project Team

Austroads
Pavement Structures
Working Group



Background – 40 year history



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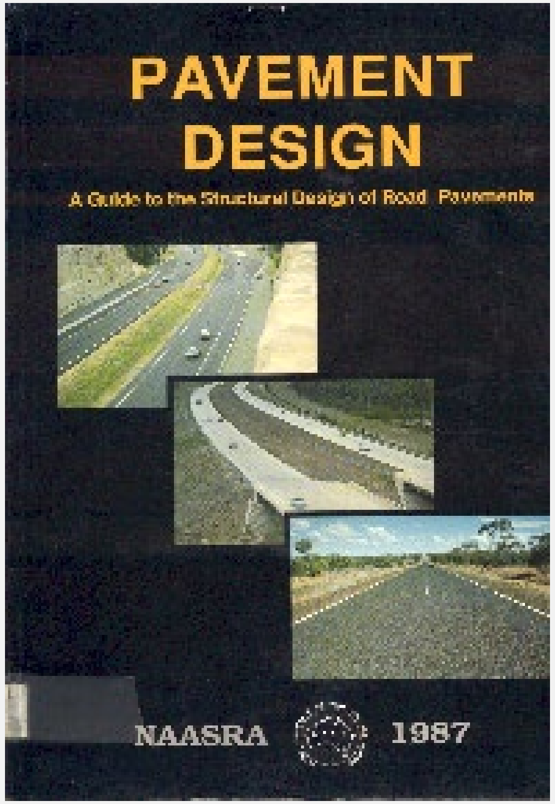

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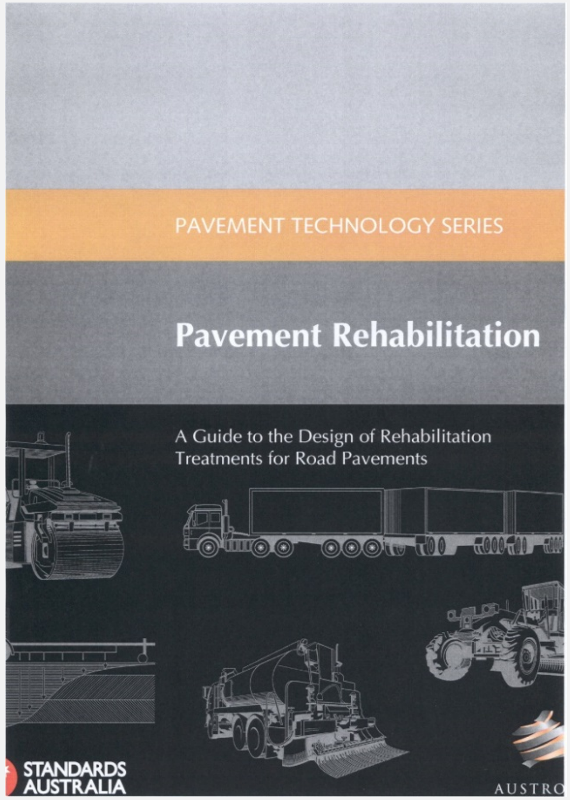
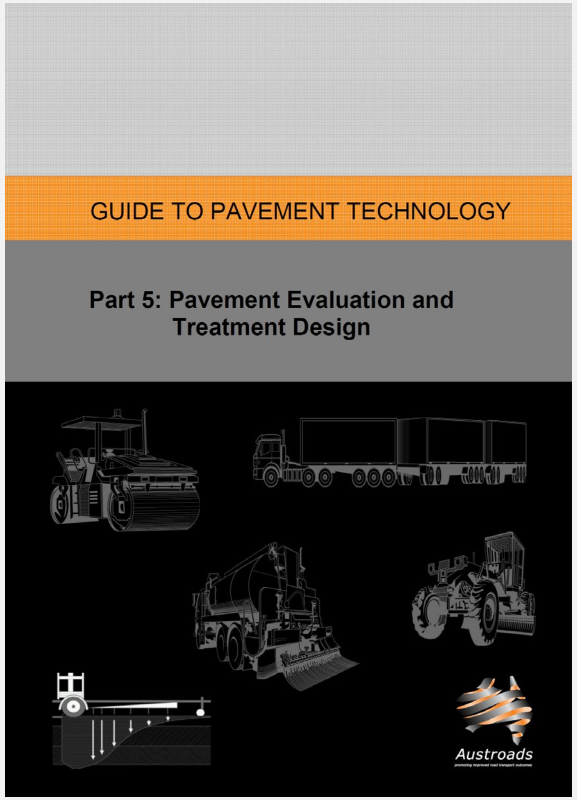


2004



2011

Project objectives

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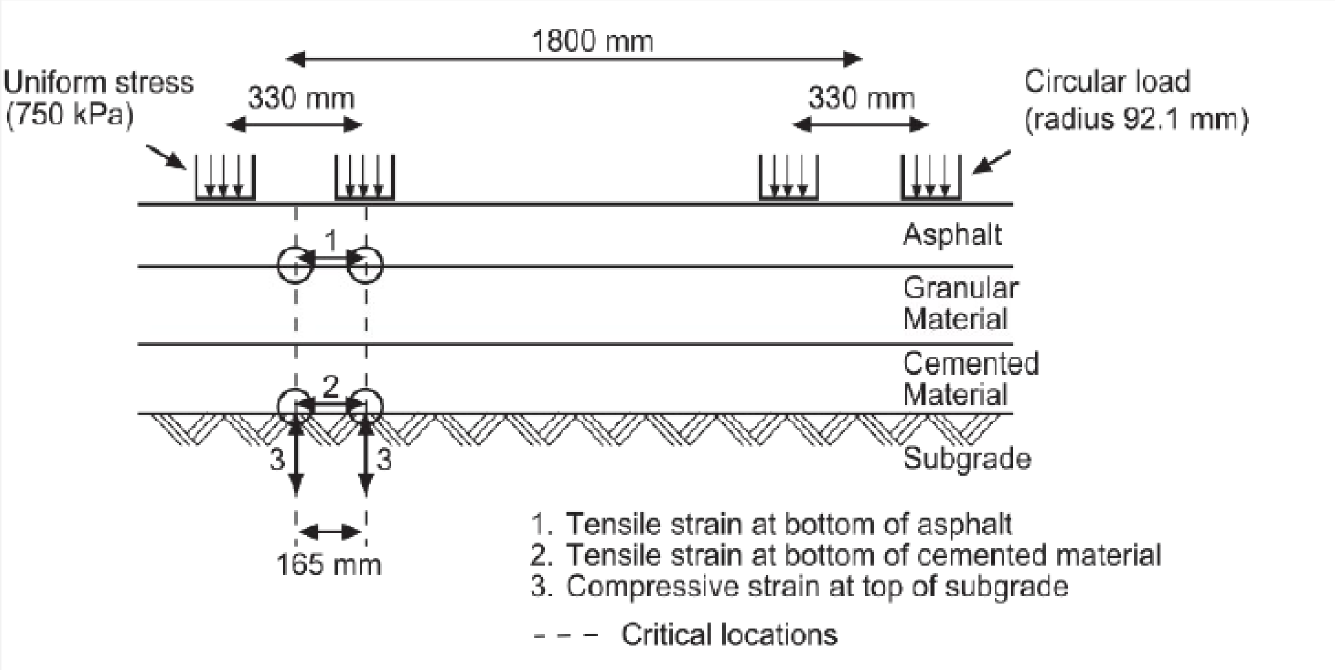
- Align the structural design with the mechanistic-empirical (ME) design method for new pavements (Part 2 of the Guide 2017)
- Improved guidance on thickness design of flexible treatments for flexible pavements
- Review the entire text to incorporate developments since last published in 2011

Mechanistic-empirical thickness design

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

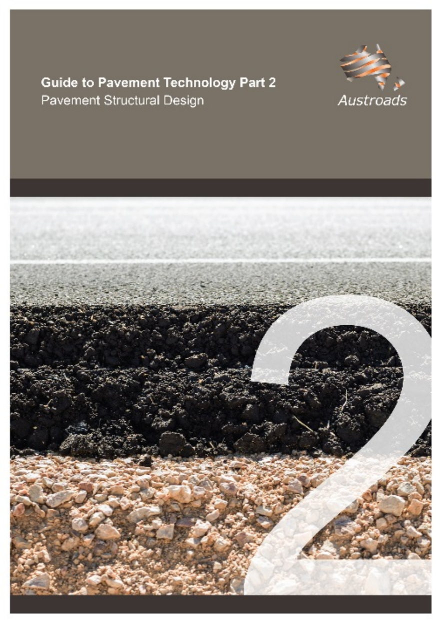


Asphalt fatigue relationship

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

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



Axle group load (kN)	Expected group repetitions	Axles in group	Critical strain (microstrain)	Allowable group repetitions	Damage
10	66 334	1	21.9	2.06E+11	1.14E-09
20	166 094	1	43.8	6.42E+09	1.45E-07
30	448 086	1	65.6	8.46E+08	1.19E-06
40	418 863	1	87.5	2.01E+08	1.59E-05
50	320 880	1	109.4	6.58E+07	1.60E-04
60	183 475	1	131.3	2.64E+07	5.82E-04
70	124 150	1	153.1	1.22E+07	1.45E-03
80	88 299	1	175.0	6.27E+06	2.52E-03
90	56 708	1	196.9	3.48E+06	3.54E-03
100	26 606	1	218.8	2.06E+06	5.70E-03
110	7 827	1	240.6	1.28E+06	7.95E-03
120	2 212	1	262.5	8.26E+05	1.17E-02
130	466	1	284.4	5.54E+05	1.72E-02
				Total SADT damage	0.271

Change in Part 5 mechanistic-empirical design process

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

Revised Format

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Reformatting

See Table of Contents

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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

See Table of Contents

Austroads

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

See Figure 1.1

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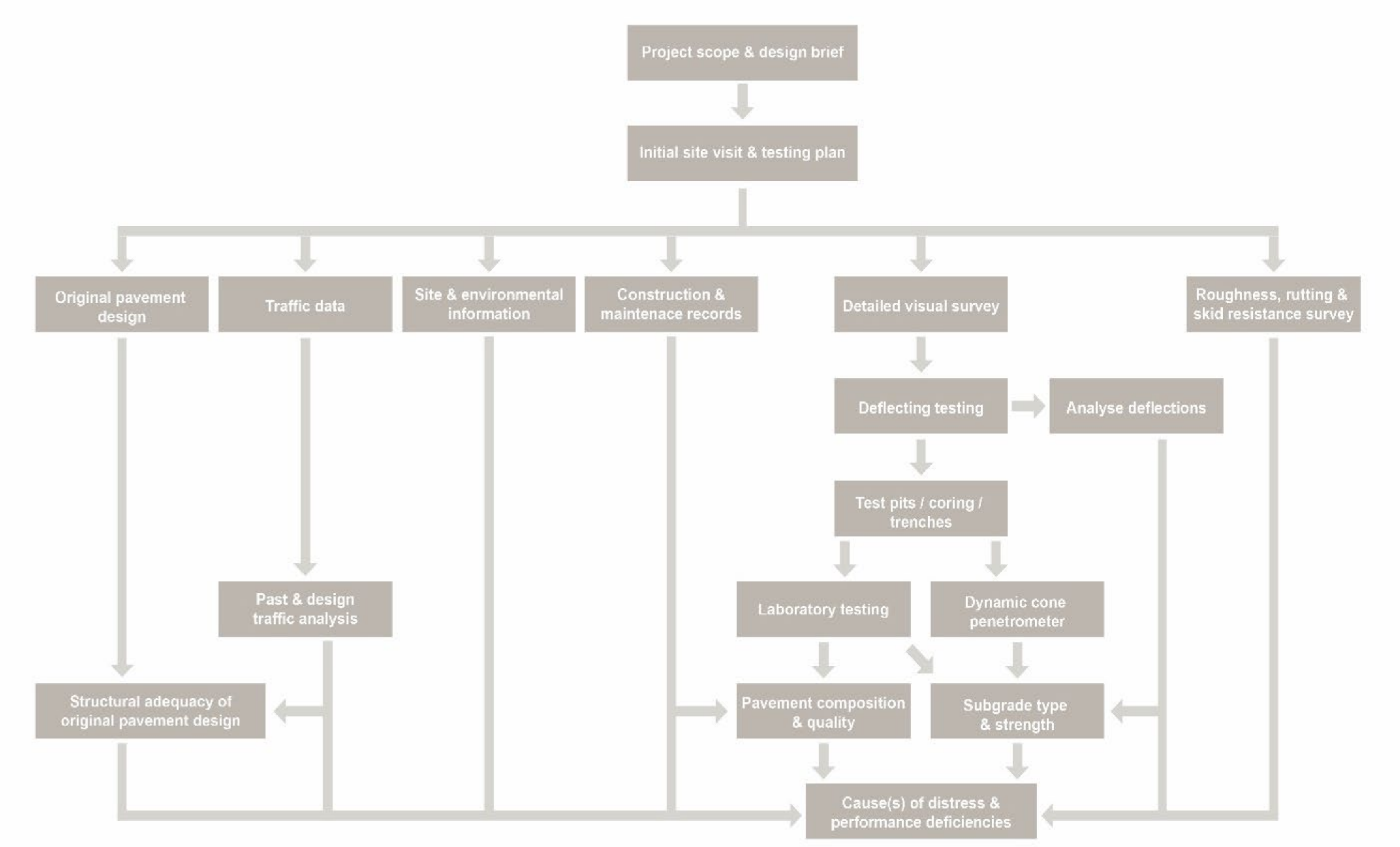

Overview of rehabilitation design process

See Figure 1.2

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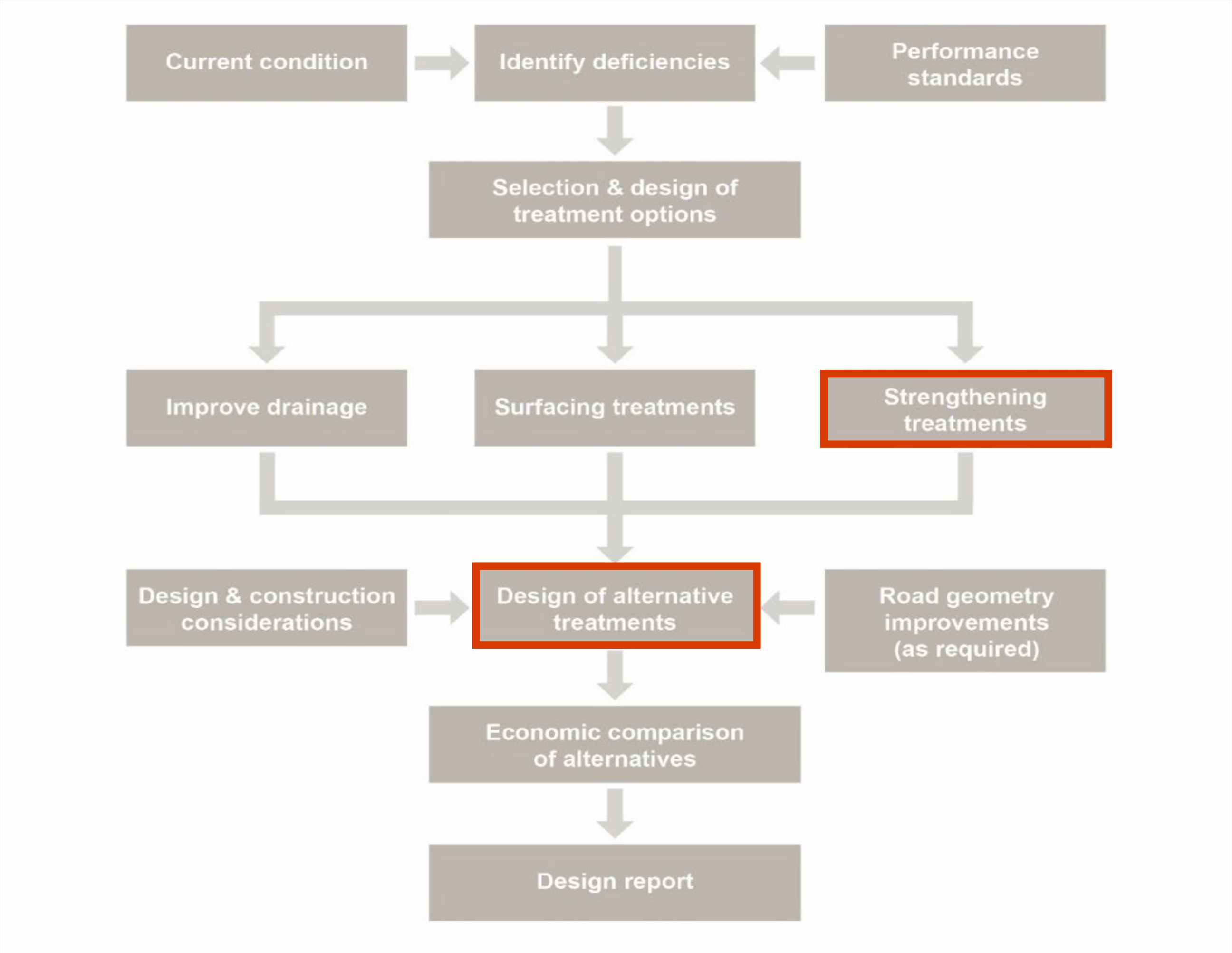

Use of TSD Pavement Deflections

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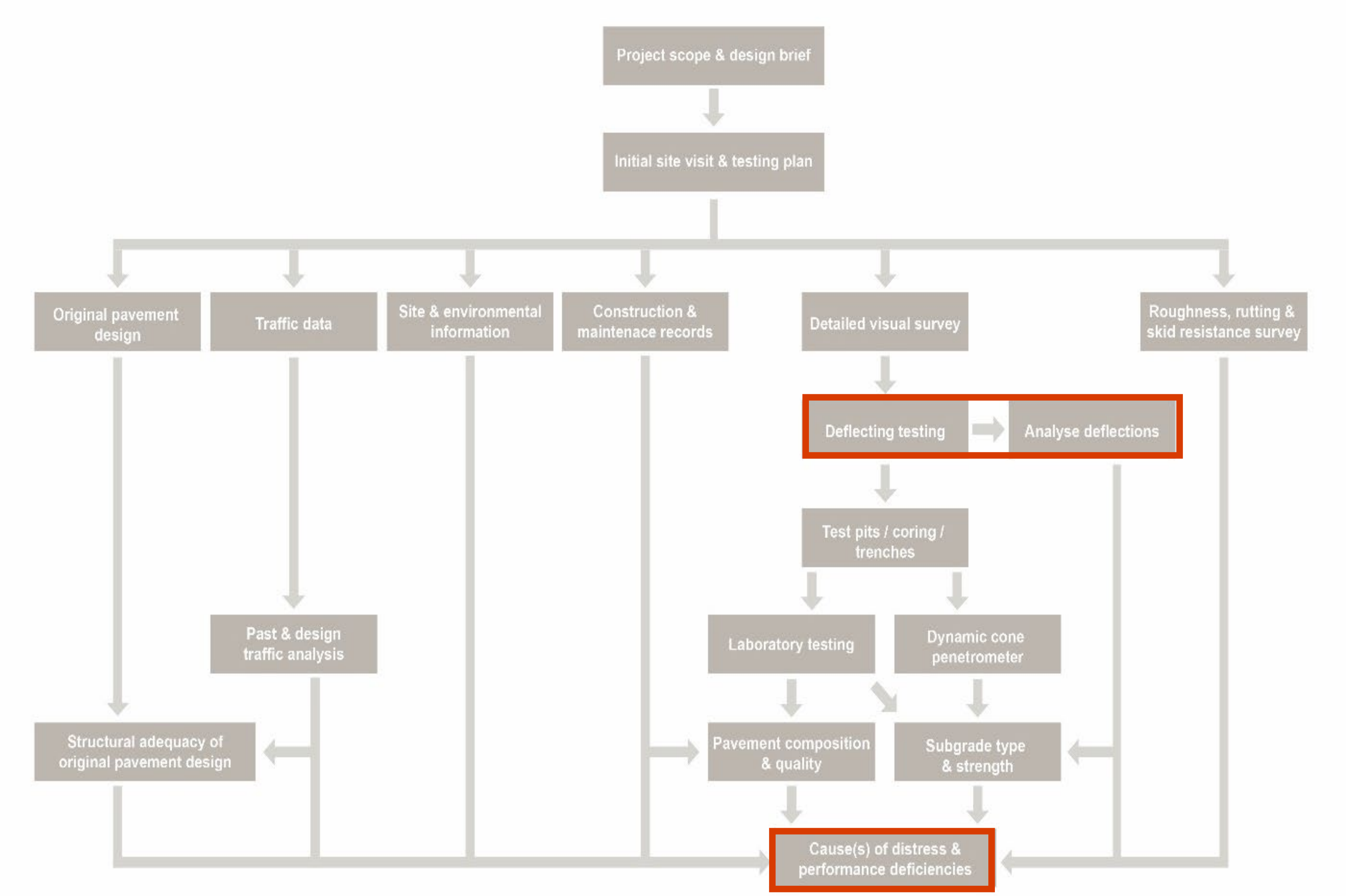
Pavement response to load useful to evaluate structural adequacy



Traffic speed deflectometer (TSD)

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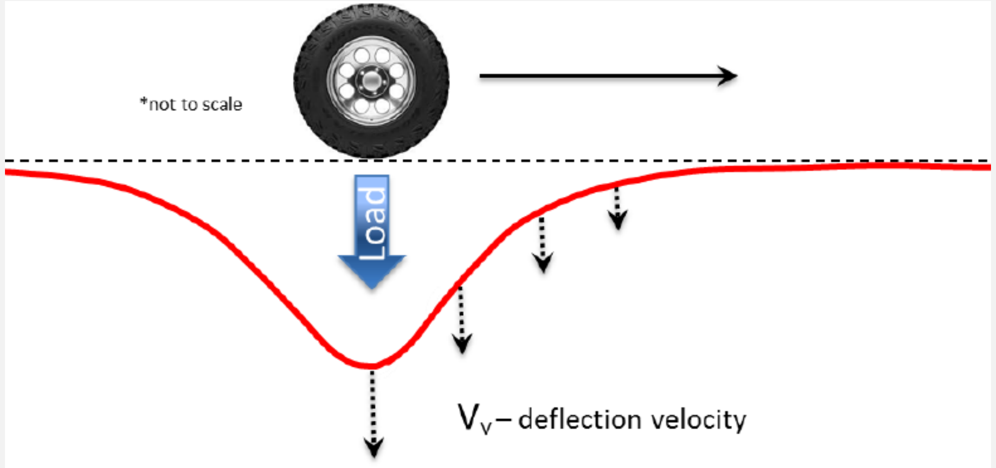
- 7 laser sensors measure deflection velocities
- Deflections are estimated from the vertical and horizontal velocities
- Use area under the velocity curve as described in test method

AUSTROADS TEST METHOD AG:AM/T017

Pavement Data Collection with a Traffic Speed Deflectometer (TSD) Device



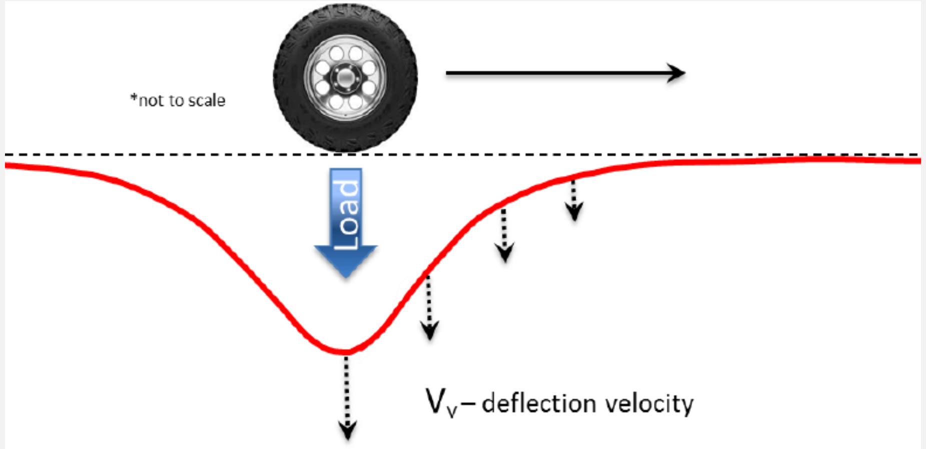
Devices used Part 5 (2011) thickness design methods

Benkelman Beam

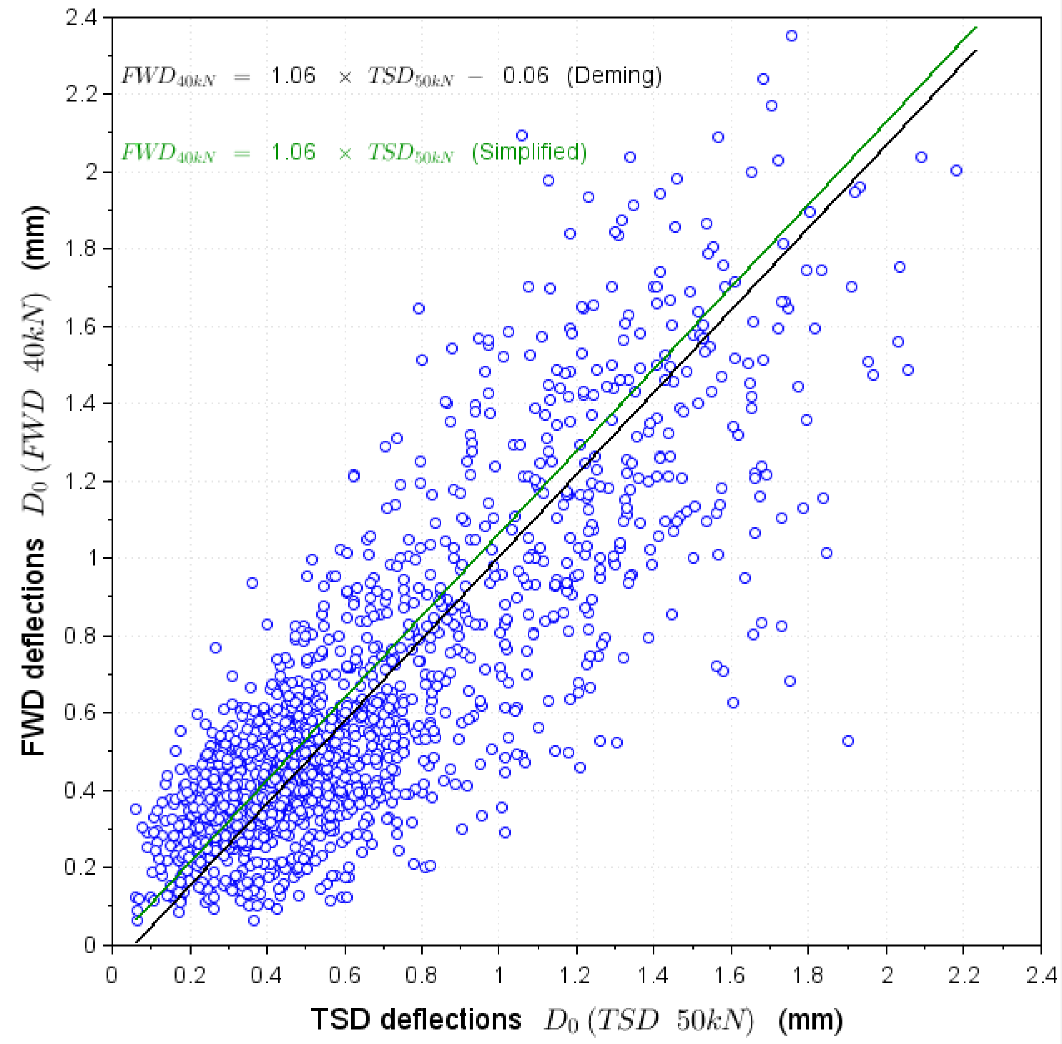
Deflectograph

Falling weight deflectometer (FWD)

Can TSD be used to design treatments?



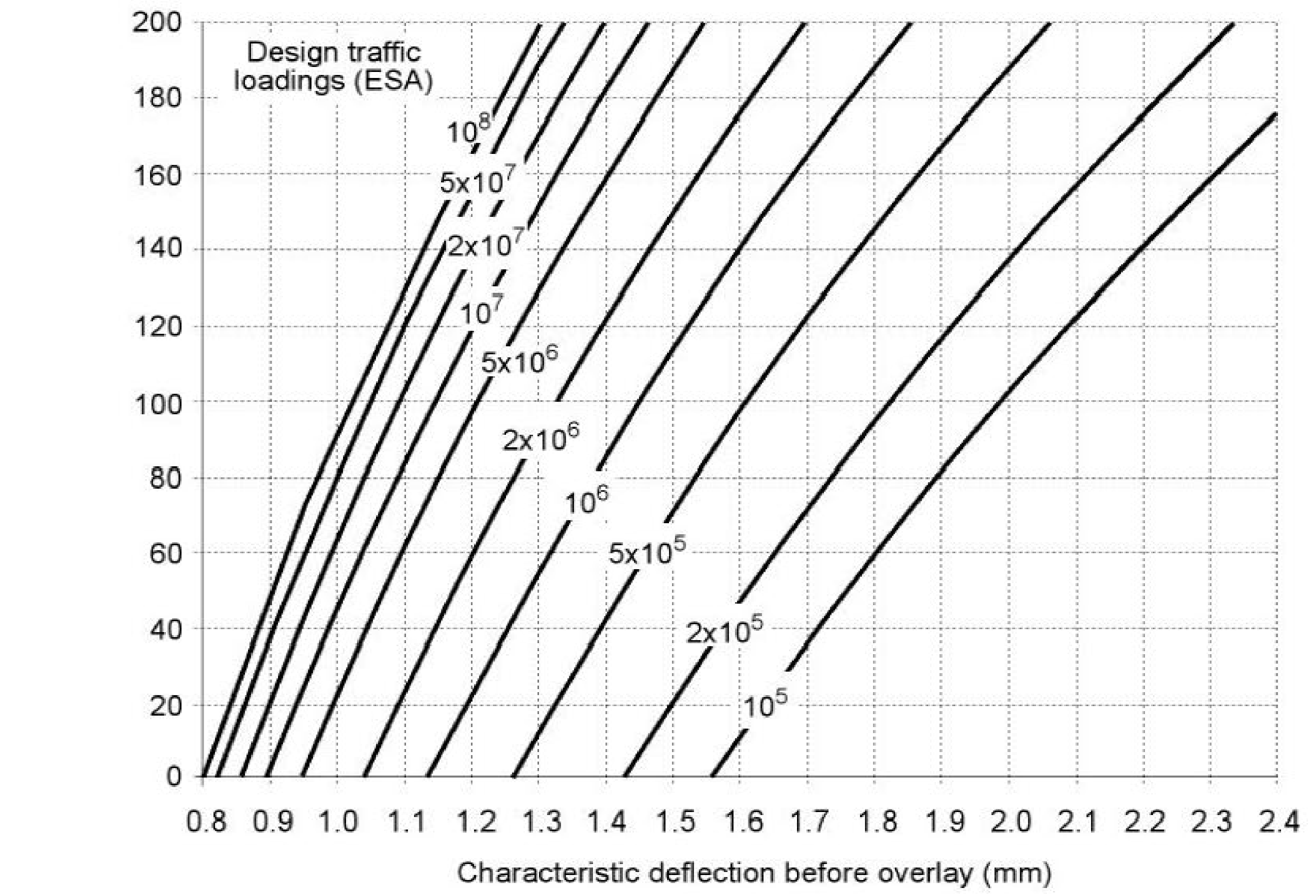
TSD maximum deflections correlated with FWD values



D_0 (FWD 40 kN) = 1.06 D_0 (TSD 50 kN)

Empirical method of granular overlay design based on Benkelman Beam maximum deflections D_0

Figure 9.3: Granular overlay design charts



Estimation of Benkelman Beam D_0 from TSD values

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Table 9.2: Deflection standardisation factors

D_0 (BB) = 1.06 x 1.1 D_0 (TSD 50 kN)

Deflection measurement device	Deflection standardisation factor
Deflectograph, 80 kN single axle with dual tyres	1.2
TSD, 50 kN dual tyres	1.2
Falling Weight Deflectometer, 40 kN load	1.1

D_0 (BB) = 1.2 D_0 (TSD)

Use of TSD data in project level design

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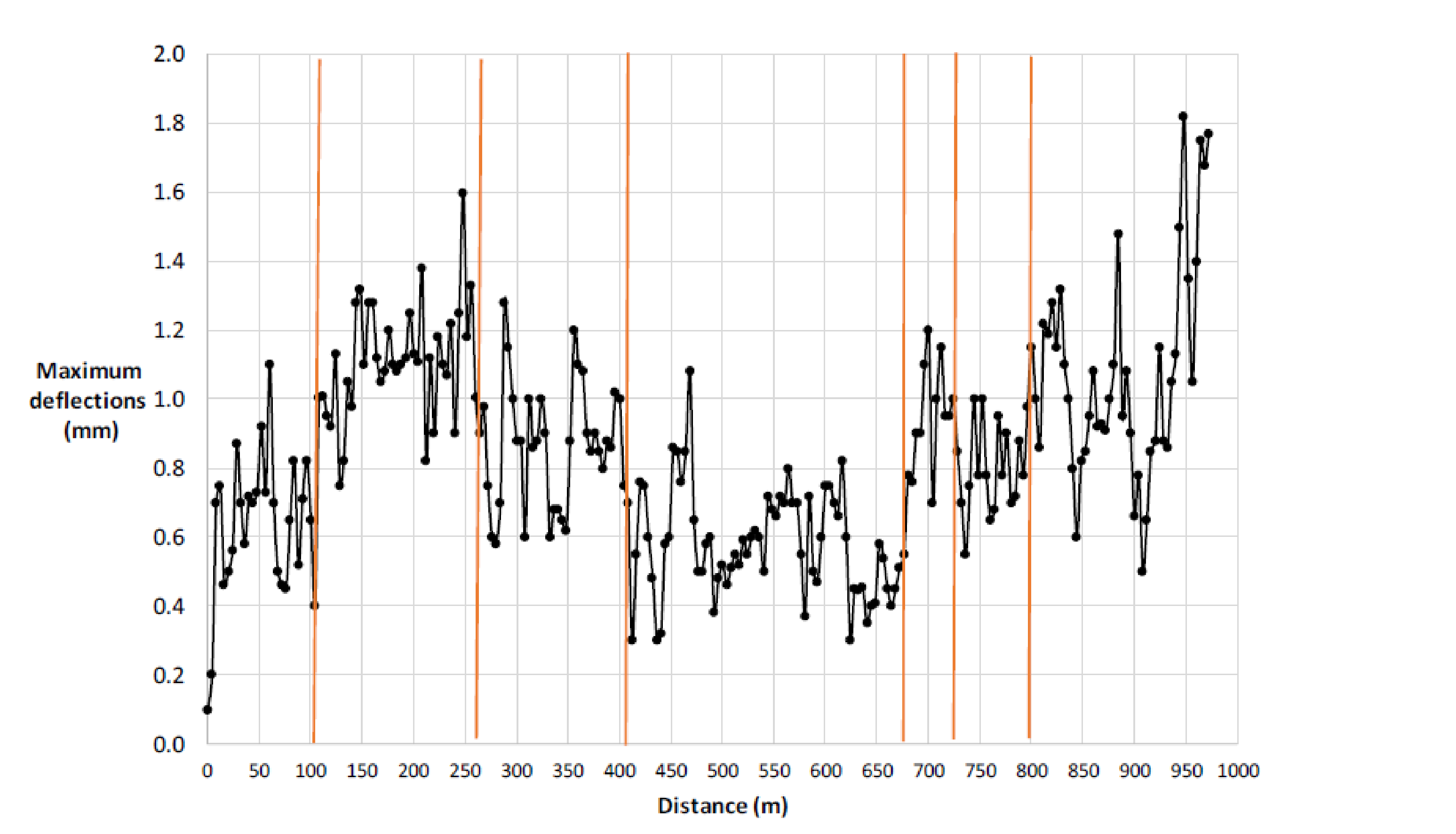
- To identify homogeneous subsections

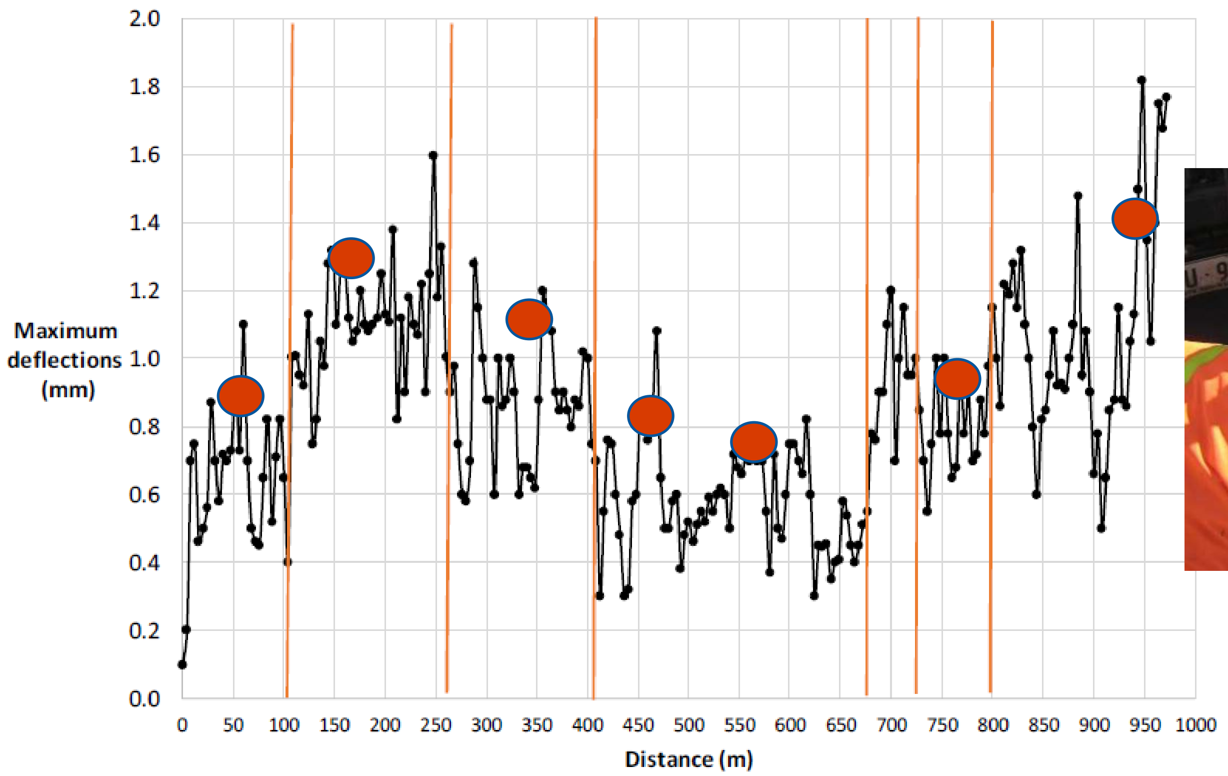
See
Section 9.2.5



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

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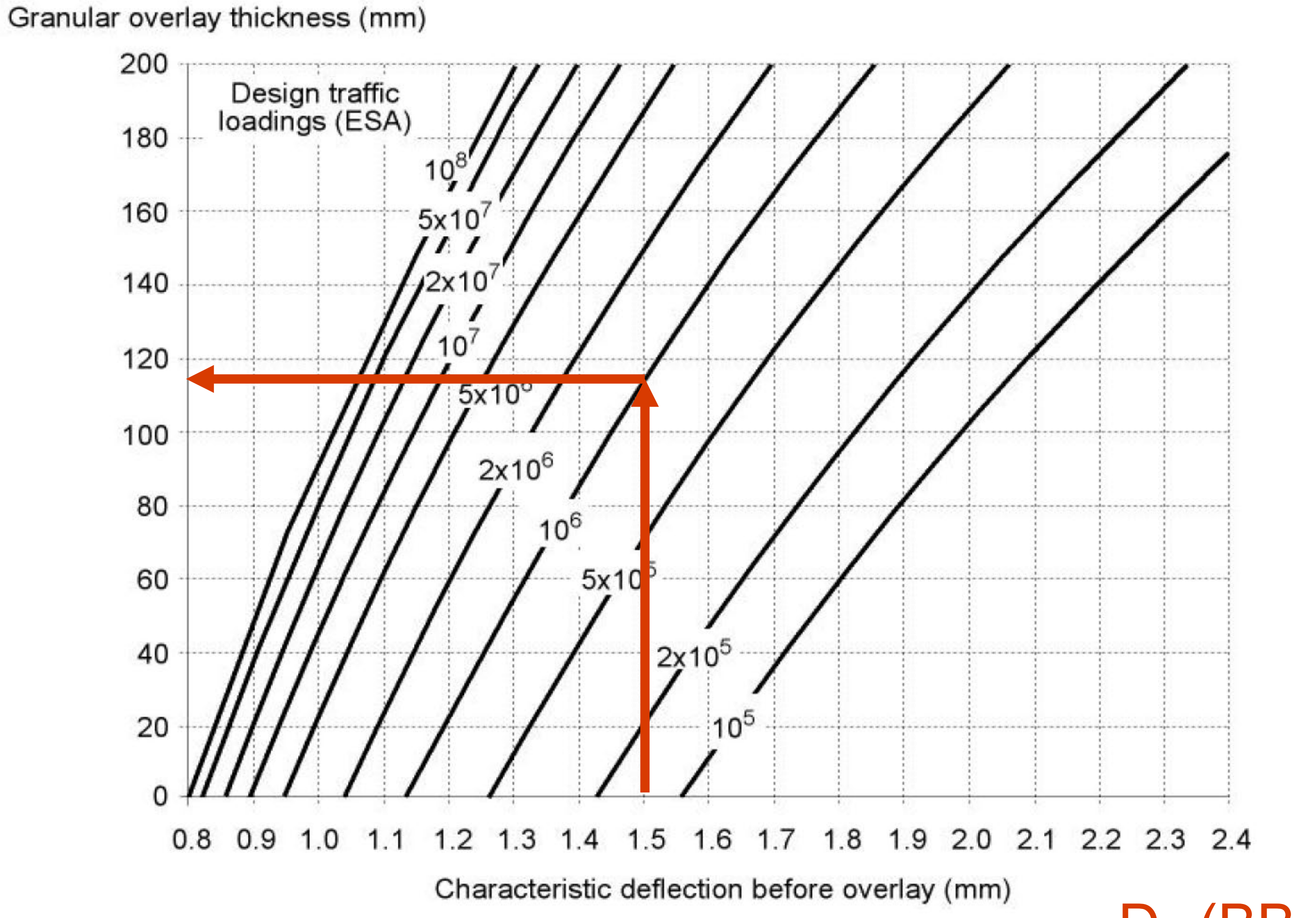
Figure 9.3: Granular overlay design charts



D_0 (BB) = 1.2 D_0 (TSD)

Calculation of Characteristic Deflection

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Characteristic deflection (CD)

See
Section 9.2.6

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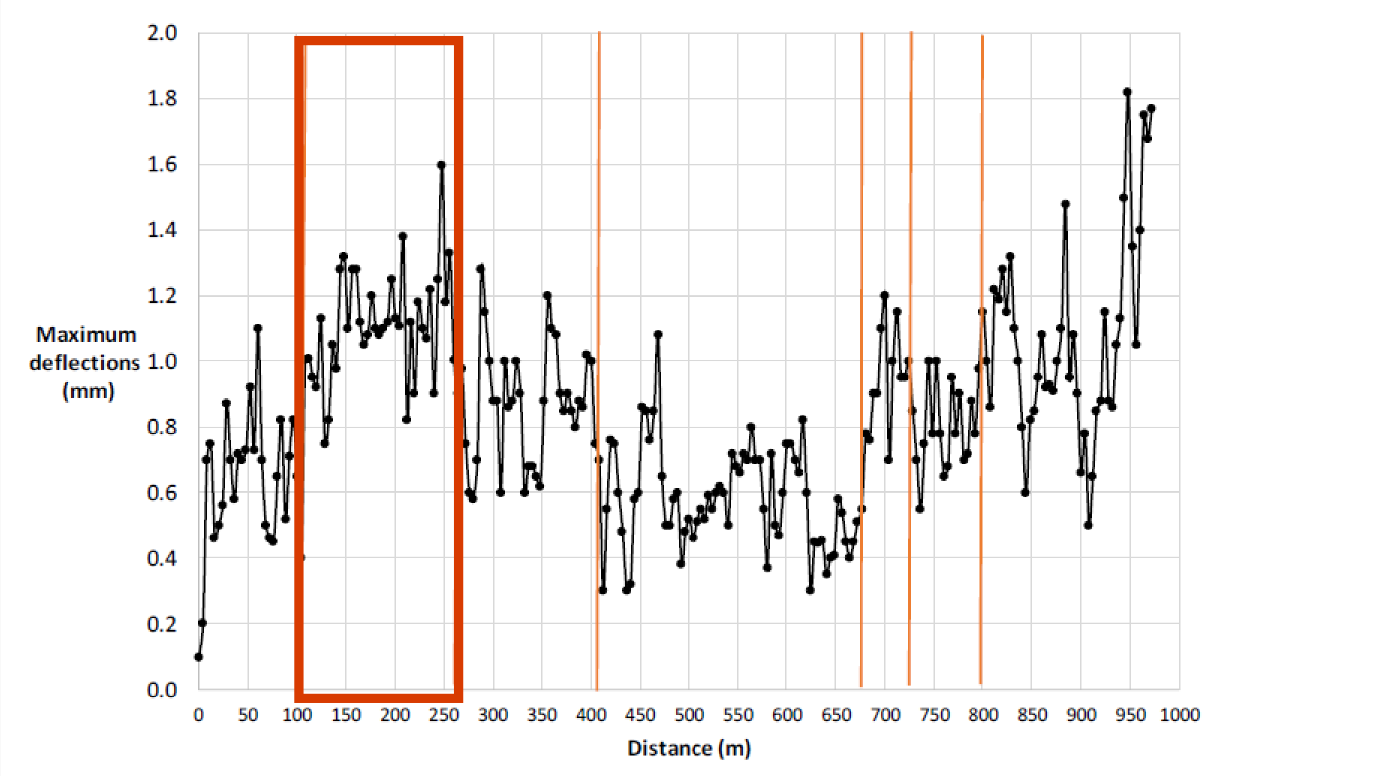
- Pavement deflections vary within a homogeneous sub-section
- Need to identify a deflection value that best reflects the weakest chainages that limits life



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 6.3: Recommended values for '*f*'

Road Class	*f**	Per cent of all deflection measurements which will be represented by the Characteristic Deflection**
Freeway and arterials/highways with lane AADT > 2000	2.00	97.5
Arterials/highways with lane AADT < 2000	1.65	95
Other roads	1.30	90

* *f* values applicable for 30 or more deflection measurements.

** After identifying areas to be patched/reconstructed.

2019 Guide method

See
Section 9.2.6

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CD reflects the weakest 10% of the project length

$$CD = \mu + f \times SD$$

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*'

Number of deflection measurements *	*f* *
10	1.38
12	1.36
14	1.35
16	1.34
19	1.33
24	1.32
≥ 30	1.31

** After identifying areas to be patched/reconstructed.*

Deletion of Charts for Design of Asphalt Overlays

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2011 Guide thickness design methods for asphalt overlays

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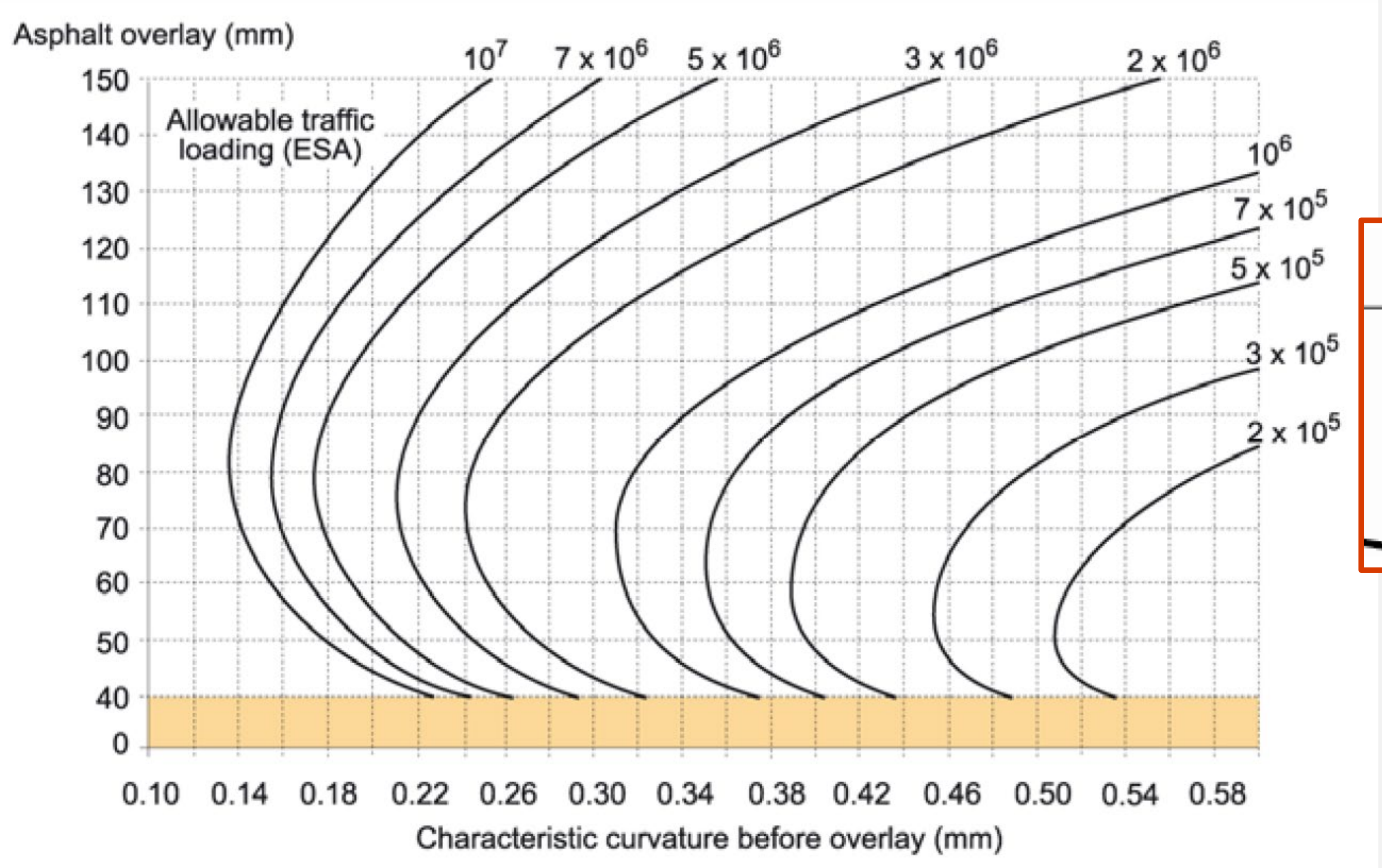
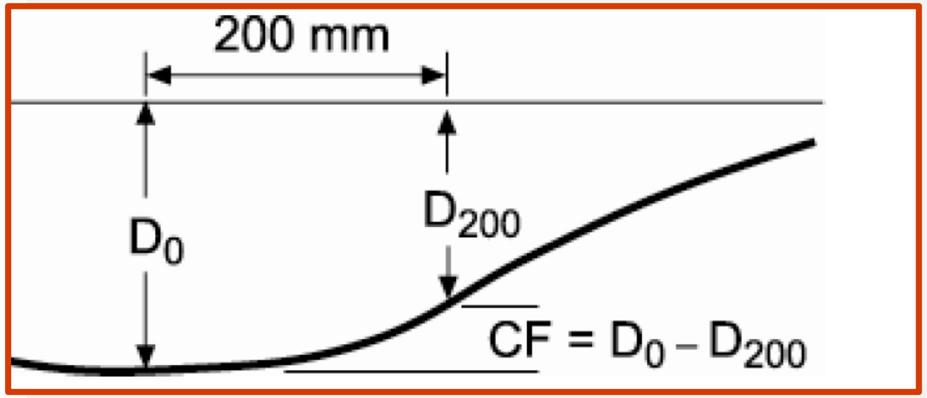
Existing pavement type	Section
Flexible pavements without cemented materials	6.2 (using Design Charts)
All flexible pavements	6.3 (using General Mechanistic Procedure)

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

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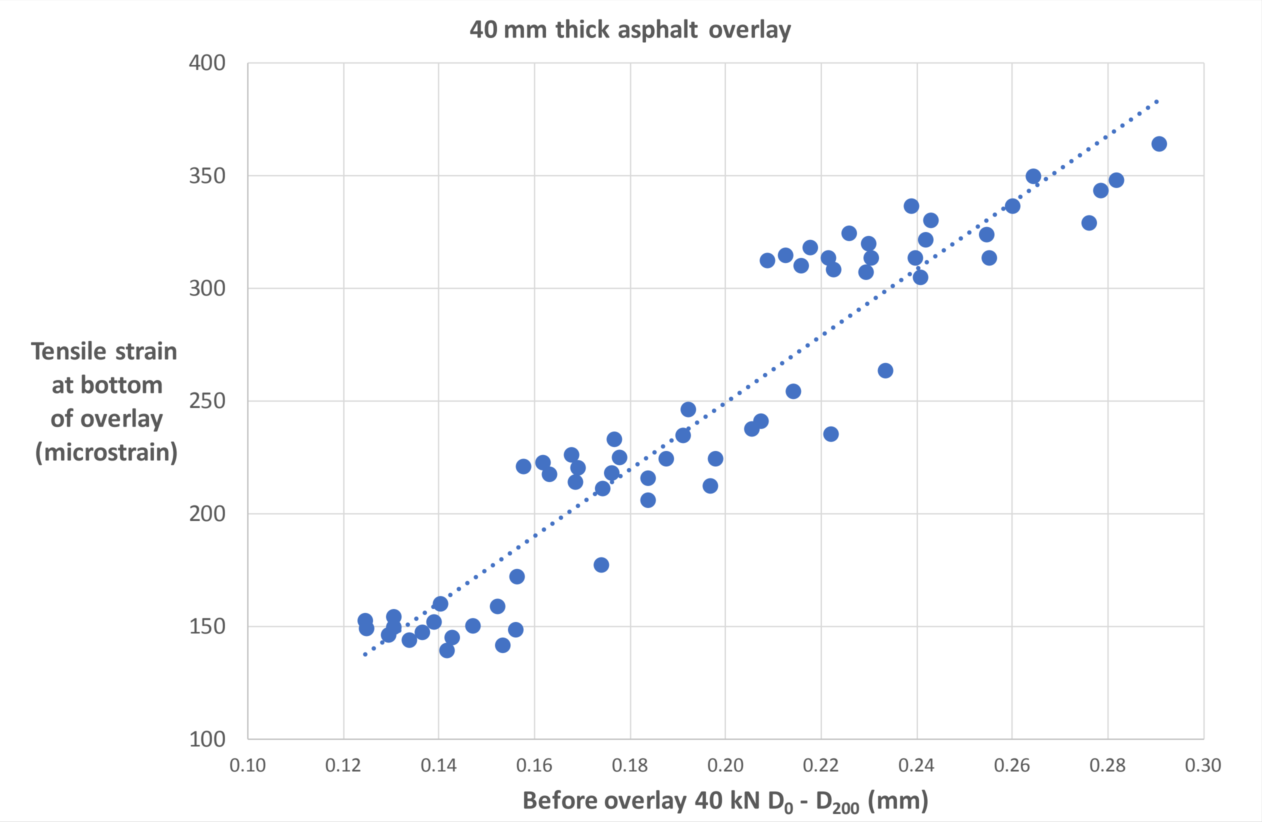
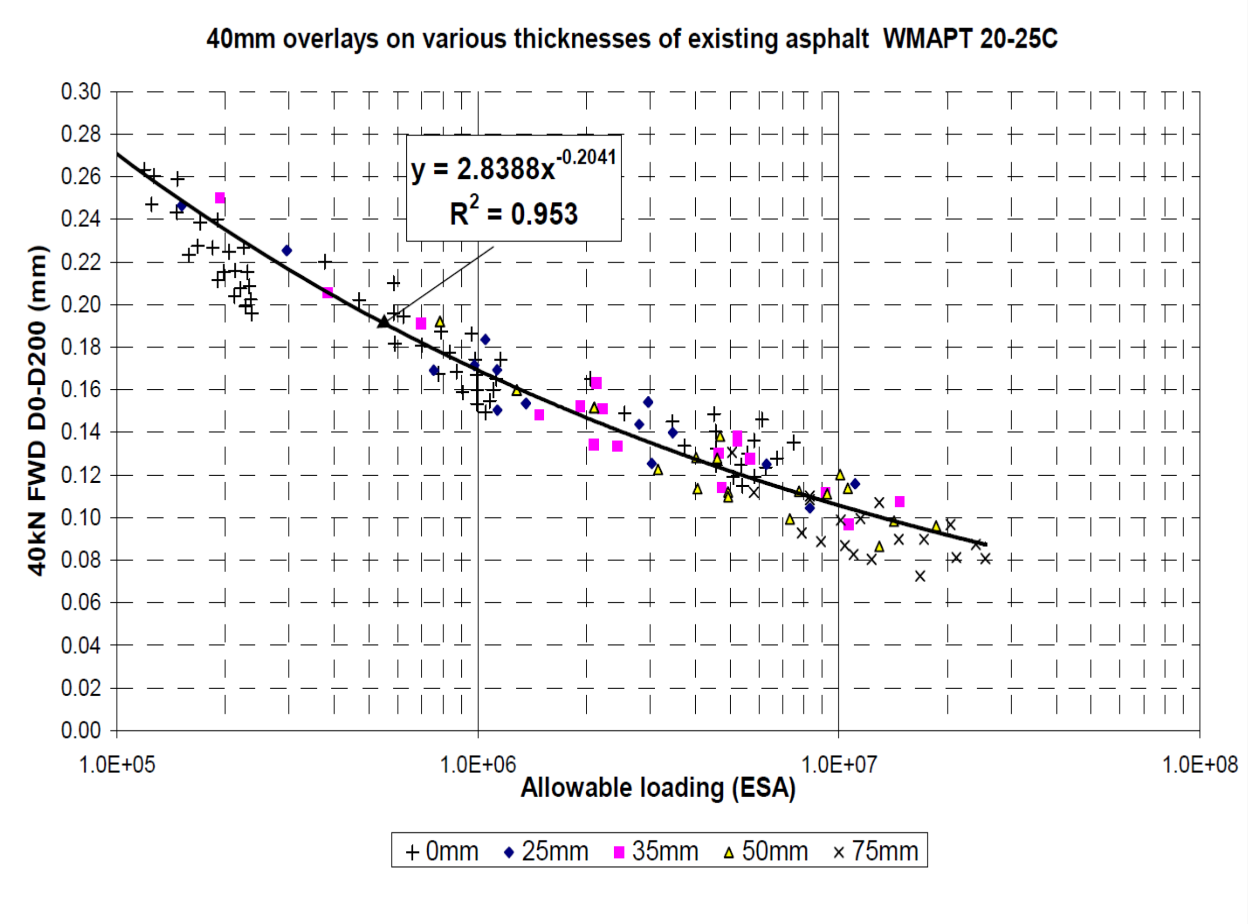
- D_0-D_{200} before overlay can be related with Standard Axle strain at bottom of an asphalt overlay
- Method assumes fixed asphalt moduli for overlay and existing asphalt
- e.g. Adelaide, Sydney & Perth overlays E = 3000 MPa



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

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- 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

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Mechanistic-empirical procedure (MEP)

See
Section 10

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- Previously called the GMP - **g**eneral **m**echanistic **p**rocedure 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

Scope of MEP

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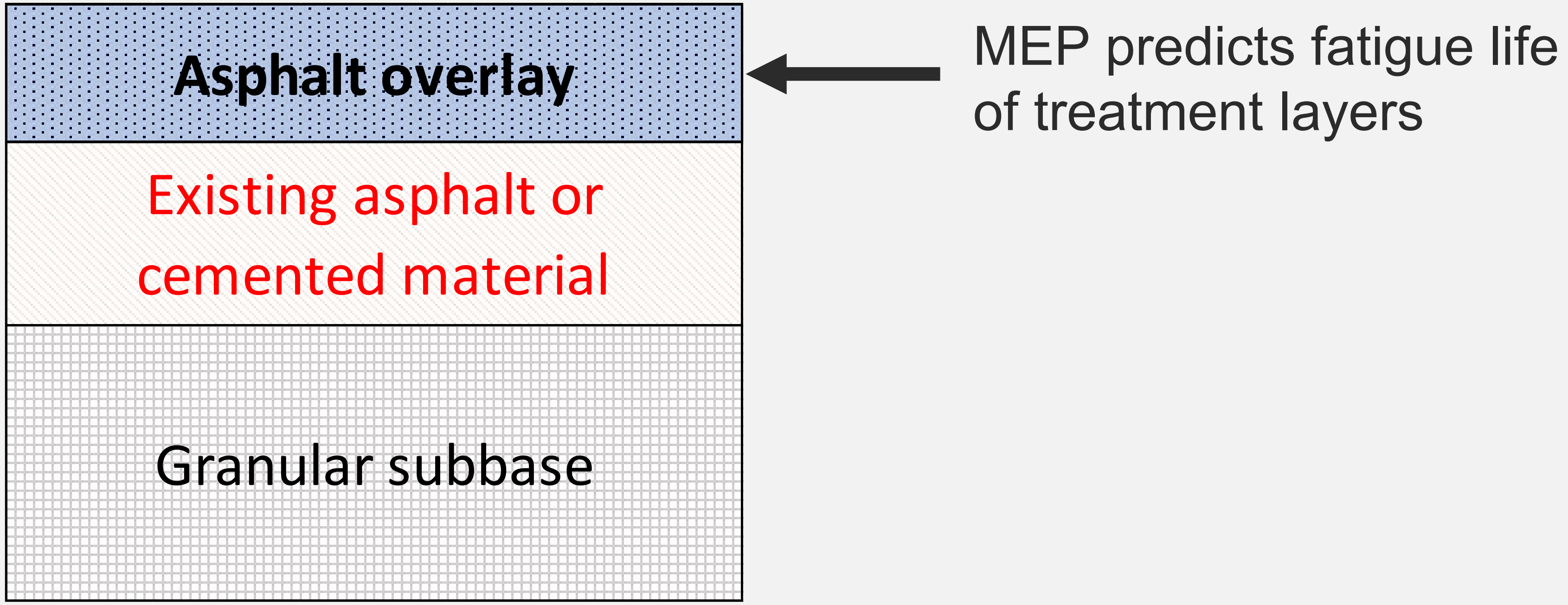
- Strengthening treatments are designed to limit fatigue cracking in treatment layers and permanent deformation of the treated pavement



Scope of MEP

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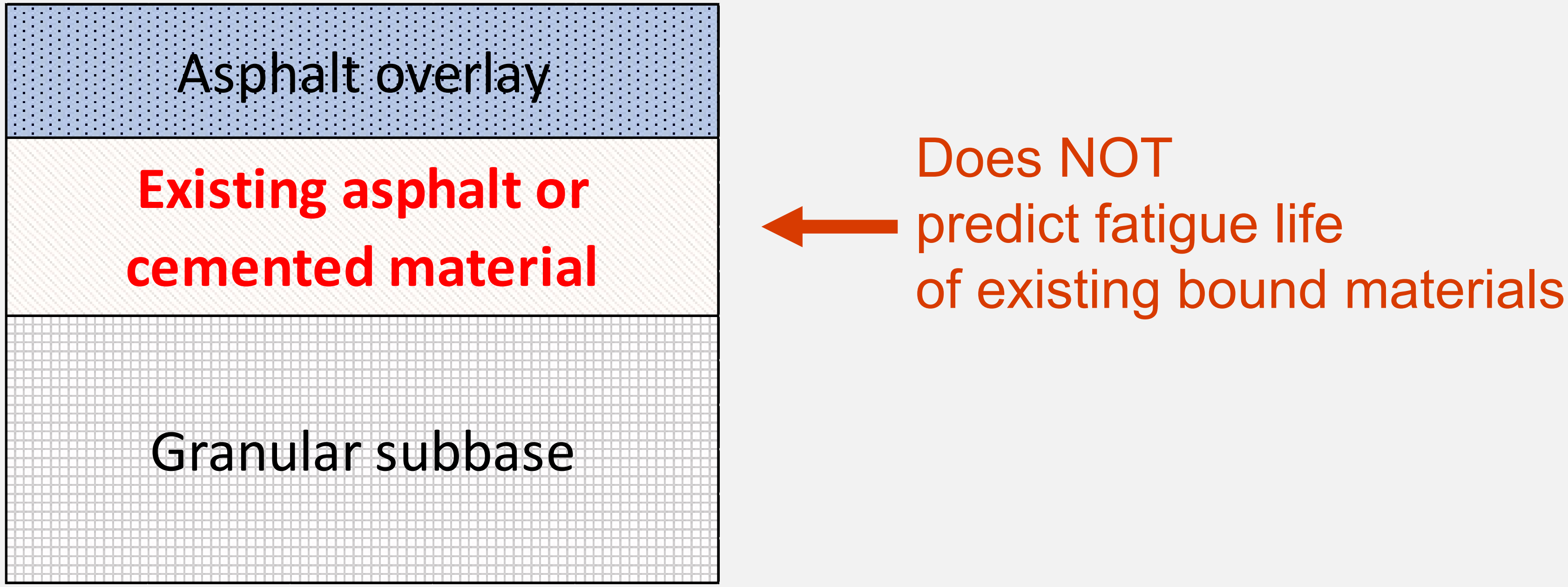
- Procedures yet to be develop to design treatments to limit fatigue cracking of existing bound materials
- Concepts of remaining structural life yet to be developed
- Similarly MEP not applicable to newly-constructed pavements



Reflective cracking

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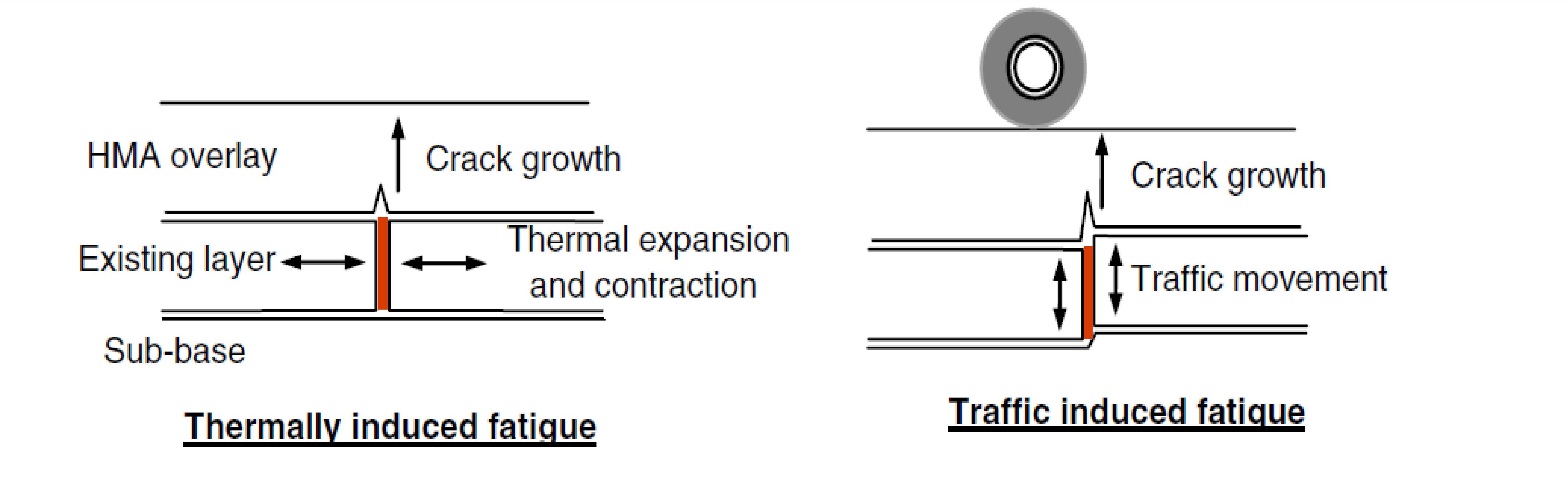
- The MEP does not predict allowable traffic loading in terms of reflective cracking from any cracked underlying material
- Designer needs to consider cost-effective treatment options



MEP treatment design similar to Part 2

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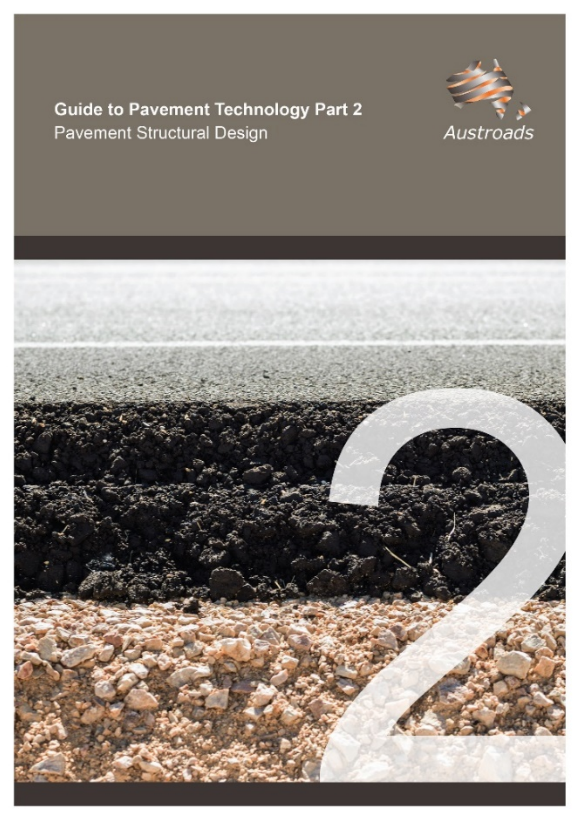
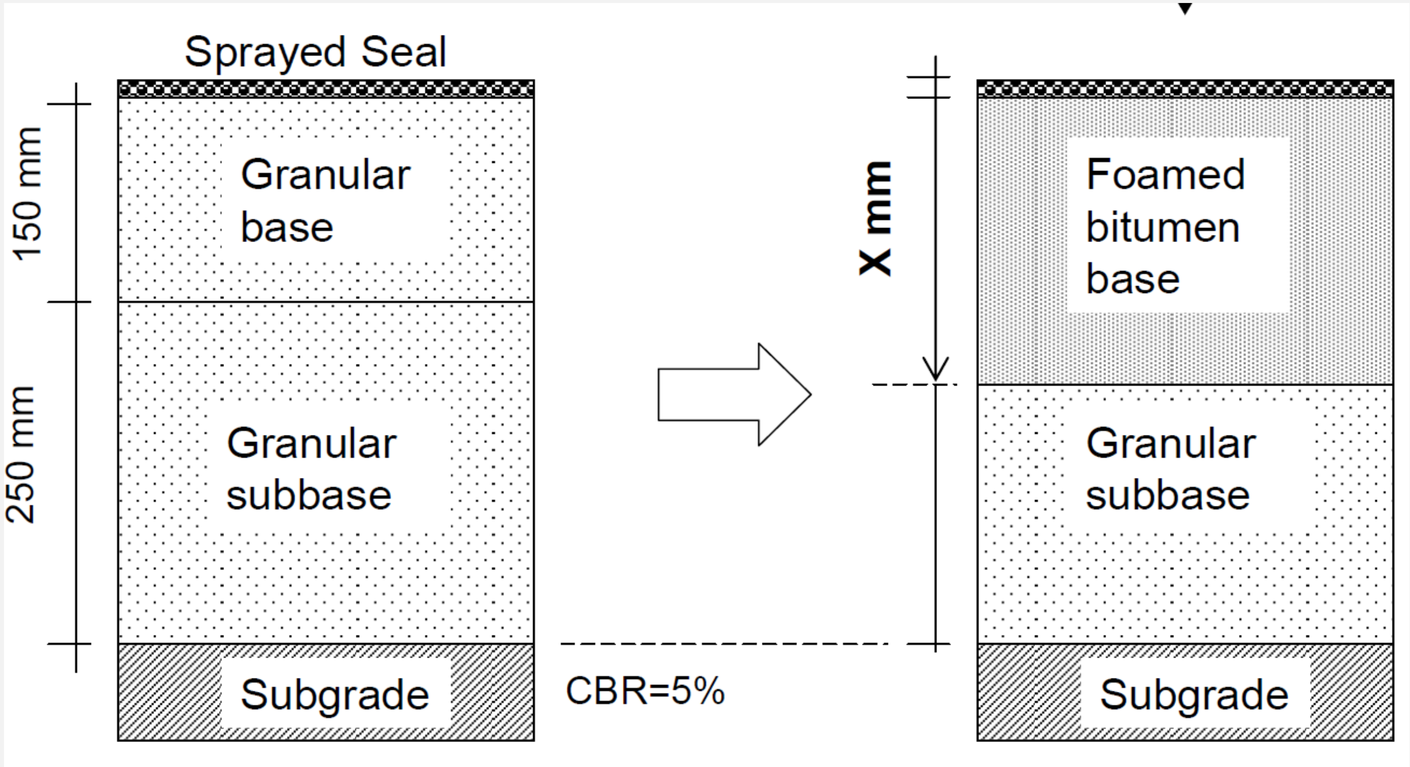
Similar to Part 2 for new pavement design, except there is an initial phase in which the properties of in situ materials are determined





Part 5 uses same performance relationships as Part 2

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Asphalt fatigue relationship

See
Section 10.9

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

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 in-service fatigue lives (presumptive value = 6)
RF	=	reliability factor for asphalt fatigue (Table 6.16)

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

See
Section 10.7

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- 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

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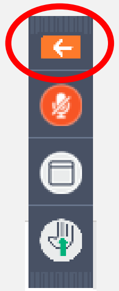

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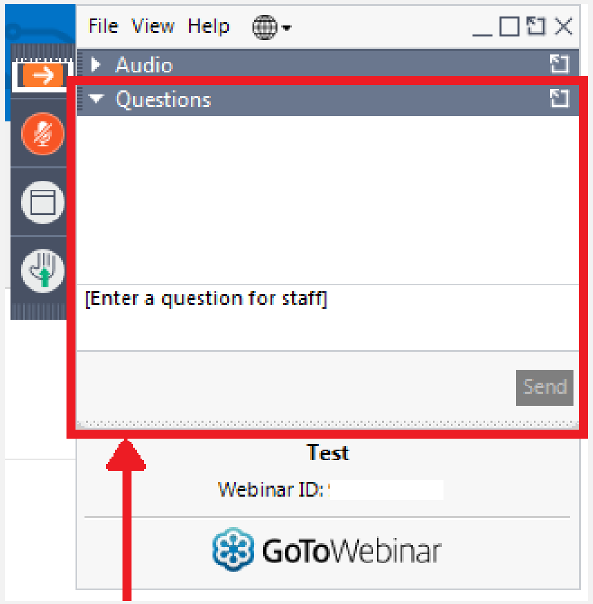

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Let us know the slide number your question relates to

Back-calculation of Moduli from Deflection Bowls Measured on the Pavement Surface

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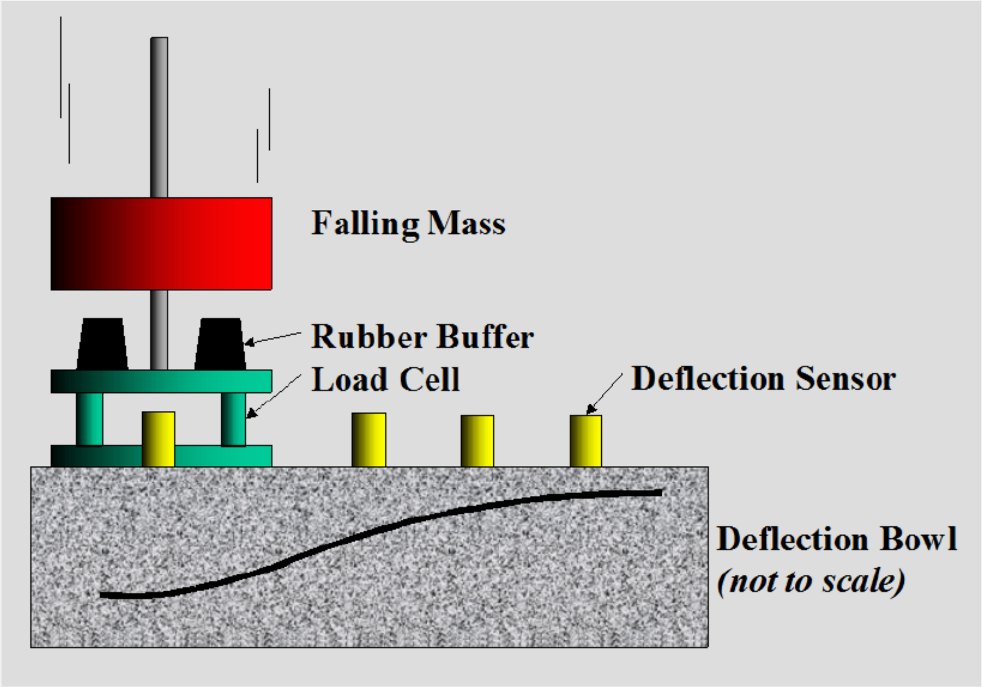
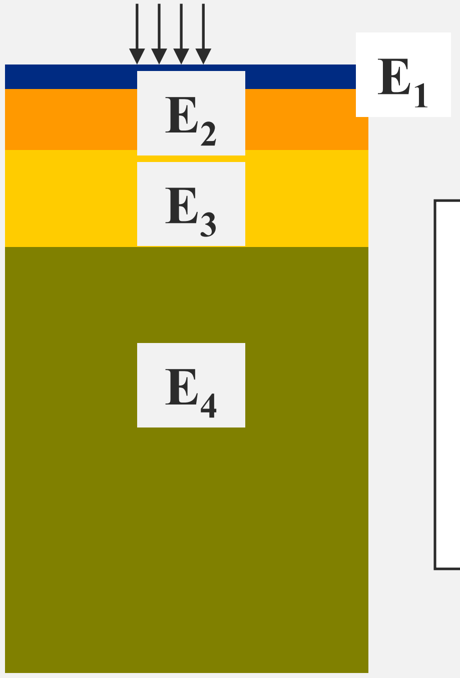
If FWD deflections have been measured opportunity to back-calculate layer moduli

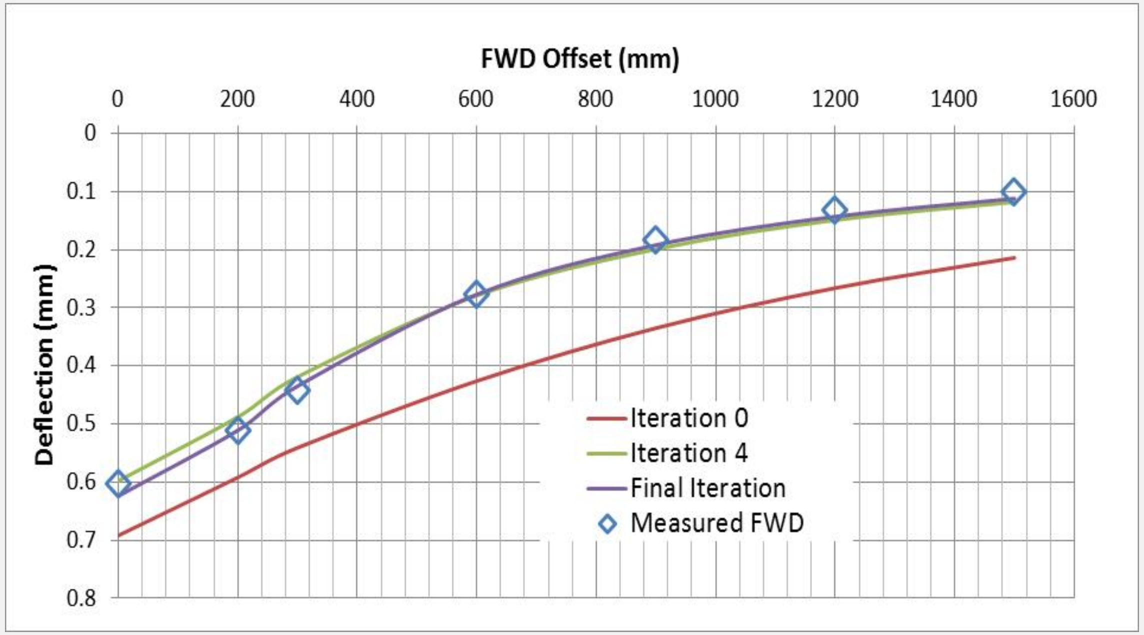


Modulus back-calculation concept



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

See
Section 10.5

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- 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

$$CM_r = \sigma_0(1 - \mu^2)\left(\frac{a^2}{r\ x\ d_r}\right)$$

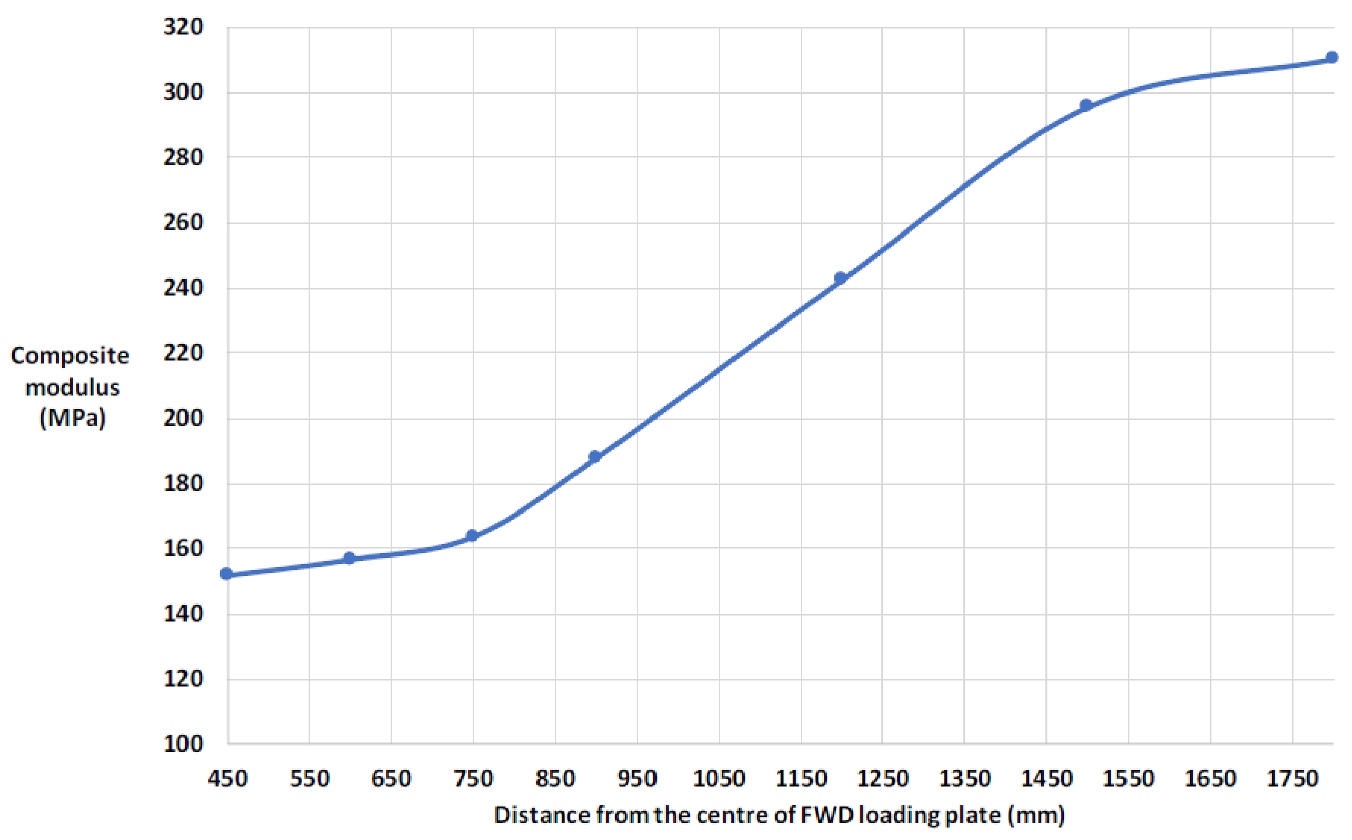
Appendix G example of use of Composite Modulus

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

Figure G 2: Example of composite modulus values reflecting subgrade modulus variation with depth



Improved back-calculation guidance

See
Section 10.5

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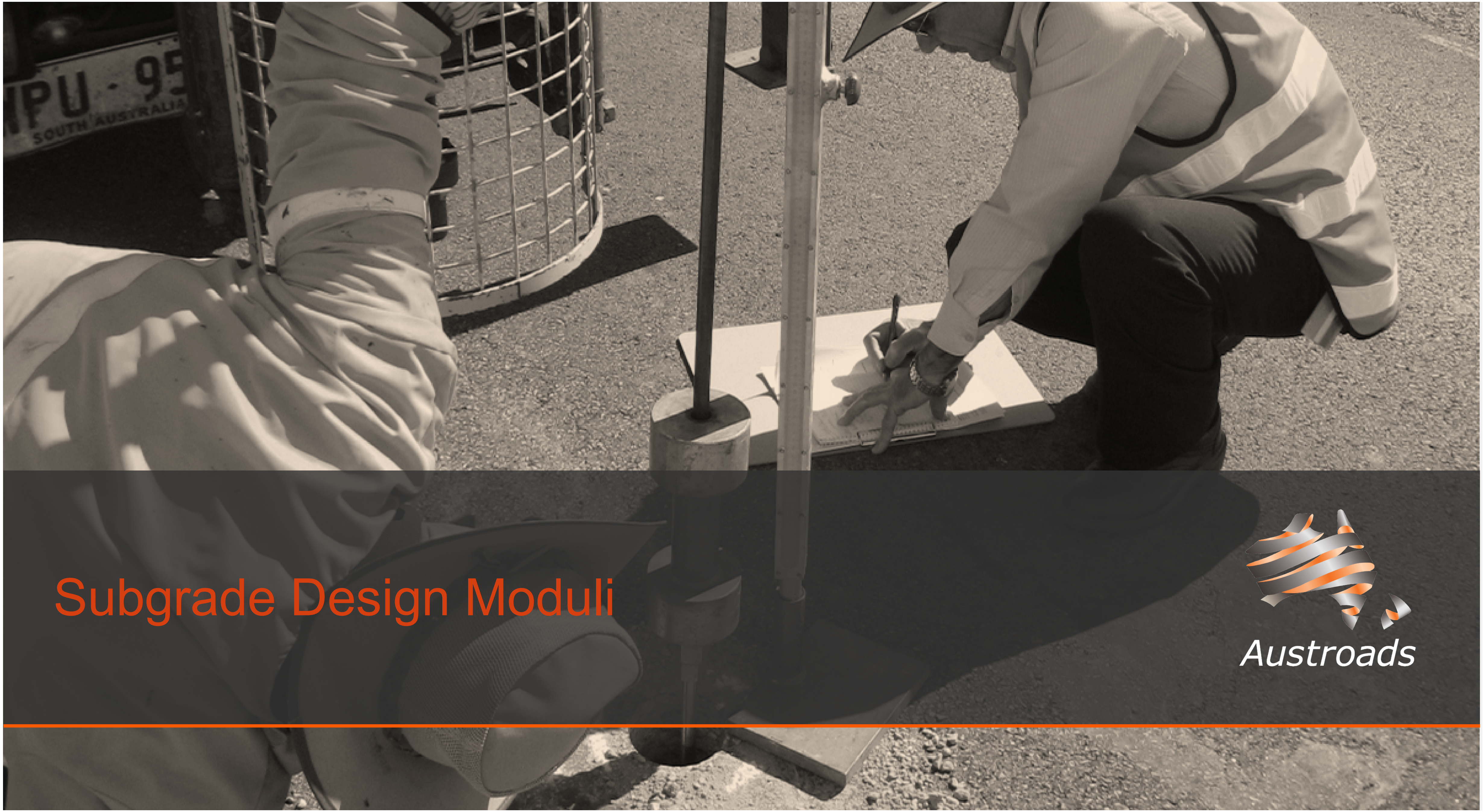
- In Part 2 and Part 5, use anisotropic modulus characterisation for granular materials and subgrade

  Vertical modulus (Ev) = 2 x Horizontal modulus (Eh)

- 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

  Ev = 2 x Eh = 1.1 x Eiso



Subgrade Design Moduli

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Selection of subgrade design modulus

See
Section 10.7.2

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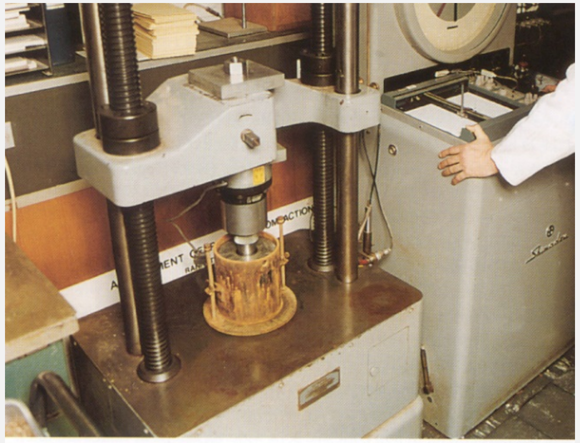
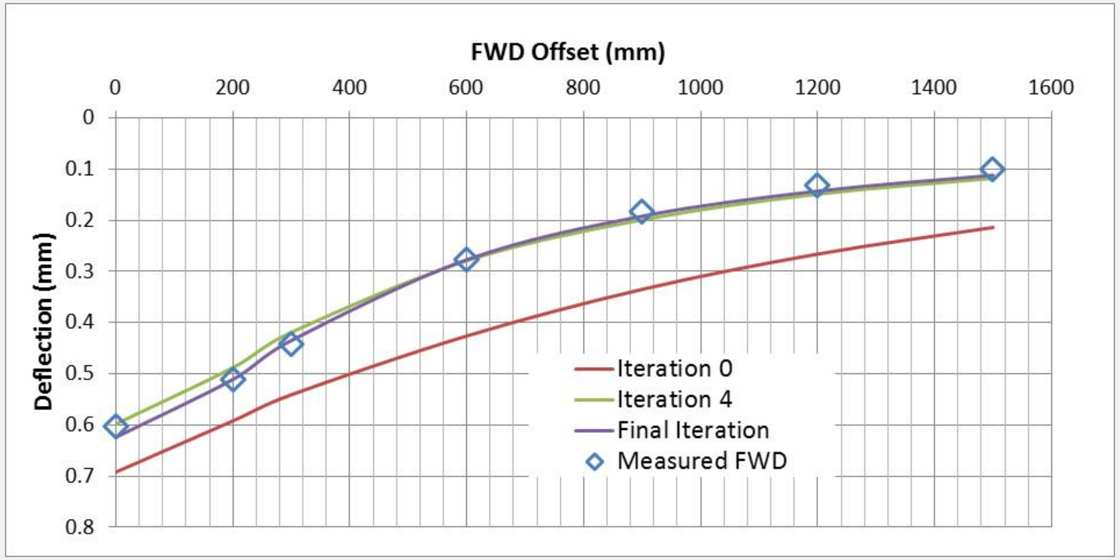
Designer needs to consider:

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





Selection of subgrade design modulus

See
Section 10.7.2

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

Table 10.1: Suggested maximum subgrade design modulus values

Description of subgrade material		Maximum vertical design modulus (MPa)(1,2)	
Material	**Unified soil classification**	**Excellent to good drainage**	**Fair to poor drainage**
Highly plastic clay	CH	100	50
Silt	ML	80	40
Silty-clay, sandy-clay	CL	100	70
Sand	SW, SP	150	150

Existing Granular Materials Design Moduli

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Selection of granular design moduli

See
Section 10.7.4

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- 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

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Table N 2: Modelled pavement configuration

Material type	Thickness (mm)	Elastic modulus (MPa)		Poisson's ratio		f value
		E_v	E_h	ν_v	ν_h	
Sprayed seal surface	–	–	–	–	–	–
FBS	300	2200	2200	0.40	0.40	–
Granular	20	87	43.5	0.35	0.35	64.4
Granular	20	78	39	0.35	0.35	57.7
Granular	20	70	35	0.35	0.35	51.6
Granular	20	62	31	0.35	0.35	46.2
Granular	20	56	28	0.35	0.35	41.4
Subgrade	Semi-infinite	50	25	0.45	0.45	34.5

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

See Section 10.7.4

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

Table N 2: Modelled pavement configuration

Material type	Thickness (mm)	Elastic modulus (MPa)		Poisson's ratio		f value
		E_v	E_h	ν_v	ν_h	
Sprayed seal surface	–	–	–	–	–	–
FBS	300	2200	2200	0.40	0.40	–
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Subgrade	Semi-infinite	50	25	0.45	0.45	34.5

Existing Asphalt Design Moduli

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Existing asphalt moduli

See
Section 10.7.5

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

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

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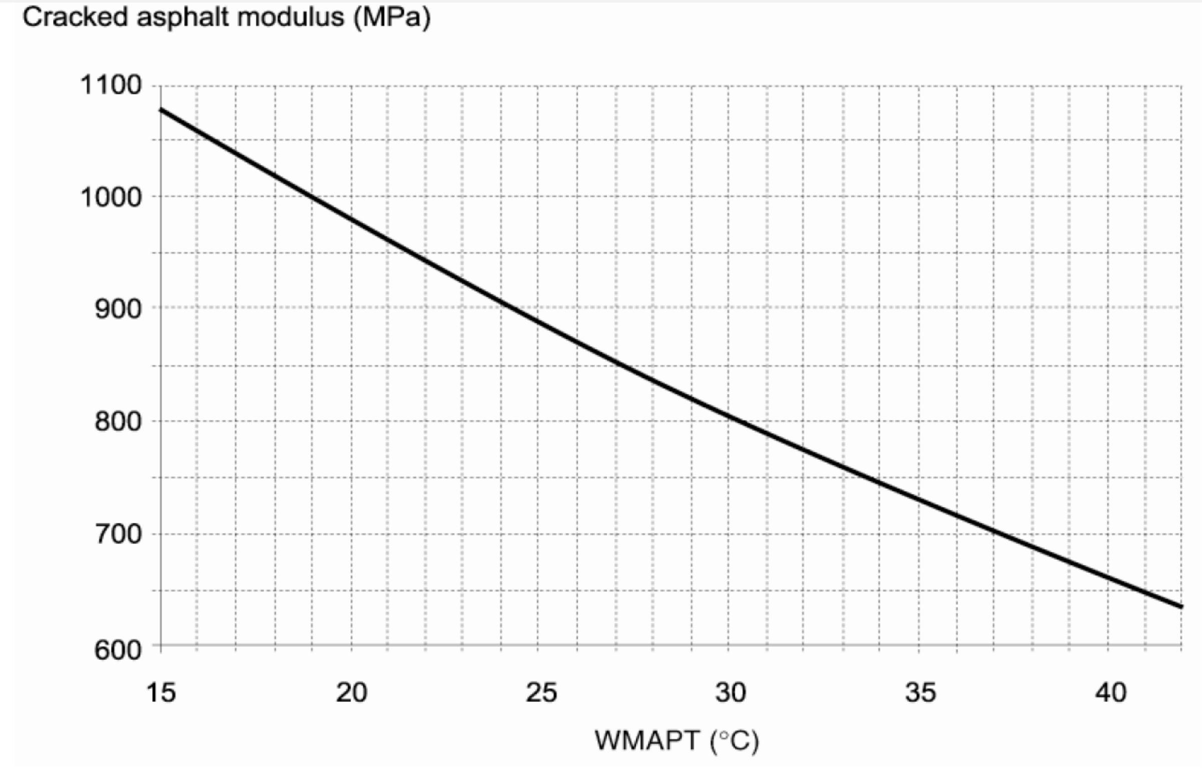
- How will the modulus change during treatment design period?
- Additional load-induced strains during the treatment design period
- If the existing asphalt is fatigue cracked due to past traffic, it is likely that it will continue to be damaged during treatment life

→ 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

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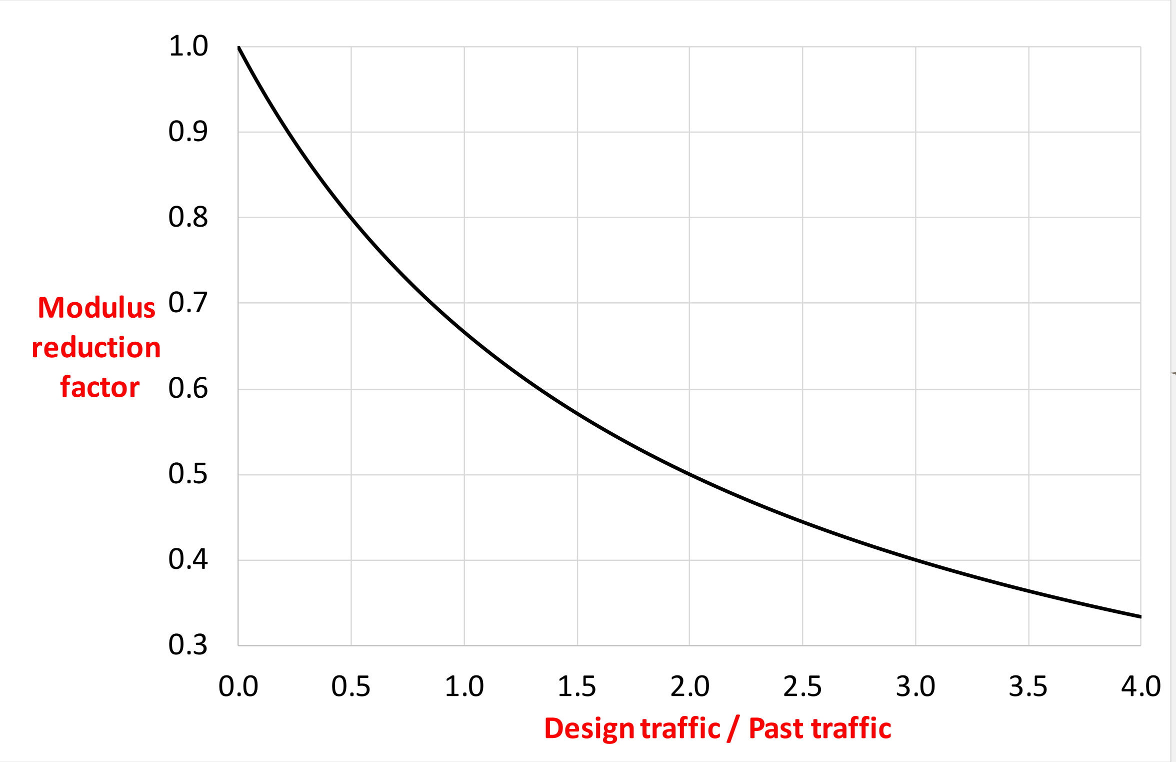
If core or back-calculated moduli available, a process is provided to determine design modulus of existing asphalt

Field cores

Moduli back-calculated from measured deflections

Modulus reduction factor to allow for future damage

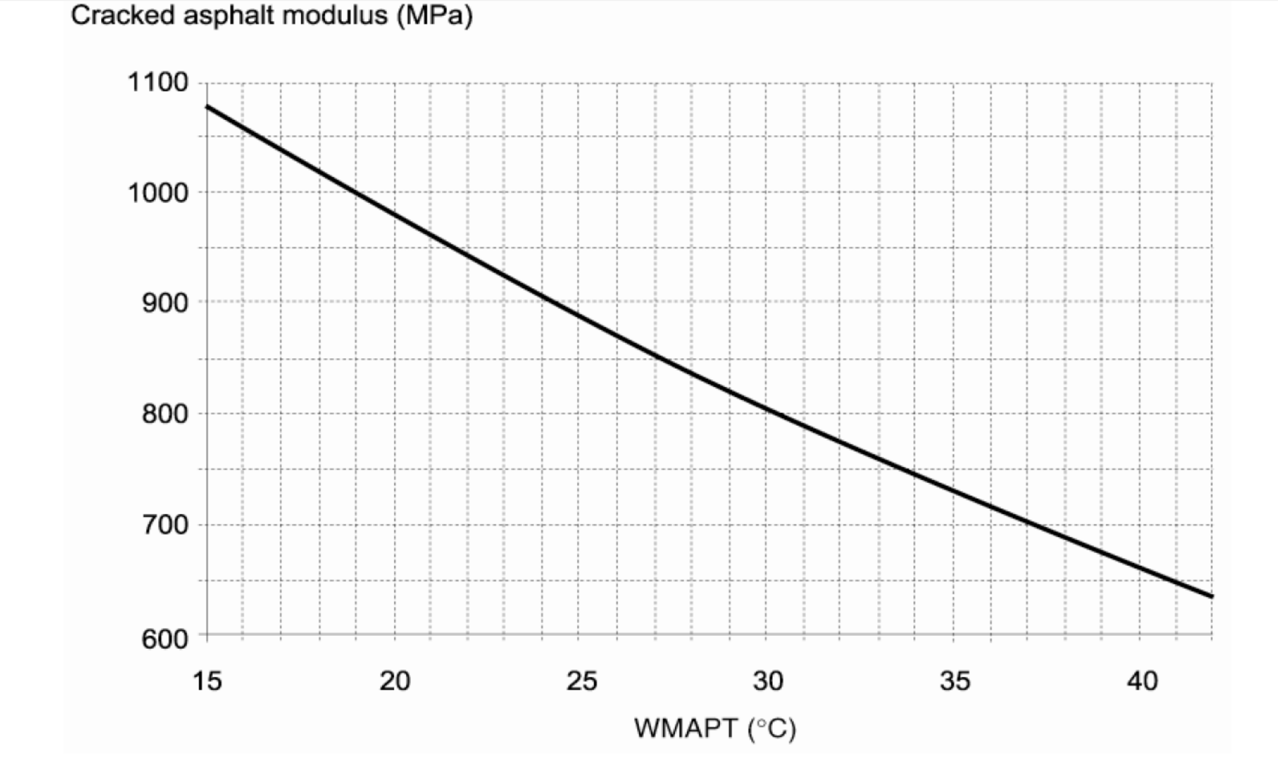
If the existing asphalt is fatigue cracked, the design modulus is calculated by multiplying the core or back-calculated moduli by a Modulus Reduction Factor (MRF)



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

1987 Guide to Visual Assessment of Pavement Condition

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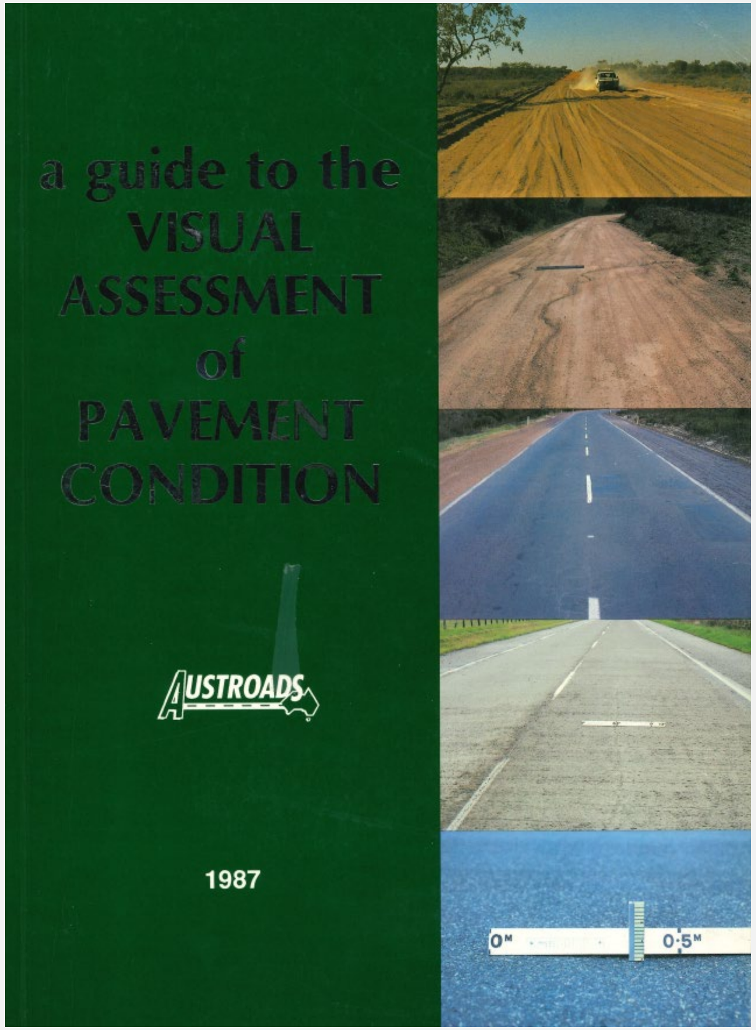

Austroads has many requests

Out of print

No longer available from Austroads, but ....

Appendix A of Part 5 is an update of the old green guide

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A.1.2 Deformation – Shoving, Plastic Flow (DS)

Description:
Shoving: Bulging and horizontal deformation of the road surface – generally occurs in areas of high shear stress.

Plastic flow: Deformation in asphalt of asphalt surfaces.

Causes:
- lack of containment at pavement edge combined with swelling of moisture-susceptible pavement material and/or repeated passage of heavy vehicles on relatively narrow sealed formations
- inadequate pavement thickness
- inadequate quality of pavement materials e.g. asphalt mixes with poor aggregate interlock combined with turning/accelerating traffic; or poor binder/aggregate adhesion (stripping)
- inadequate compaction of surfacing or base material
- localised softening of asphalt binder due to fuel/oil spillage, or temperature-susceptible binder or excess binder content in asphalt
- lack of bond between pavement layers
- moisture in pavement and/or subgrade.

Non-structural treatments:
- in-place asphalt recycling
- cold planing of unsound material and replacement with adequate material
- where due to deficiency of unsealed shoulder, resheet shoulder.

Structural treatments:
- drainage improvements
- asphalt or granular overlays
- partial reconstruction and overlay
- in situ stabilisation
- heavy patching
- reconstruction.

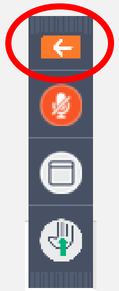
A.1.15 Stripping of Sprayed Seals (SS)

Description:
The loss of aggregate from a sprayed seal leaving the binder exposed to direct tyre contact.

Causes:
- low binder application rate
- poor binder to stone adhesion due to dirty, dusty or wet aggregate exacerbated by lack of pre-coat on the aggregate
- age hardening (oxidation) or adsorption of binder
- incorrect blending of binder (cutter or flux oil content too high)
- stone deterioration
- inadequate rolling before opening of seal to traffic, particularly on curves and bends
- inappropriate stone size in reseal
- temperature susceptible bitumen.

Treatments:
- enrichment or rejuvenation of binder – only where aggregate loss is limited to a few stones
- reseal.

Send us your questions



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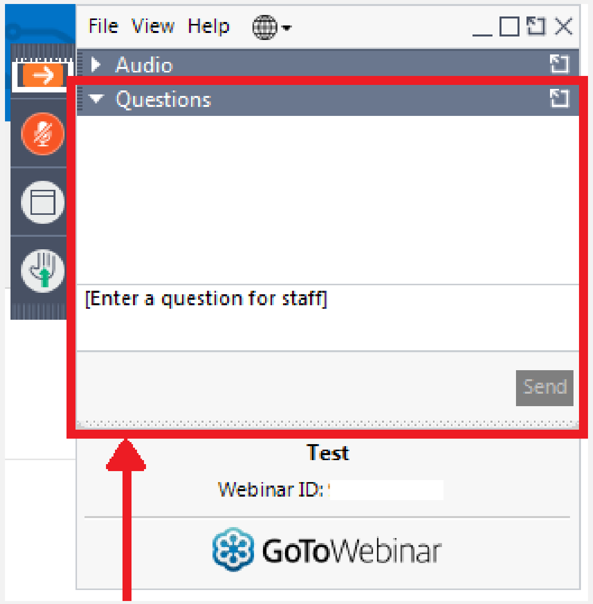

Step 2: Type questions here

Let us know the slide number your question relates to

Questions?

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Dr Michael Moffatt
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Infrastructure Management
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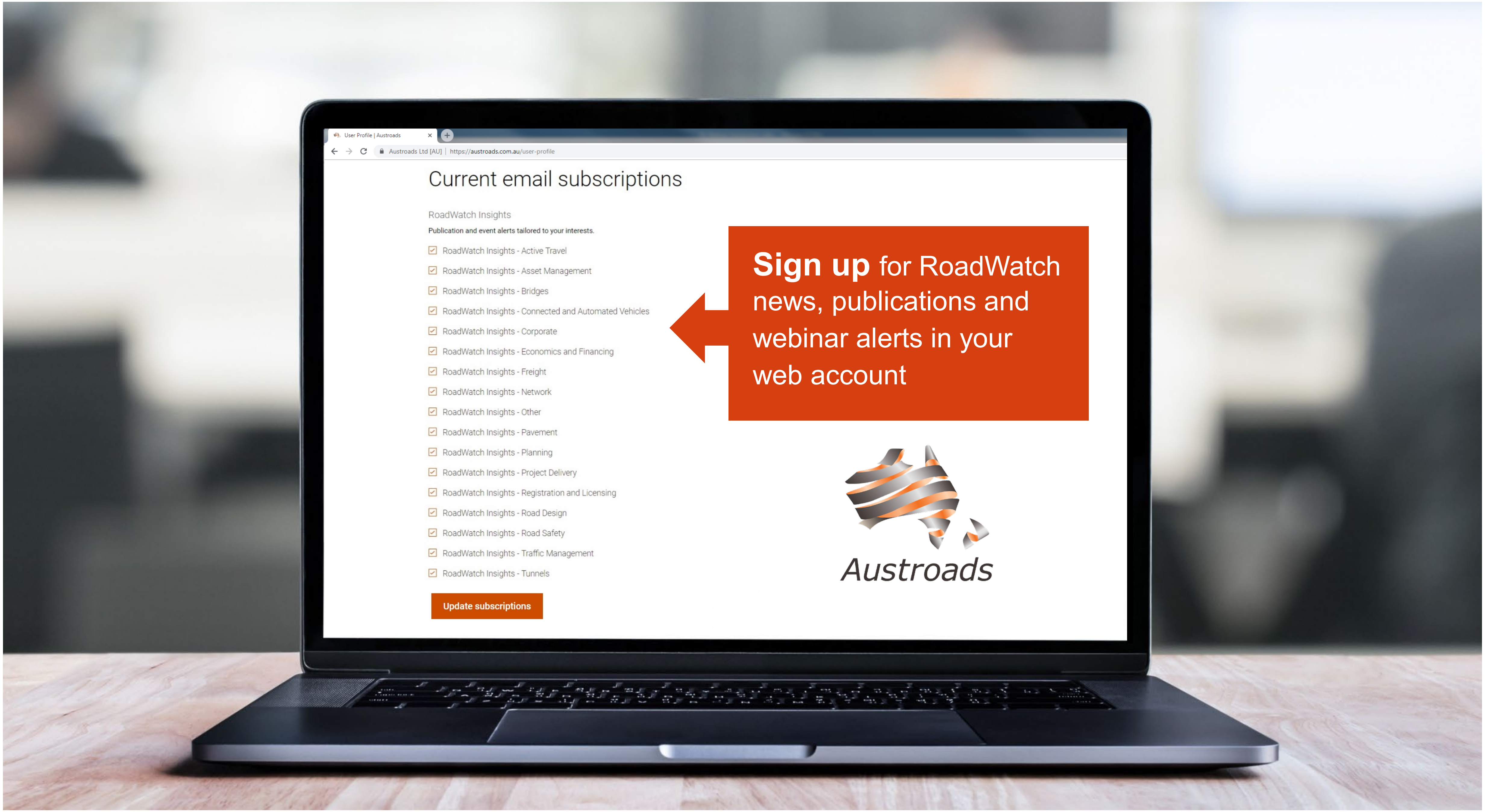
Upcoming Austroads webinars

Topic	Date
Guide to Road Tunnels Part 4: Retrofitting Tunnels	29 August
Opportunities in Mobility as a Service (MaaS)	3 September
Dangerous Goods in Tunnels	12 September
Key Freight Routes – Heavy Vehicle Usage Data Project	3 October

Register at austroads.com.au/webinars-and-events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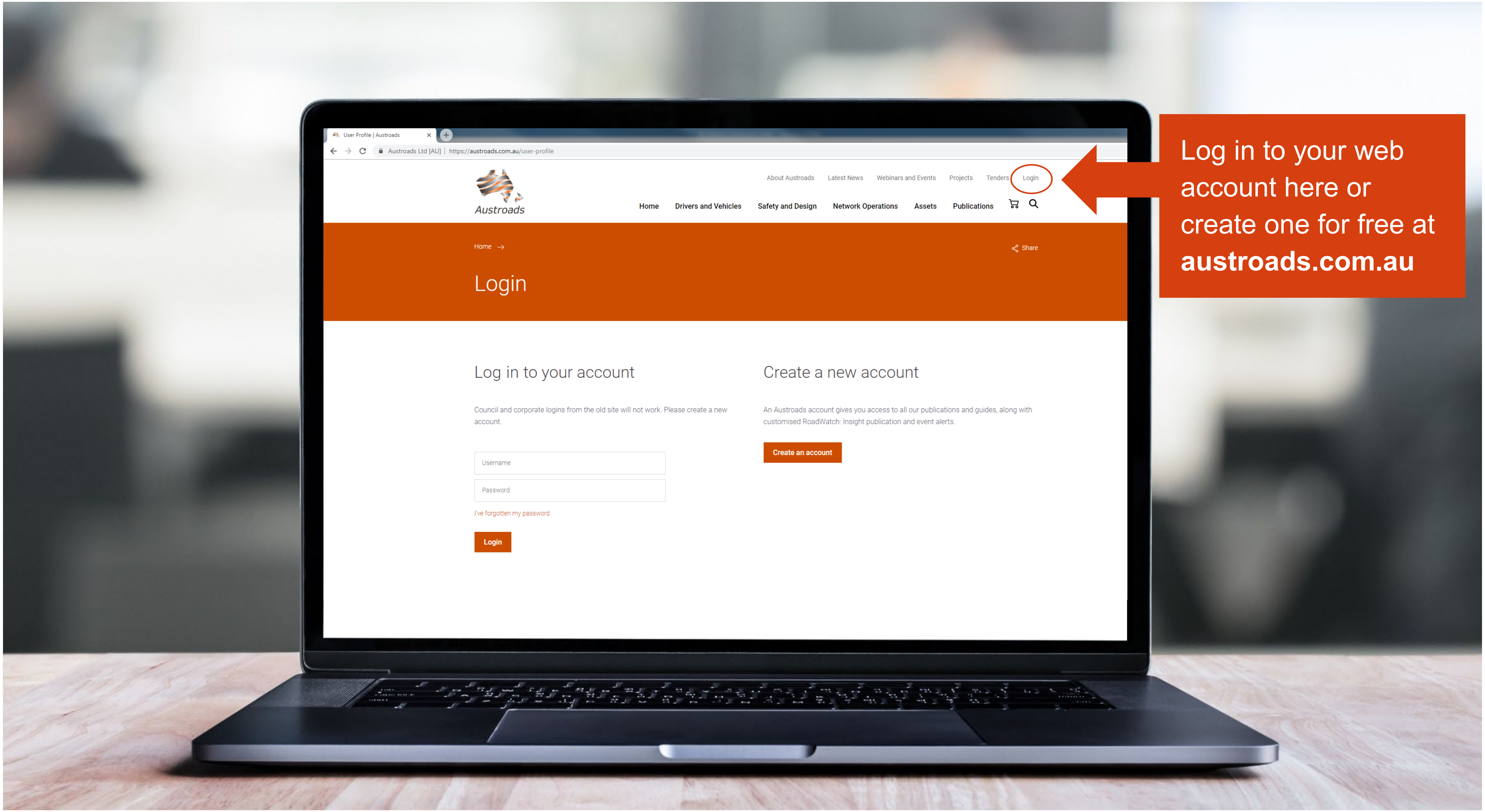
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